MAI4CAREU
Master programmes in Artificial Intelligence 4 Careers in Europe

University of Ruse

INTELLIGENT COMPUTER SYSTEMS

Svetlana Stefanova

September, 2022

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INTRODUCTION INTO INTELLIGENT SYSTEMS

1. Introduction
2. Genome
3. Intellect
4. Artificial intelligence
5. Intelligent system
6. History
7. Intelligent system popularity today

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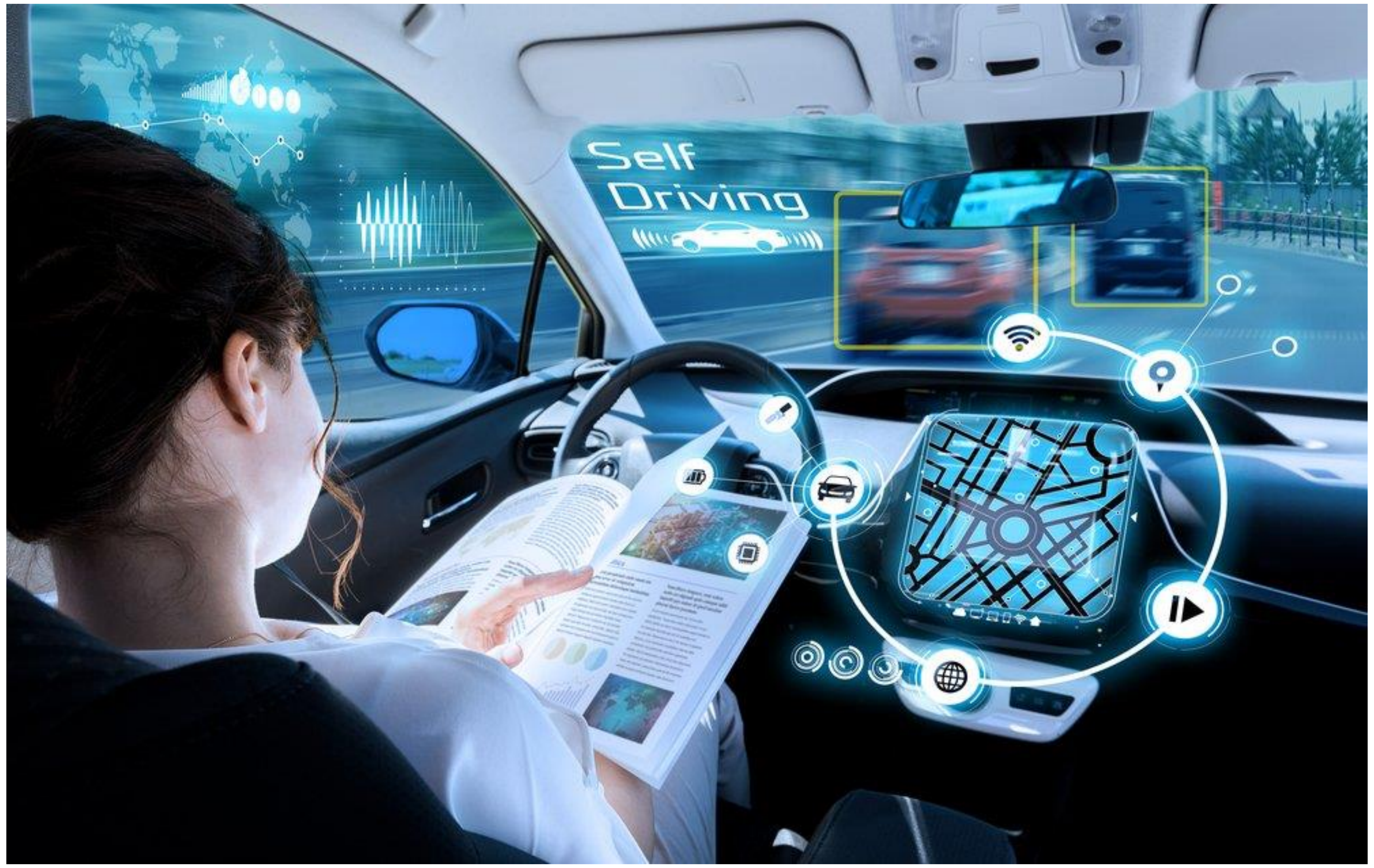
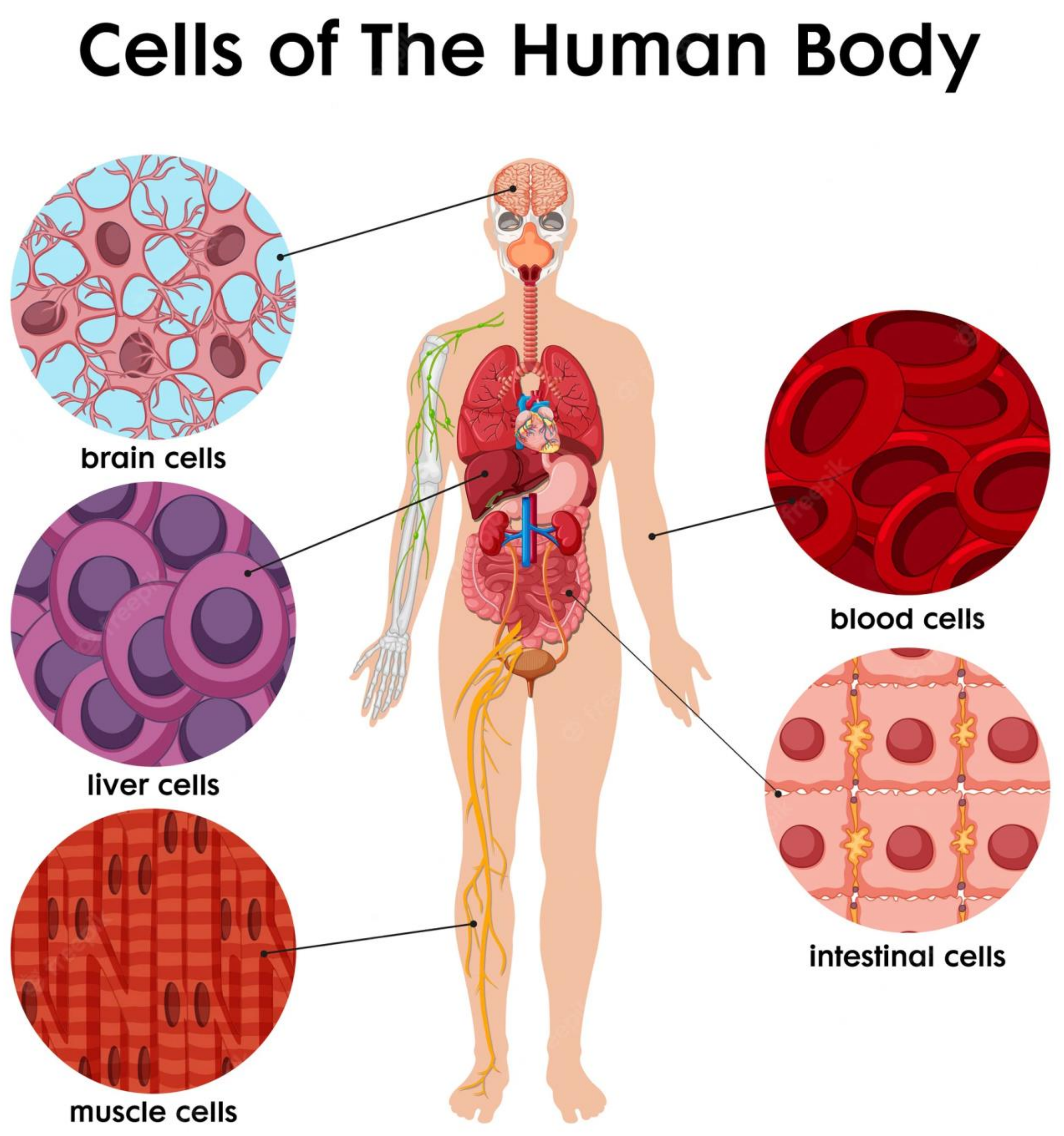
Why do we study this discipline?



CONTENT 1

The human body

- 100 trillion **cells** – most with a size across less than 0.01mm;
- each cell has a **core** inside**;**
- inside the core there are **2 sets of the human genome** (1 from the mother and the father each) – excluding eggs and sperm cells with 1, and red blood cells – without.



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Genome („book“)

A set of instructions for construction and management of the human body.

- 23 **chromosomes („chapters“)** – a pair of DNA molecules;
- 30-80 000 **genes („stories“) –** one-dimensional digital codes:

➢ **Exons** – logical informational paragraph;

➢ **Introns** – illogical paragraphs;

- Each paragraph consists of **codons („words“)** – 3 letter (64 combinations);
- Each codon consist of **bases („letters“)** – 4: A, C, G and U;
- 20 amino acids;

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CONTENT 2

Genome - operations

- **Reading/translation**;
- **Copying/replication.**

History:

On 26/06/2000 Bill Clinton and Tony Blair simultaneously announce that the preliminary version of the human genome is ready.

CONTENT 2

Genome - determination

Humans are determined by the instructions of our genes, but what we learn in our lives defines us even more.

- Genome is a computer that processes information.
- Natural selection is a process of extracting useful information from the surrounding environment and encoding it into genes. This is a slow process – generations are necessary for each change.

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CONTENT 2

Genome and the brain

The genome has discovered a much faster and more useful machine that, in a matter of minutes or seconds, can extract information from the world around it and realize that information through behavior. This machine is **the brain**.

Example: Our genome gives us the nerves which tell us when we burned our hand, our brain gives us the action to remove our hand from the stove.

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CONTENT 3

What is intellect?

- How quick the mind is?
- The ability to reflect?
- Memory?
- Vocabulary?
- Mental calculation?
- Spiritual energy?
- …..

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CONTENT 3

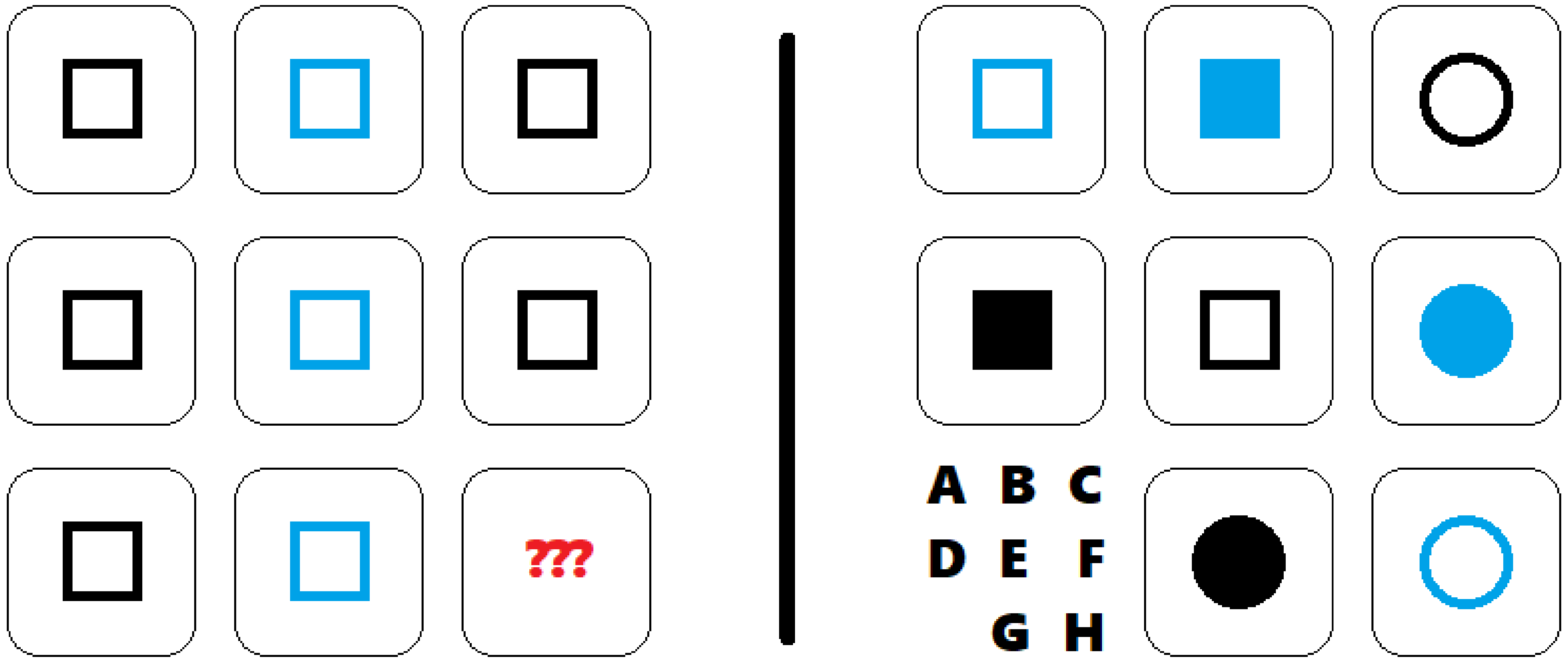
Intellect - theories

- About the **multiple intelligence** – each talent is a separate ability.
- About the **3 types of intelligence**:
  - **analytical** - analytical tasks are clearly formulated by someone else, carry all the information necessary to solve them and have only 1 correct answer, are not directly related to everyday life and are not interesting outside themselves;
  - **creative;**
  - **practical** - practical tasks require you to recognize and formulate them, they are not strictly defined, they lack some essential information, they may or may not have 1 single correct answer, they come directly from everyday life.

CONTENT 3

IQ (Intelligence Quotient) tests – what is determining?

- congenital abilities?
- education?



CONTENT 3

IQ tests

- Directed towards analytical problems;
- Oriented towards a specific frame of mind;

CONTENT 3

IQ inheritance?

The hypothesis is checked upon 2 groups: twins and adopted

- Single human, tested twice – 87% proximity;
- Identical twins, who grew up together – 86% proximity;
- Identical twins, who grew up separately – 76% proximity;
- Fraternal twins, who grew up together – 55% proximity;
- Biological brothers and sisters – 47% proximity;
- Parents and children, who live together – 40% proximity;
- Parents and children, who live separately – 31% proximity;
- Adopted children, who live together – 0% proximity;
- Unrelated people, who live separately – 0% proximity.

Conclusion-hypothesis: You do not inherit IQ, but the ability to develop a high IQ under certain environmental conditions.

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CONTENT 3

Intellect - definition

A set of specific capabilities of each self-organizing system to generate strategies to extract, formulate, and use knowledge in purposeful behavior in unknown problem situations.

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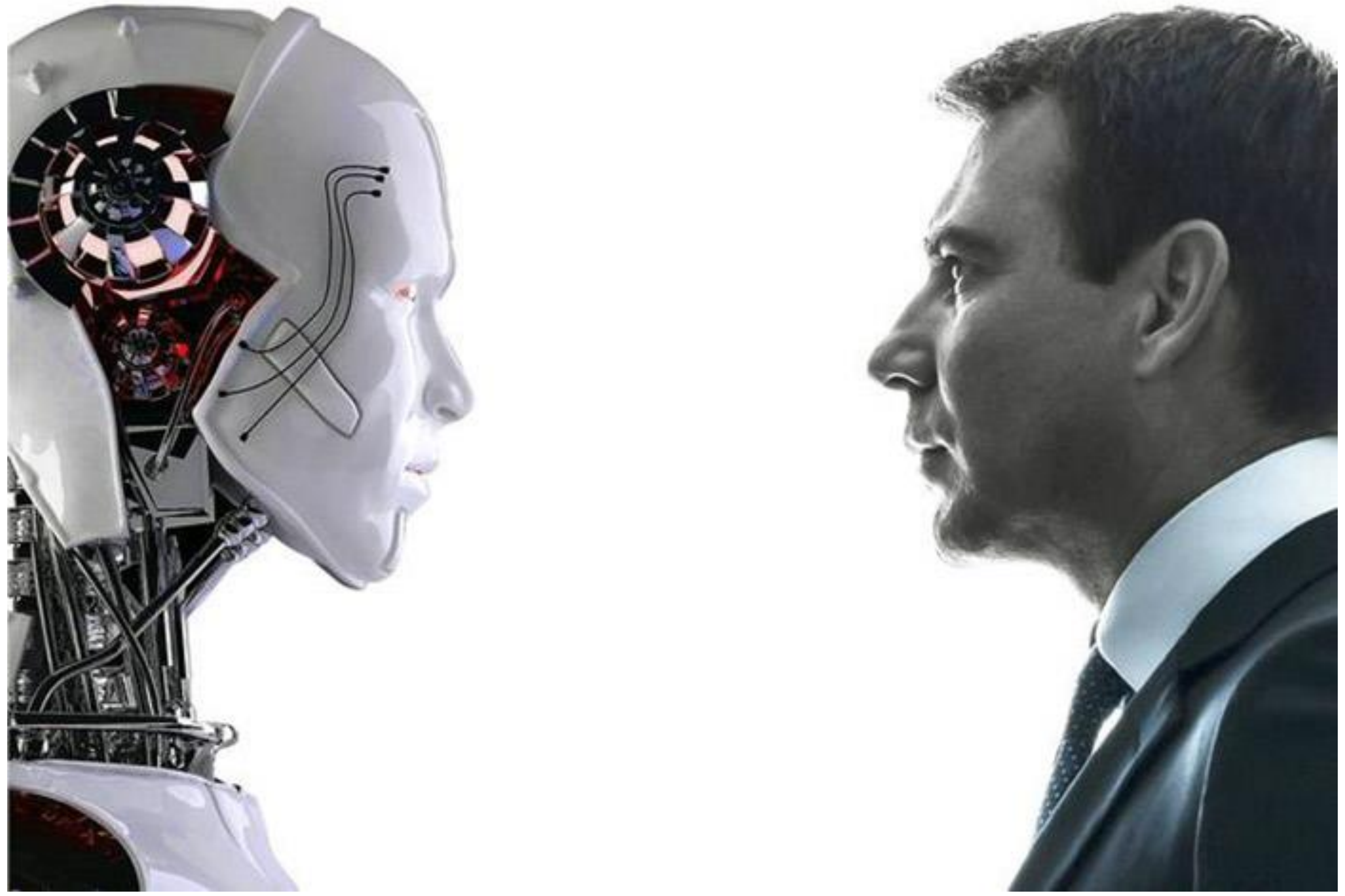
CONTENT 3

Types of intellect

- natural;
- artificial.

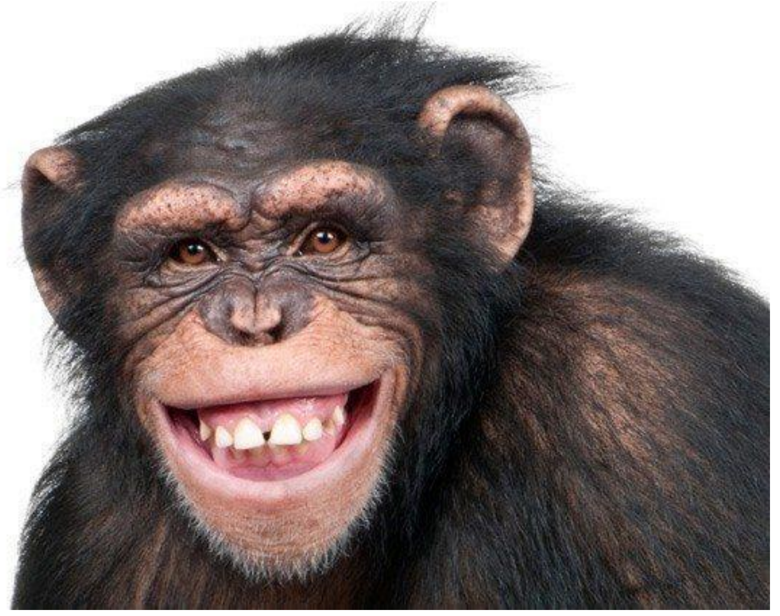


CONTENT 3

Natural intellect





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CONTENT 4

Artificial intelligence

- concept - **Artificial Intelligence (AI)**;
- introduced by John McCarty in **1956;**
- reason – different projects, designed to get computers to think and learn.

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CONTENT 4

Artificial intelligence

„ **Artificial Intelligence (AI)** is the science of concepts that allows computers to do things that seem reasonable to humans”.
(P. Winston)

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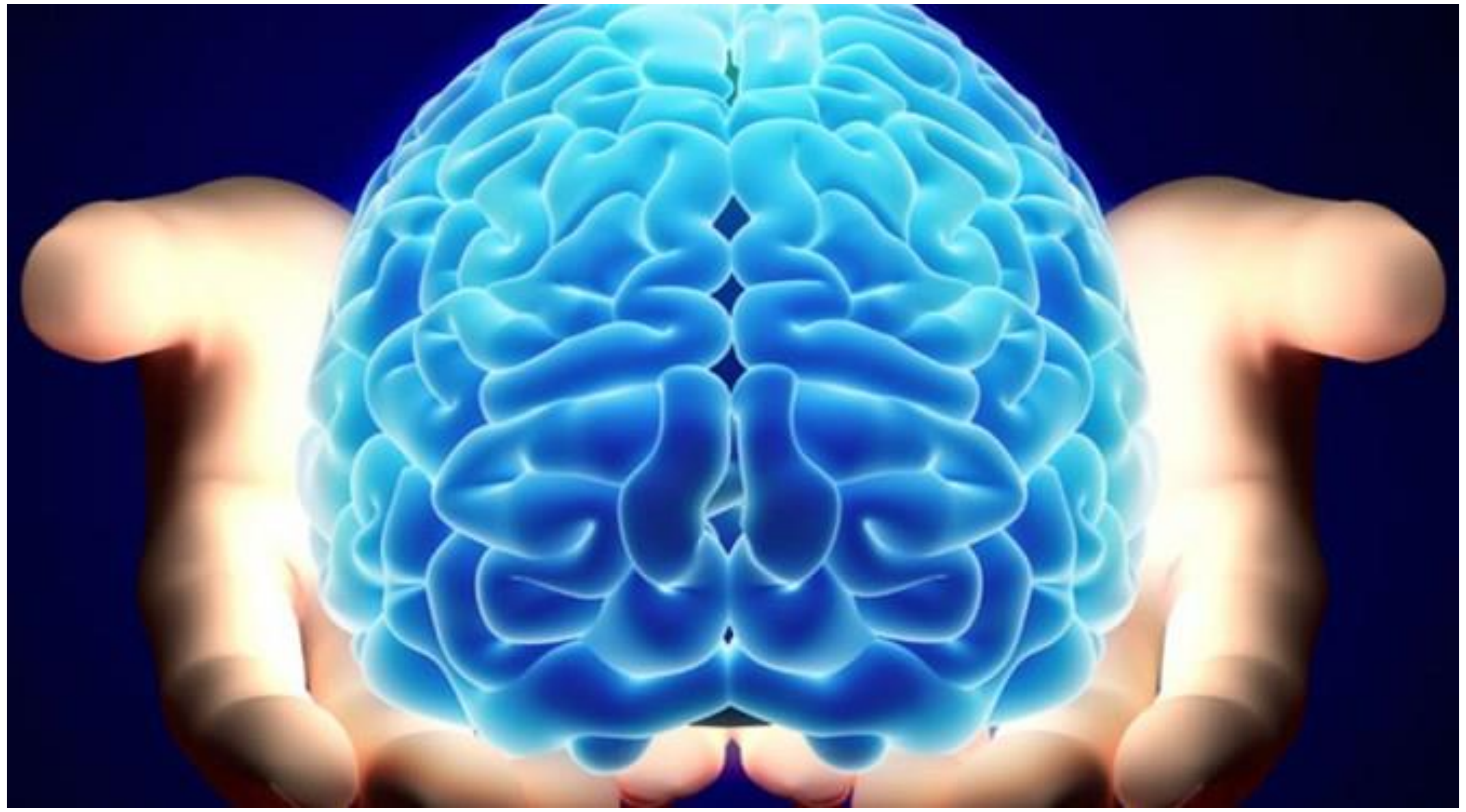
CONTENT 4

Advantages of natural intelligence from computer science’s perspective

- Parallel organization of the brain;
- Proven difference in the specialization of the right and left hemispheres of the brain;
- The human brain is made up of neurons, organized into a complex network;
- The search for information in the brain happens through the associative principle;



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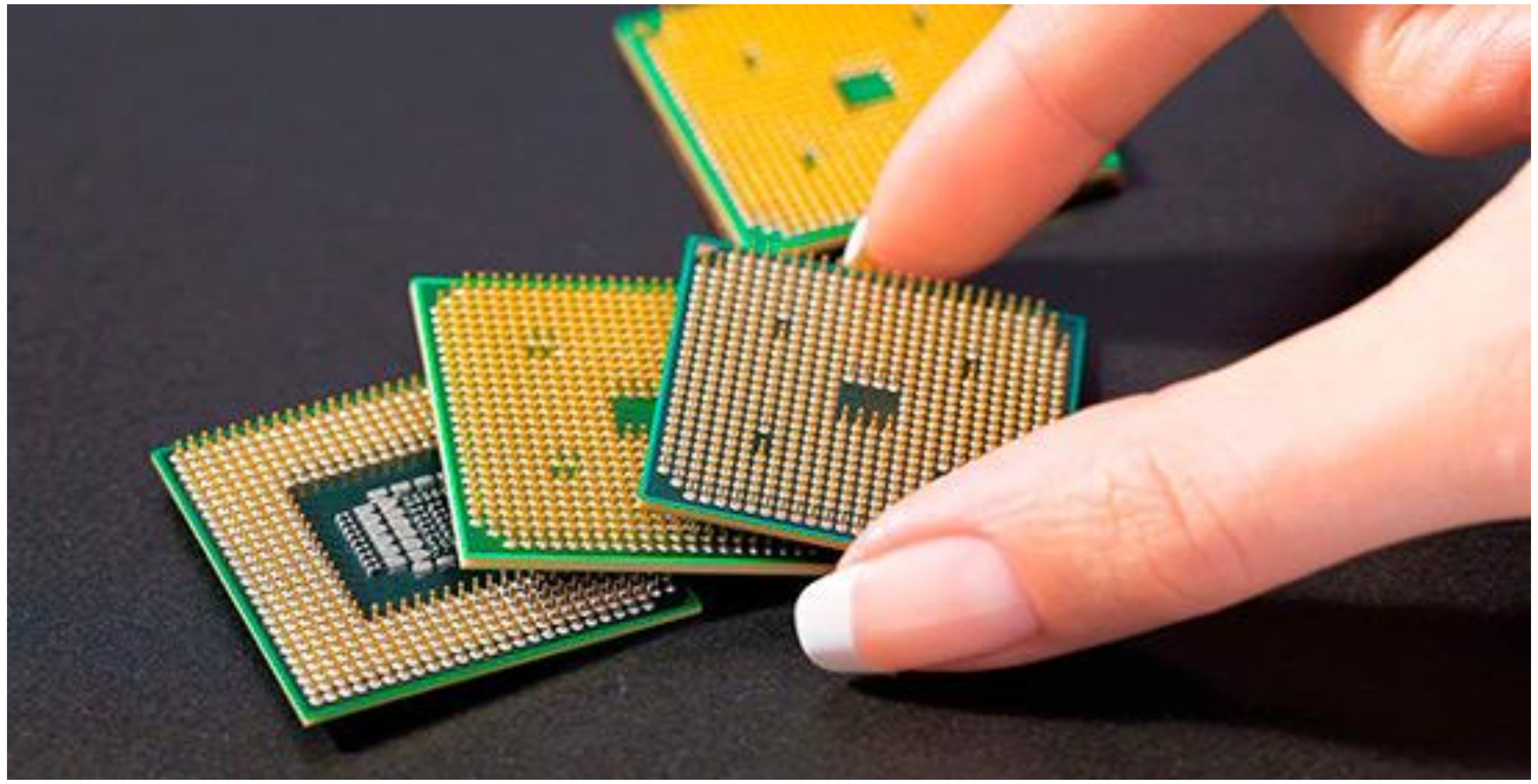
CONTENT 4

Advantages of natural intelligence from computer science’s perspective

Parallel organization of the brain – using this feature, multi-core processors and parallel computers were created.

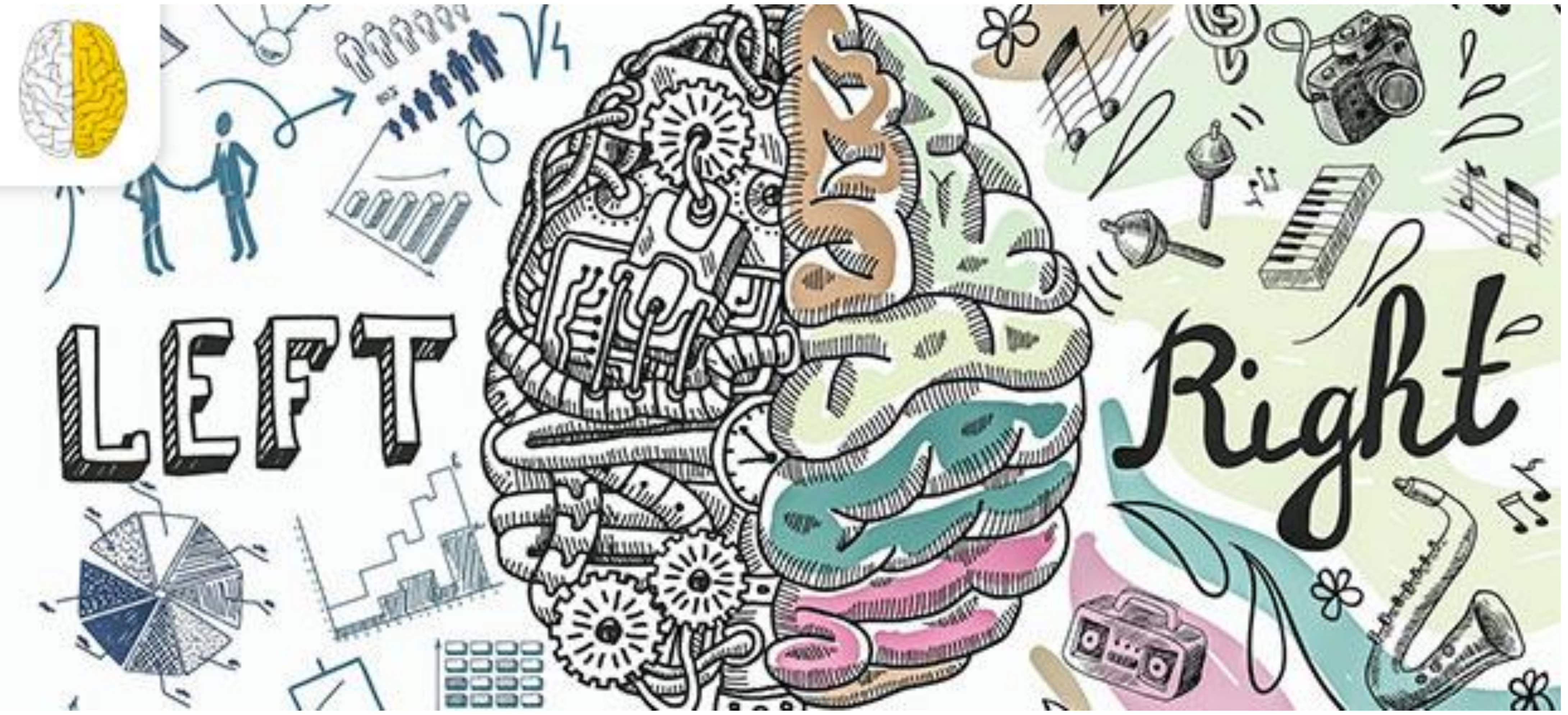
NPU (neuron processing unit) - part of the processor responsible for processing tasks related to AI.



CONTENT 4

Advantages of natural intelligence from computer science’s perspective

Proven difference in the specialization of the right and left hemispheres of the brain (the right is mostly responsible for the imaginary thinking and the left - for the symbolic) – separating the video processing to the video card.



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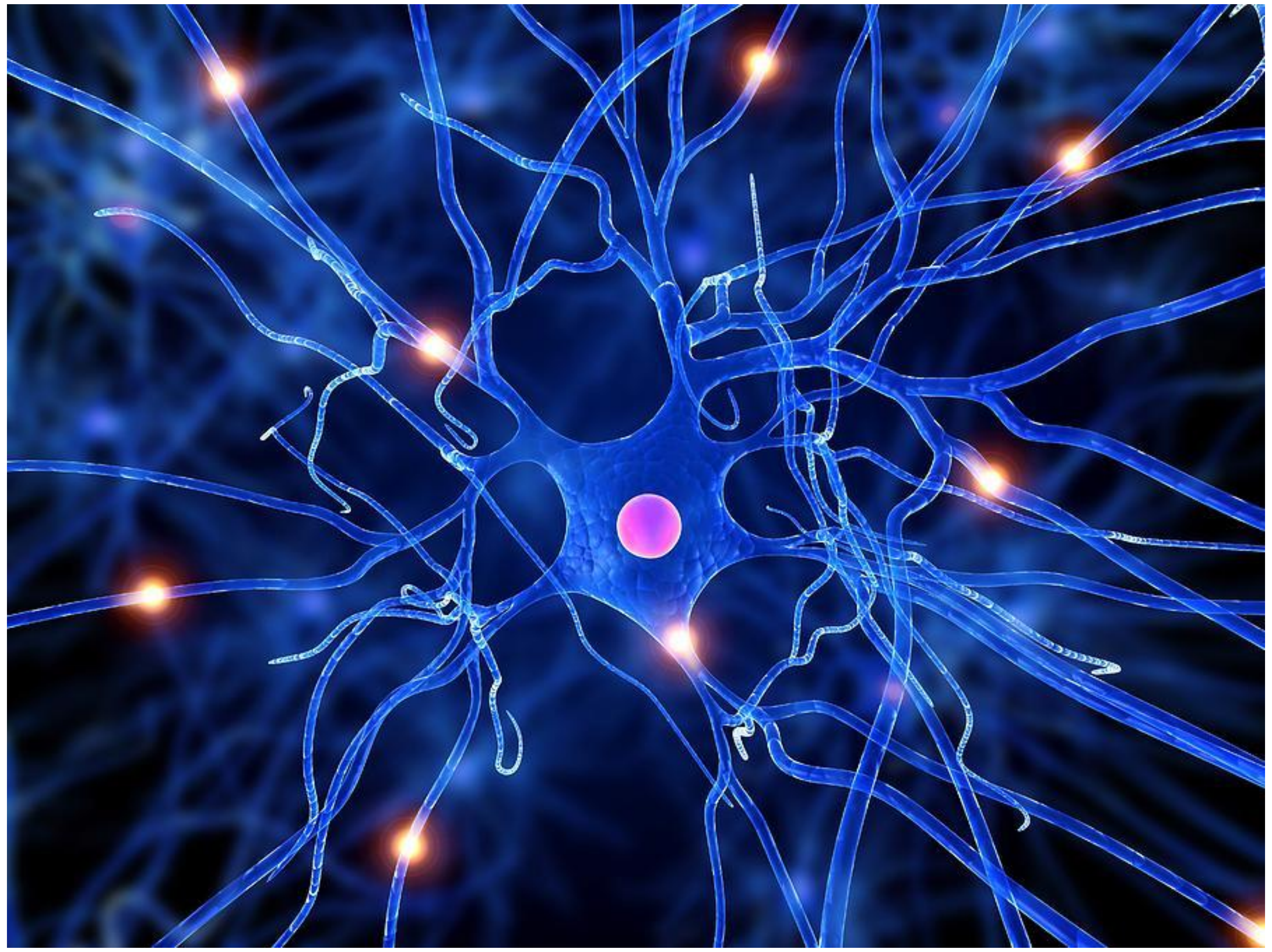
CONTENT 4

Advantages of natural intelligence from computer science’s perspective

The human brain contains over 10^{11} neurons and each one is in contact/connection with a range from 10^{4} to 10^{10} other neurons – this fact determines the contours of the new generation computers and nets.

Proven layered architecture.



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CONTENT 4

Advantages of natural intelligence from computer science's perspective

The search for information in the biological memory happens through the associative principle – a transition begins from address memory devices to associative.

CONTENT 5

Intelligent system (IS)

- complex adaptive system;
- makes rational decisions and can be self-taught.

Has:

- senses;
- executive mechanisms;
- goal – to reach it, it chooses an action based on its experience and knowledge.

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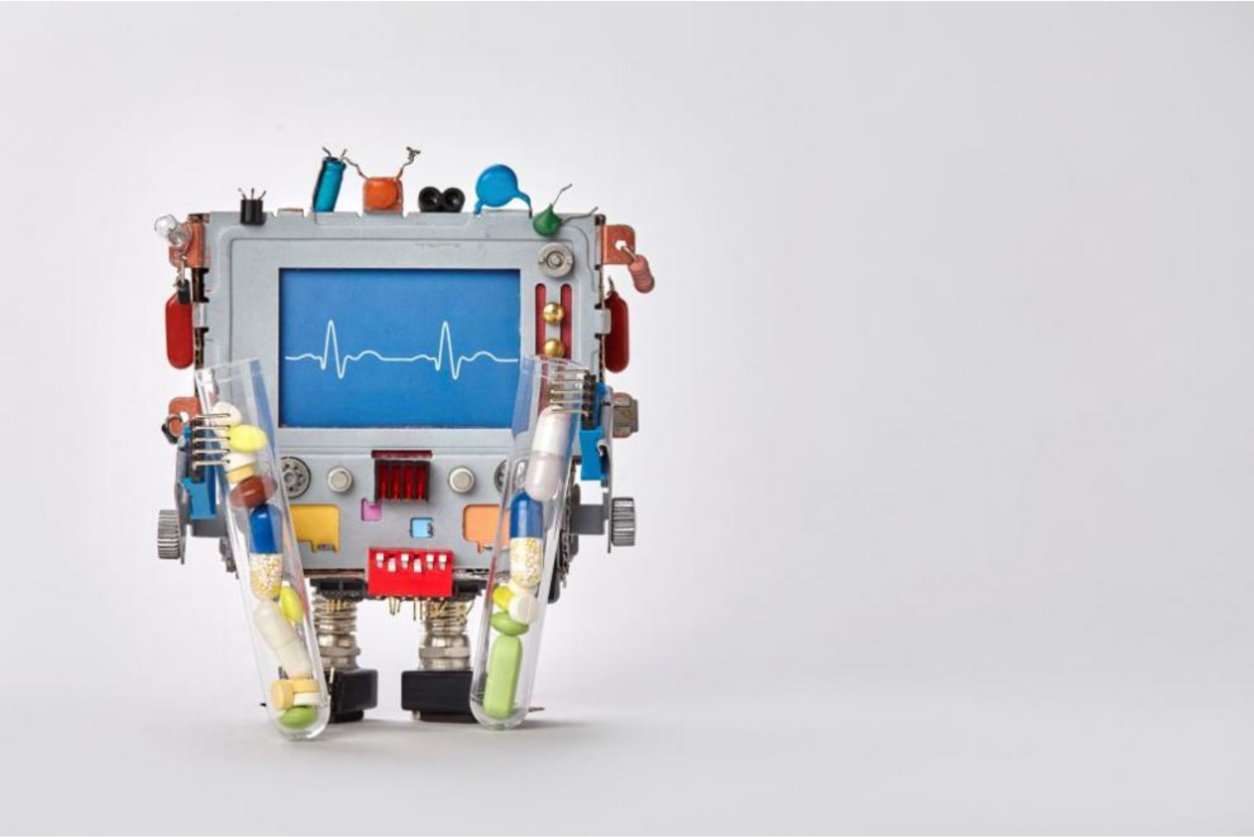
CONTENT 5

Examples of intelligent systems

- human;
- higher animals;
- computer;
- robot;
- other



CONTENT 5

Intelligent computer system (ICS) - features

- **Uses software algorithms with cognitive abilities similar to those of humans** (planning, self-learning, pattern discovery in random data, etc.).
- **Differs from the traditional software.**
- **Requires hardware computing power and data**.

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CONTENT 5

ICS vs standard computer system

- **Standard program** - implements a given processing algorithm;
- **Intelligent system** - makes conclusions using a knowledge base. AI algorithms must be able to recognize and react to unexpected circumstances not foreseen by the programmers.

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CONTENT 5

Real ICS

Just a tool that, in contrast to fantasy films, only helps and complements people, processing huge amounts of data with precision and speed, sometimes inaccessible to human abilities.

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CONTENT 6

History – industrial revolutions

- 1st – **steam engines** replace human labor;
- 2nd - **electricity** replaces steam engines;
- 3rd - **automation**, i.e. computers appear, that follow specific instructions;
- 4th – **autonomy**, i.e. machines plan and learn.

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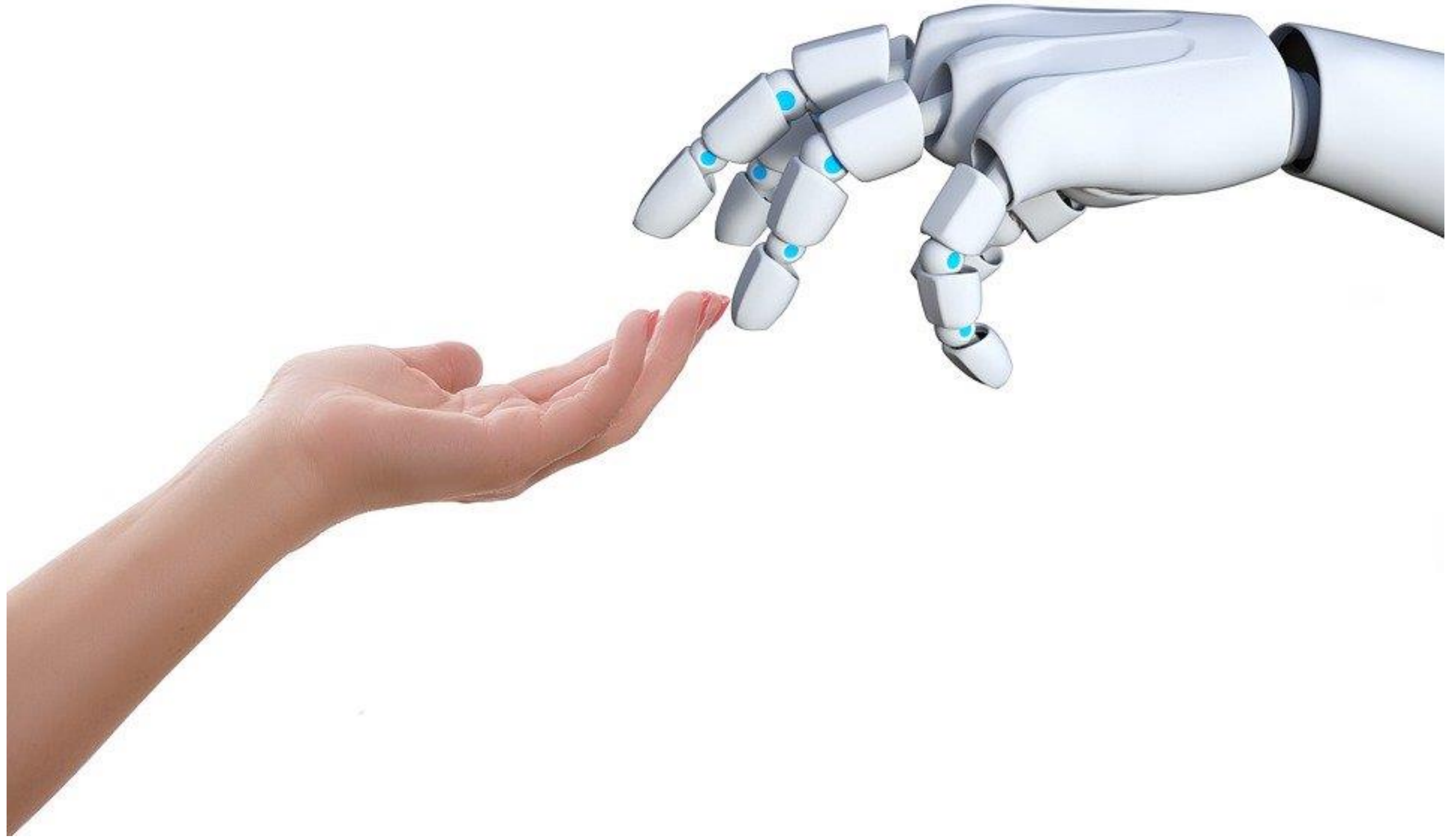
CONTENT 6

History – transition to autonomy

Example – industrial robots:

- 1st stage, automation – a hand moves and grabs objects by pre-set coordinates;
- 2nd stage, autonomy - a camera that sees the object and has an end goal without prior step-by-step instructions.



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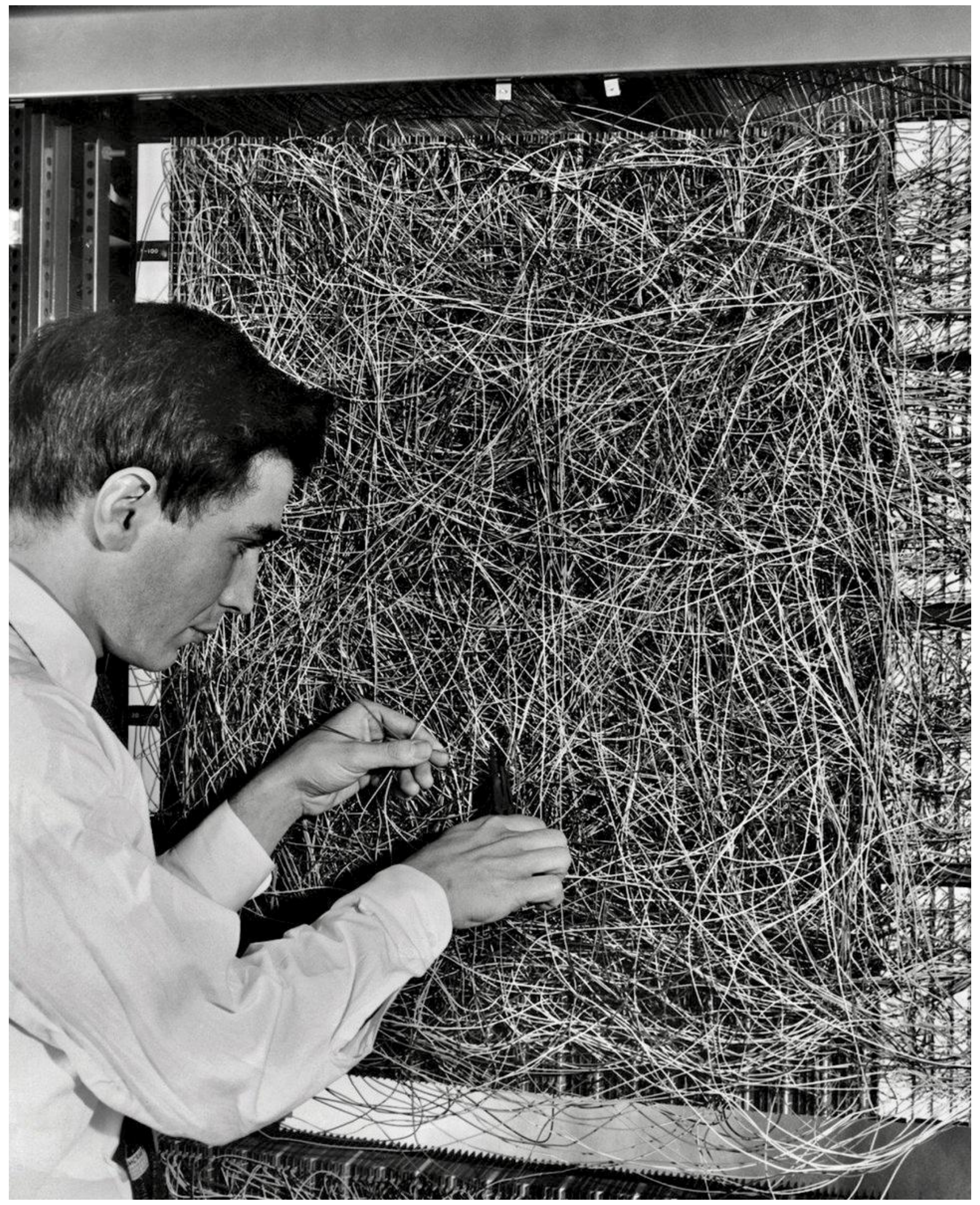
CONTENT 6

1^{st} Stage in the development of ICS

- **The 50s of the XX century**;
- Target - **building sensible machines that mimic the human brain.**
- Representative – the self-organizing machine **PERCEPTRON** (perceptual device) by the psychologist F. Rosenblatt. This machine, as a rough model of the retina of the human eye, had to be trained to recognize visual images.



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1^{st} Stage in the development of ICS - results

Similar to human vision, the input/"retina" of the device is an ordered plurality of n binary elements

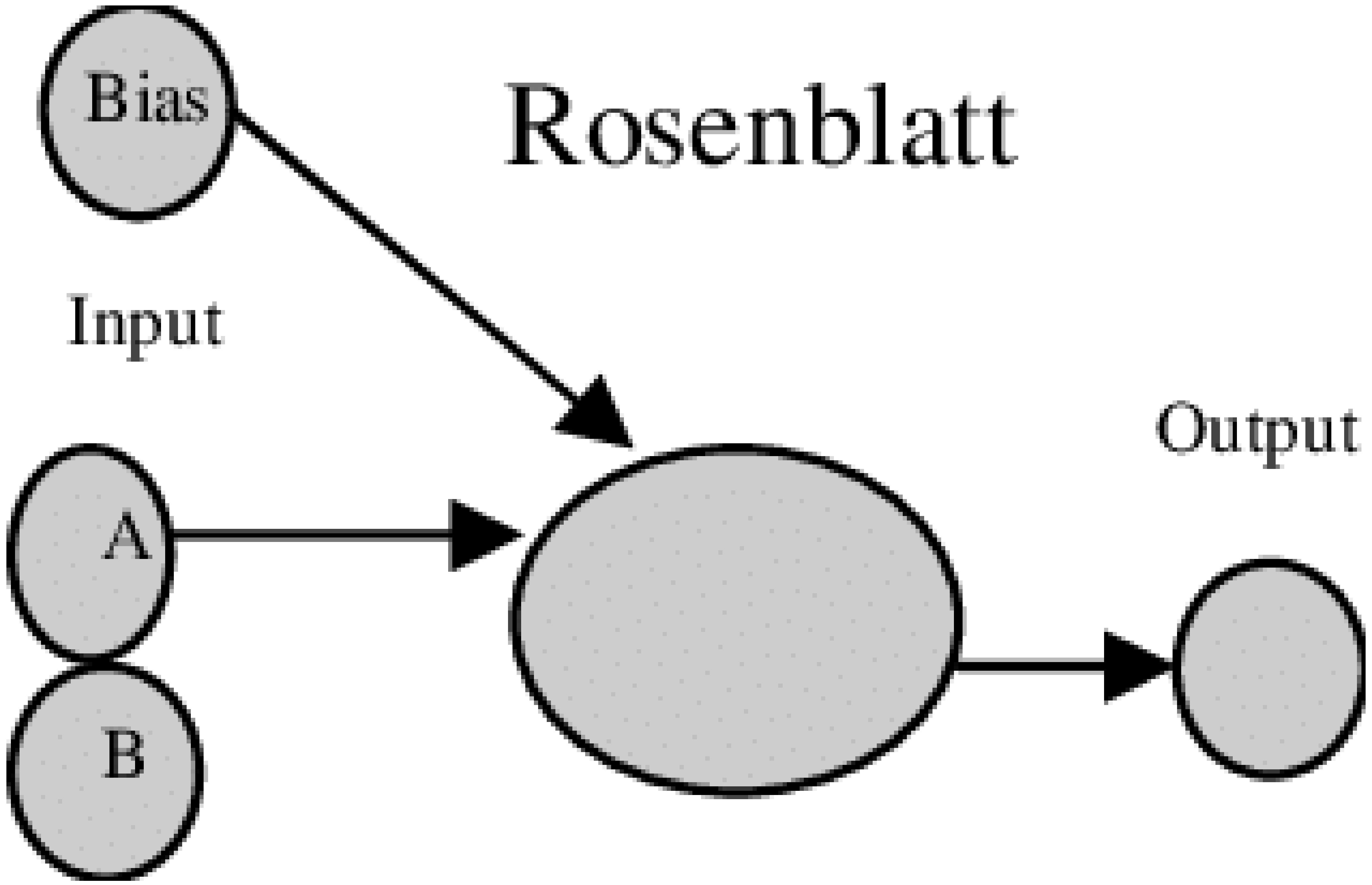
R = (XI,X2,........Xn)

One image is the sum of the values of the elements of R, for example:

R = (1,0,0,1, . . . , 1) , Xi ∈ {0,1}

If the retina has n variables, then 2^n situations are possible.

- **Conclusion** – The apparatus and program tools prove to be inappropriate for the realization of such an idea, which has not been experimentally confirmed anyway.



CONTENT 6

2nd Stage in the development of ICS

- **The 60s of the XX century**.
- Target – **Resolver of any predefined tasks**.
- Representative – the system **GPS (General Problem Solver),** created in **1959** by A. Newell and H. Simon.

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CONTENT 6

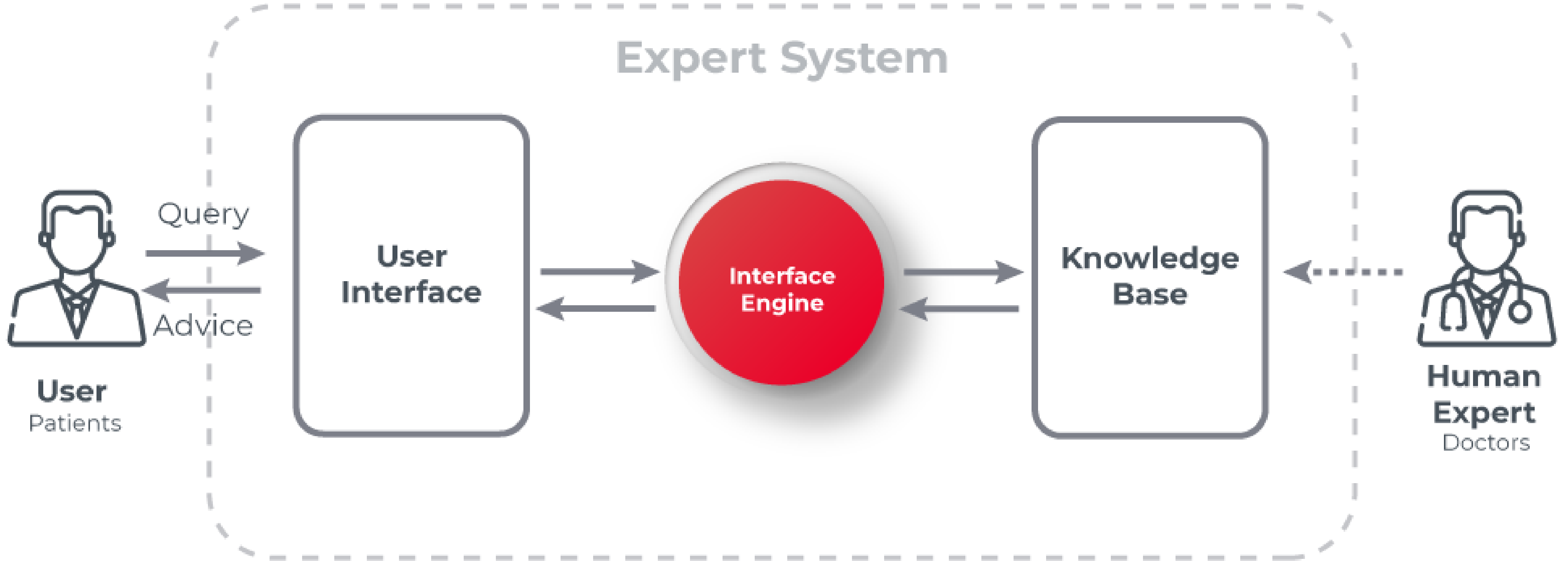
2nd Stage in the development of ICS - results

- Characteristic - **heuristic search**.
- The conceptual basis of GPS - the combination of computer science and psychology. According to A. Newell and H. Simon, the solution to each task is to search in the space of possible heuristic rules that help direct the search to the desired goal. In this sense, GPS is defined as an universal system, since each user can set the problem environment in terms of the objects and the operators that apply to them. This “universality” is applicable to a limited number of mathematical problems with a small number of states and well formulated rules.
- **Conclusion** - GPS and its modern similarities function for formalized tasks, such as “The Tower of Hanoi”, which are without particular practical value, but remain a classical program of AI.

CONTENT 6

3rd Stage in the development of ICS

- **The 70s of the XX century**.
- Target – **expert system**. Efforts are directed not towards the search for universal heuristics, but towards what every specialist expert has - skills, practices and informal rules.
- Representative - **DENDRAL** and **MYCIN** for the diagnosis of bacterial infections of the blood;



CONTENT 6

3^{rd} Stage in the development of ICS - results

1. Knowledge is set by rules

IF (1) the infection is a primary bacterial, AND

(2) the place, from which the sample is taken it sterile, AND

(3) it is supposed, that this organism has entered through the gastrointestinal tract,

THEN it can be assumed (0,7), that this organism is of bacterial character.

2. The system is robust - the rules have confidence factors that allow incredible data and inaccurate information to lead to credible conclusions.

3. The system itself can explain the reflection process.

- **Conclusion** - MYCIN, despite its limited capabilities, is workable and useful in practice.

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CONTENT 6

4th Stage in the development of ICS

- **The 80s and 90s of the XX century**.
- Target – **training and self-educating of ICS**.
- Representative – the machine-learning system **EURISKO**. It itself improves and expands its heuristic rules, and the language for descriptions of rules and concepts allows "meta-rules" in it as a "self-consciousness" in rudimentary form. It also manages its own behavior by remembering the rules it found and applying them to itself. It has won a war game three years in a row (with the rules of the game being changed every time) and it designed a completely new, 3D integrated circuit of the type AND/OR with an ultra-high degree of integration.

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CONTENT 6

4th Stage in the development of ICS - results

- **Types of learning:**
- ➢ by remembering situations;
- ➢ through analogues;
- ➢ through discoveries;
- ➢ through search guidance;
- ➢ through generalizations, etc.

- **Conclusion** – This type of IS find wide practical application.

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CONTENT 7

ICS popularity

- Devices in which we can integrate a microprocessor and memory are potential intelligent systems.
- The development of information technologies is a prerequisite for the wide integration of ICS in all aspects of life.

CONTENT 7

ICS application

- cars;
- robots;
- CNC machines;
- online stores;
- systems for traffic management;
- terminals for sales of goods;
- …in almost all of the industries in the world.

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CONTENT 7

Scenarios for future development

- **Scenario 1**: a stage of rapid progress and reaching the human level in the performance of many tasks.

- **Scenario 2**: stage of slowdown of progress due to:

➢ the large amount of data that will have to be processed;

➢ critical attitude in people;

➢ the introduction of regulations.

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CONTENT 7

ICS problematics

- **Search for a solution (in the state space);**
- **Action planning;**
- **Communicating with the computer in a language, close to the natural;**
- **Visual image recognition;**
- **Knowledge representation;**
- **Expert systems;**
- **Neural networks**.

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INTELLIGENT COMPUTER SYSTEMS

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LECTURE 2

INTELLIGENT COMPUTER SYSTEMS NOWADAYS

1. Introduction
2. Types of intelligent computer systems
3. Risks
4. Quantum computers

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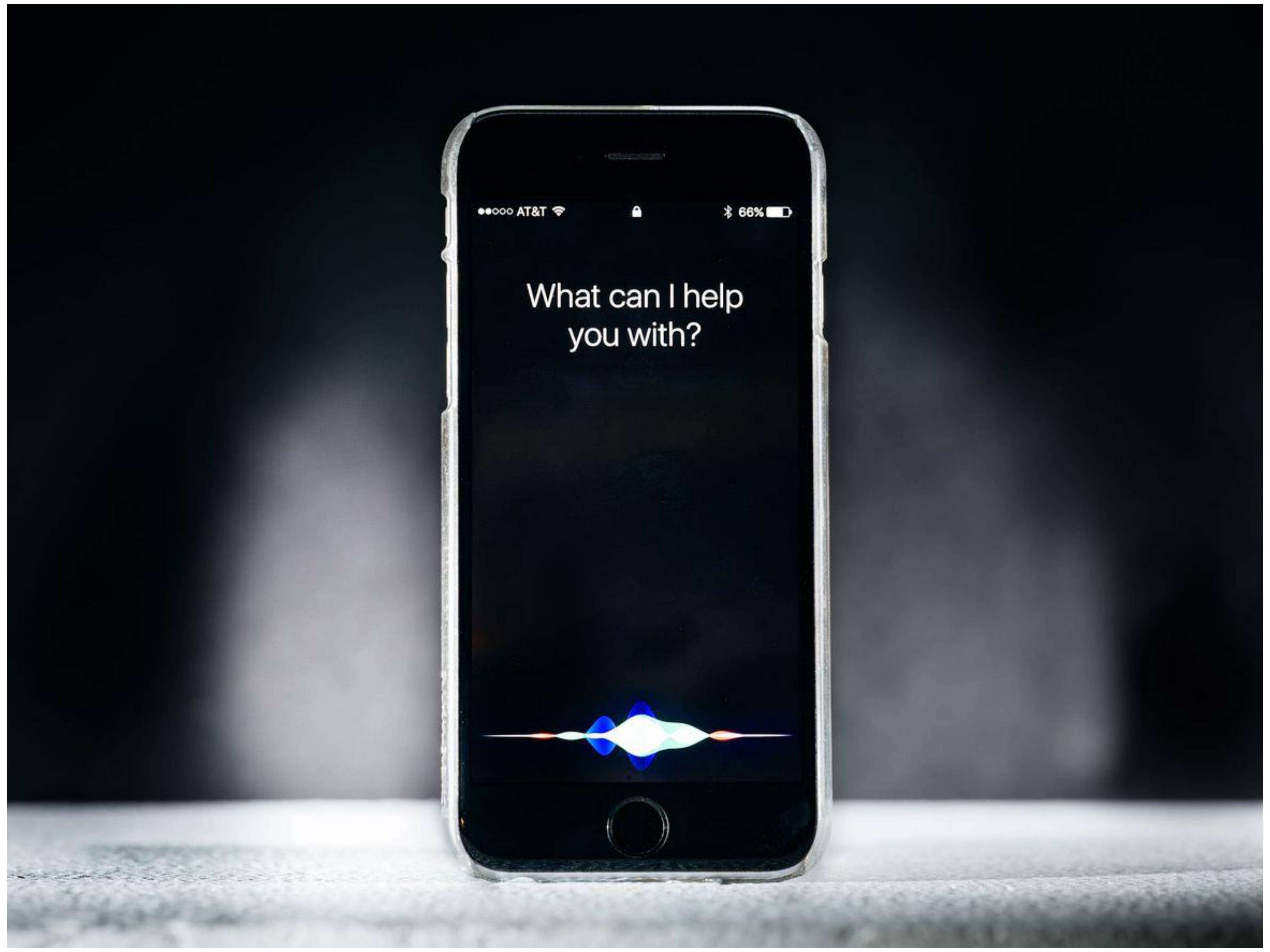
Popularity nowadays

From SIRI (Apple) and Cortana (Microsoft) to self-driving cars.

While science fiction often portrays AI as robots with human-like characteristics, AI can encompass anything: from Google's search algorithms to IBM's Watson for autonomous weapons.

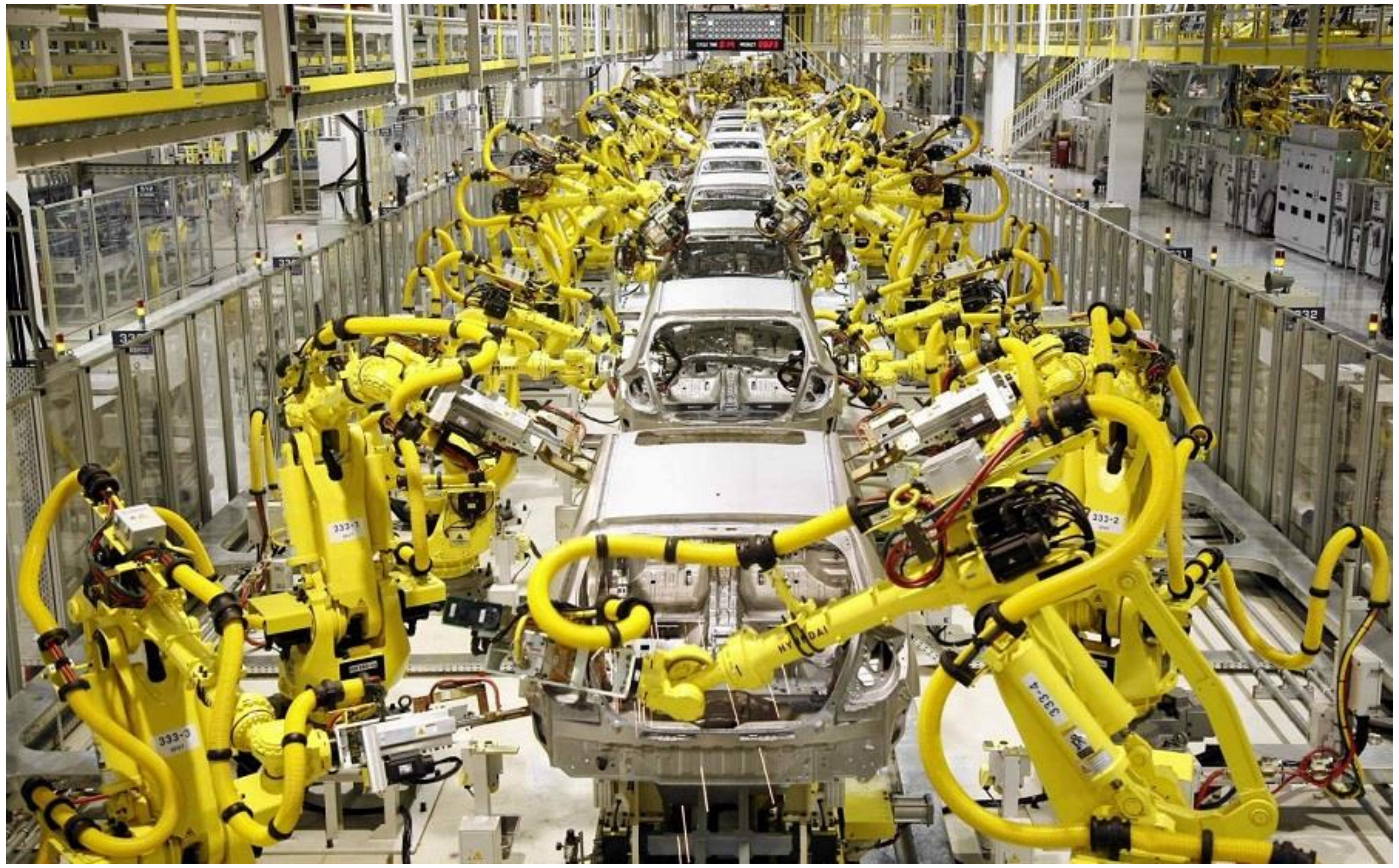


CONTENT 1

Application of robots

3D:

- **D**irty;
- **D**ifficult;
- **D**angerous.



Possible outcomes for the future of ICS (according to Nick Bostrom, philosopher)

- **“Oracle”** – answers queries with absolute accuracy;
- **“Genie”** – executes commands and awaits for the next one;
- **“Sovereign”** – assigned a main goal and works independently in the world around it, by making decisions on how best to achieve it.

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CONTENT 2

Types of ICS

- **narrow-profiled/expert** - designed to perform a specific task (e.g. only facial recognition or only internet searches or only driving a car).
- **general (AGI)** – with a long-term goal.

While narrow-profiled AI may outperform humans at any specific task (e.g. a game of chess), AGI would outperform humans at nearly every cognitive task.

CONTENT 3

Main risk

People cannot understand what an ICS is good at and what it is not.

CONTENT 3

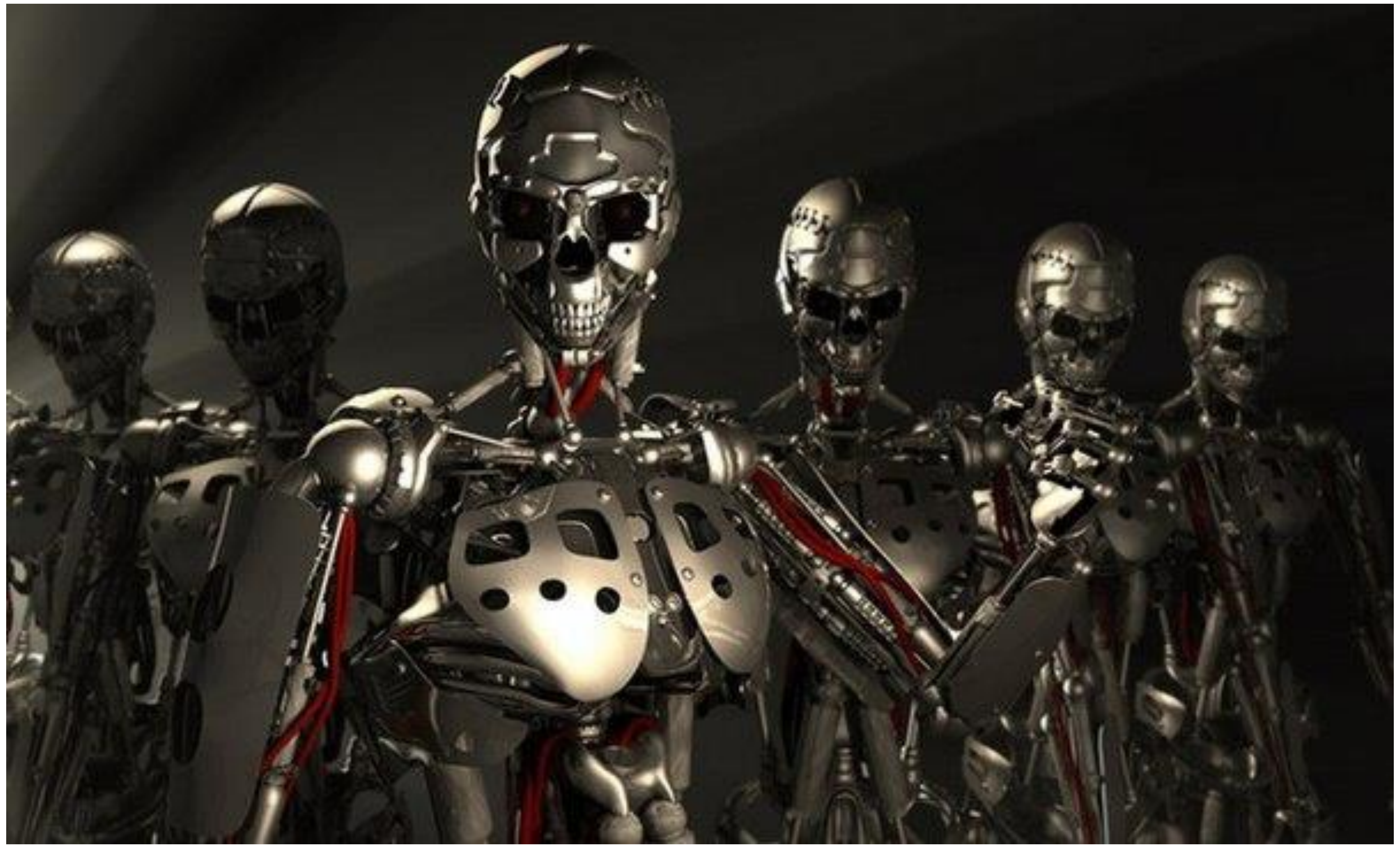
Potential risks – possible scenarios

- **ICS, programmed to do something devastating**

Autonomous weapons are ICSs that are programmed to kill. In the hands of the wrong person they could easily cause mass casualties. To avoid being stopped by the enemy, they would be designed to be extremely difficult to simply “switch off,” so humans could eventually lose control in such a situation.

CONTENT 3

The US army has a project for the replacement of ¼ of its soldiers with robots



CONTENT 3

Project “Army” of the Pentagon

- The plan - to spend $ 1 billion over the course of 5 years (since 2017) on building robots to accompany soldiers on the battlefield.
- Tasks – scouting, disposal of explosives, "sensing" of dangerous chemicals, carrying of equipment.

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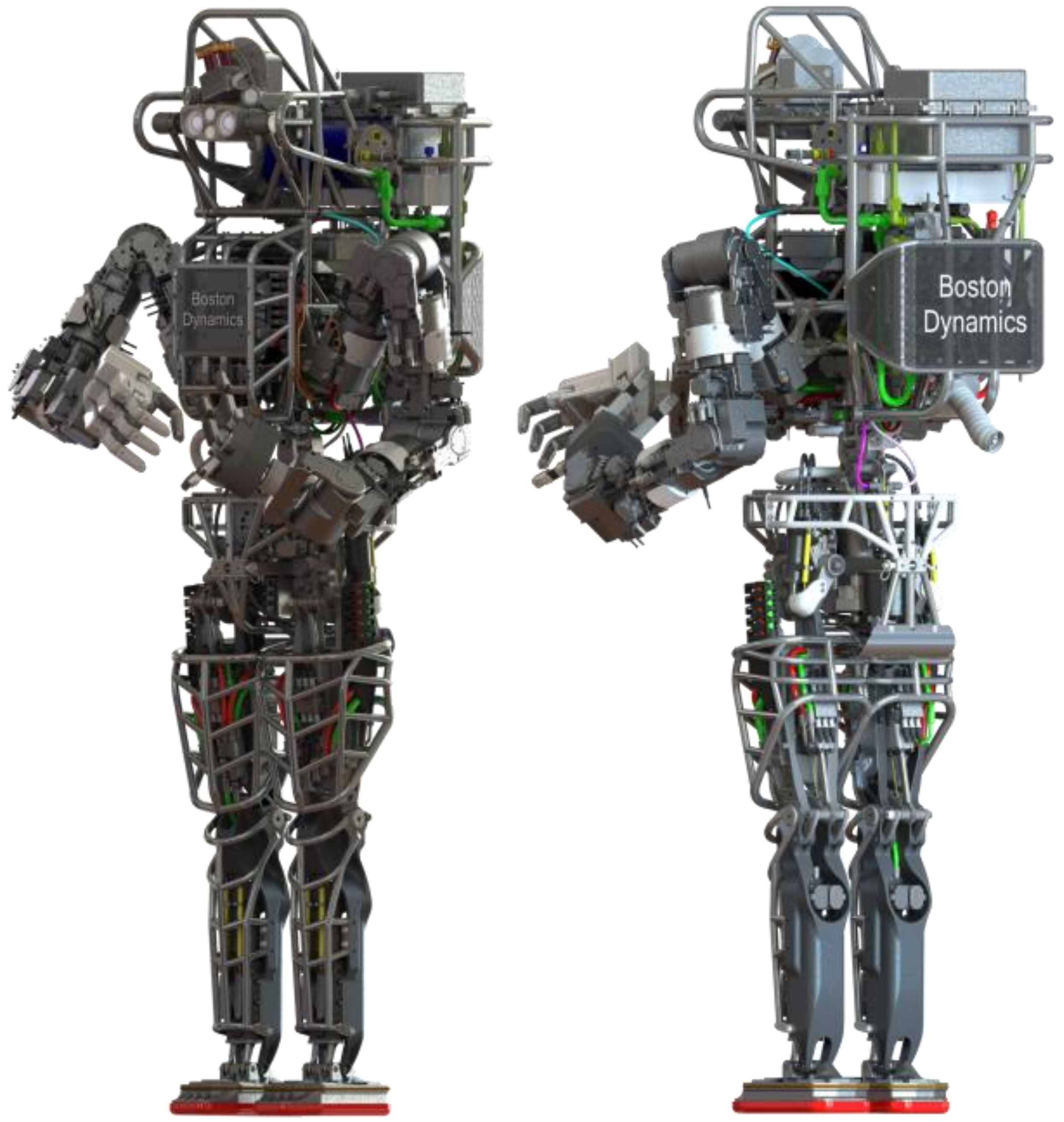
CONTENT 3

Project "Army" - FOR

- Bryan McVeigh, the project manager – thinks that by the end of the project there will be robots in every army. This new army will be times faster than a human one and it would have the ability to "see" the battlefield. According to him, there is no danger of autonomous robots such as "Terminator", because the plan is that the **commands would always be given by people** and robots will not make decisions by themselves.



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CONTENT 3

Project “Army” - AGAINST

- Elon Musk leads a group of 116 specialists from 26 countries - they issue a formal letter to the UN asking for a **ban on deadly autonomous weapons**. They believe that robots are unpredictable, and the fact that they are not being constructed to be autonomous now does not mean they will not become such.

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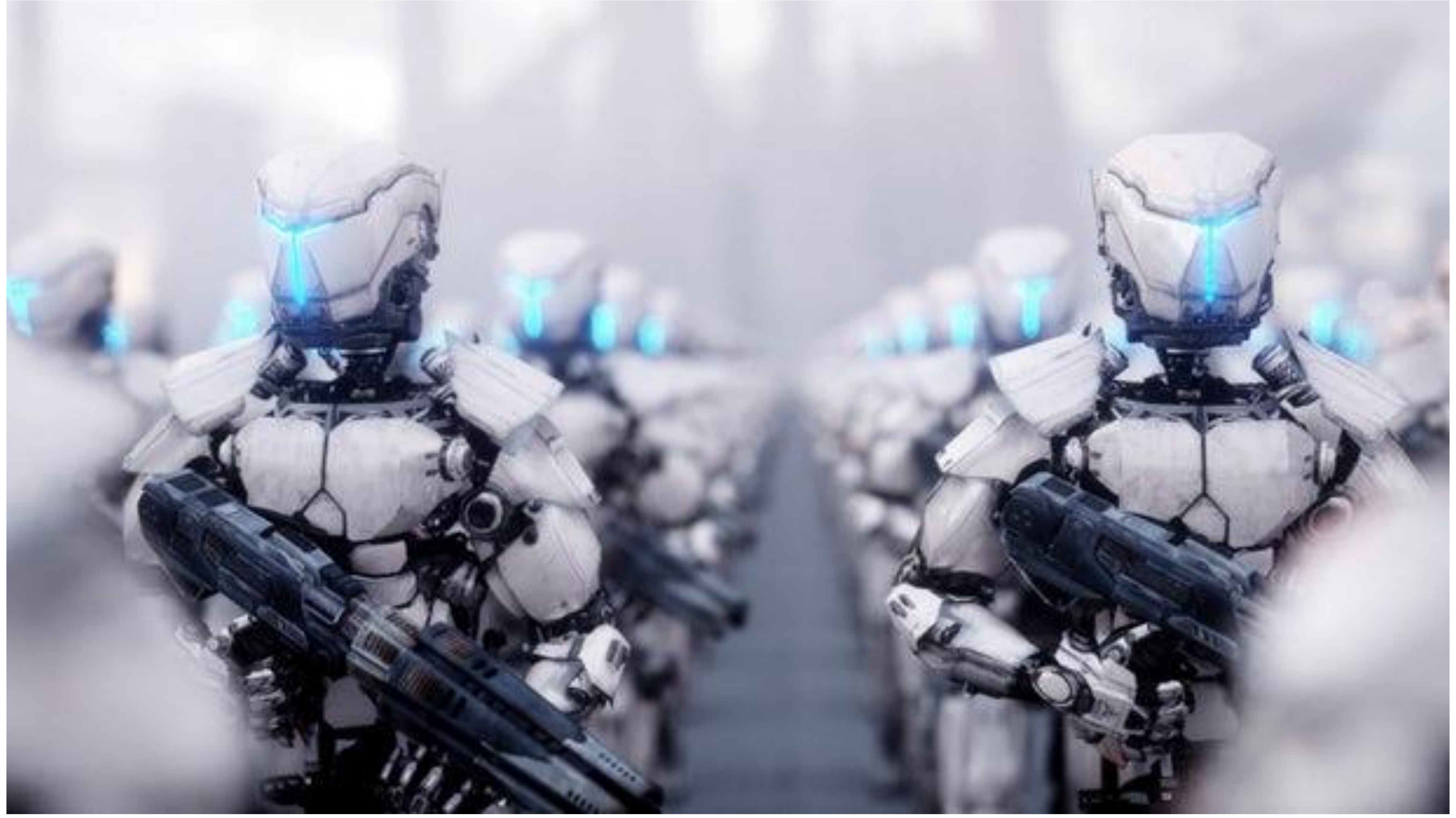
CONTENT 3

War projects

- Russia’s president, Vladimir Putin, said in an interview with Forbes: “Artificial intelligence is the future, not only for Russia, but for all humankind. It comes with enormous opportunities, but also threats, that are difficult to predict. Whoever becomes the leader in this field will become the **ruler of the world**.”



CONTENT 3

Second scenario

- **ICS, programmed to do something beneficial, but it develops a destructive method for achieving its goal -** this could happen whenever we fail to fully align the ICS's goal with ours.

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CONTENT 3

Second scenario - example

If you ask an intelligent car to take you to the airport as fast as possible, it might get you there by being a threat to the rest of the traffic participants, by doing literally what you asked for.

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CONTENT 3

Second scenario - example

The driving company Uber released its own autonomous cars and bad results were not delayed. The first death by an autonomous car is now a fact: a woman killed while crossing the street in Tempe, Arizona.

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CONTENT 3

Second scenario - example

If an ICS is tasked with an ambitious geo-engineering project, it might destroy our ecosystem as a side effect, and view human attempts to stop it as a threat that needs to overcome.

CONTENT 3

Second scenario – benefits and risks

ICSs are becoming better at accomplishing their goals, but if those goals aren't aligned with ours, we would have a problem.

What would happen if we are in charge of a hydroelectric green energy project and there's an anthill in the region and it needs to be flooded?

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CONTENT 3

Second scenario – benefits and risks

A key goal for ICS safety research - never place humanity in the position of those ants.

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CONTENT 3

Second scenario – benefits and risks

China is developing a social system, based on facial recognition algorithms and cameras that track the daily activities of people. The goal is to give every one of China's 1.4 billion citizens a personal score based on how they behave - do they jaywalk, do they smoke in non-smoking areas, how much time they spend playing video games, etc.

When you are being watched and then decisions are made based on that intel, it's not only an invasion of privacy, but it can quickly turn to social oppression.

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CONTENT 3

Risks with ICS

- **Loss of control;**
- **Possibility for manipulations:**
- ➢ of turnovers;
- ➢ of public opinion;
- ➢ of people’s desires.

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CONTENT 3

Base risks

- AI does not generalize - it is good at a certain task.

Example – The fact that an AI plays GO does not mean that it can drive a car and vice versa.

- When AI encounters a "mystery" - receives information that is not part of its training.

Example – Trained to recognize people with beards.

CONTENT 3

Can we predict the future?

Even the most powerful supercomputers cannot say definitively whether it will rain next week:

- Incredible complexity of what we are trying to model;
- A large number of variables that we need to know very precisely - wind speed and direction, solar activity, changes in the temperature of the atmosphere and water bodies, etc.

This chaotic unpredictability is the reason for the so-called **butterfly effect**, i.e. any small change in the initial conditions can lead to many different outcomes if we expand the system over time.

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CONTENT 3

Base risks - conclusion

If AI is used for making predictions - does it realize when it cannot make a good prediction, based on the information it has?

A human can generalize and ask for help when he is unsure, but today's ICS cannot.

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CONTENT 3

Perfect determination

Knowing the exact initial conditions in a system would allow us to calculate how that system evolves: cause and effect.

In reality - it is impossible to know and control the initial conditions, as well as all other ongoing effects, to infinite precision, in a system that is even simpler than weather.

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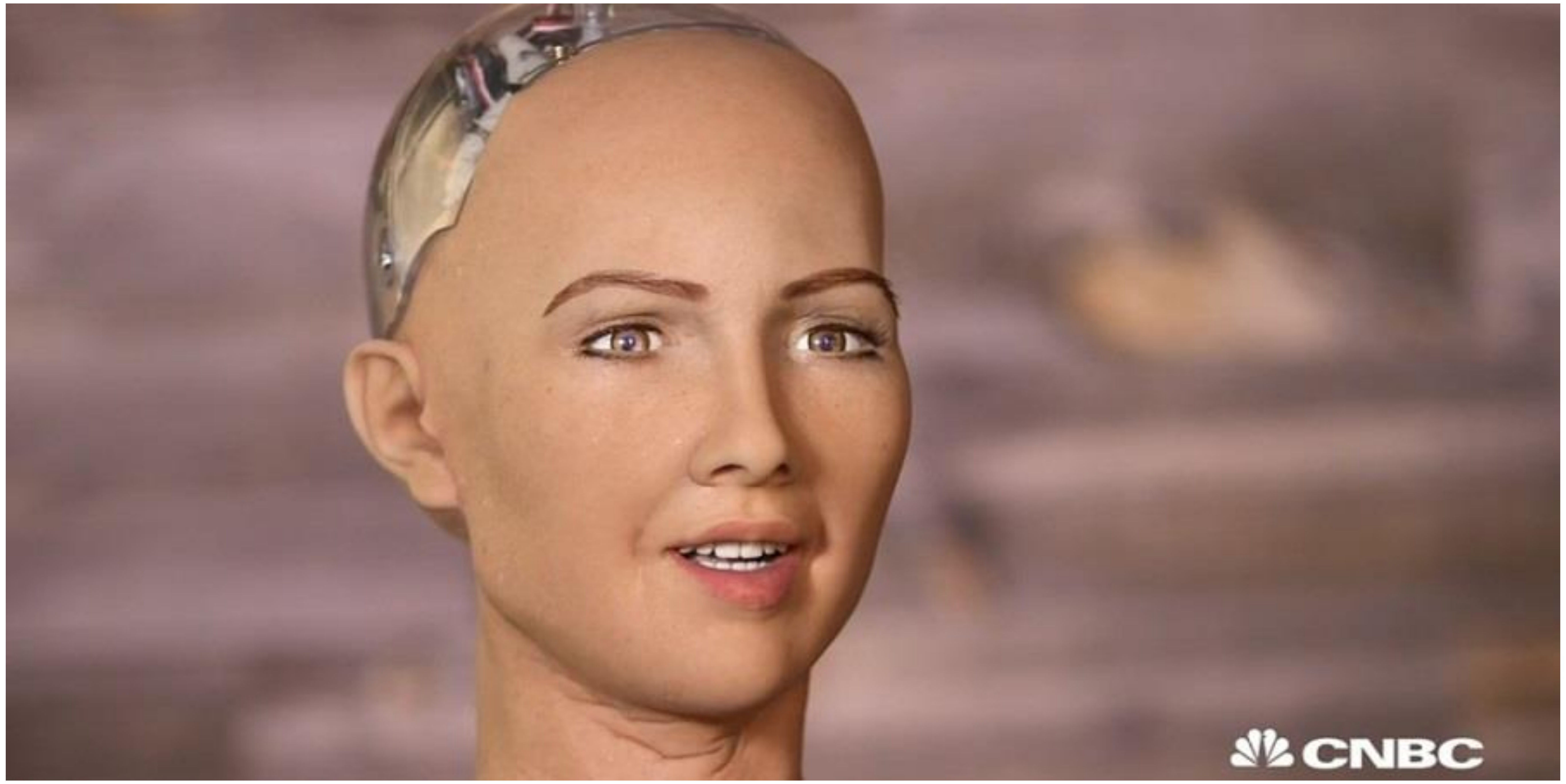
CONTENT 3

Sophia – first robot with citizenship



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CONTENT 3

Sophia – first robot with citizenship

- Produced by Hanson Robotics in Hong Kong and activated on February 14, 2016. It is modeled after the actress Audrey Hepburn and uses AI for communication by having been given initial mimics and answers to some standard conversation topics, but is programmed to “smarten up" over time.
- The goal - to be used as a companion for elderly people in homes and to help with major events such as concerts, etc.
- In October 2017, she obtained citizenship in Saudi Arabia, and in the beginning of 2018 she was given legs and the opportunity to walk.

CONTENT 3

Sophia – first robot with citizenship

Will Smith on a date with Sophia:

https://www.youtube.com/watch?v=Ml9v3wHLuWI&t=109s

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CONTENT 3

Sophia – first robot with citizenship

- **Negative reviews** - Sophia has the opportunity to “smarten up" with time, i.e. she develops new "thoughts" on certain topics, and can each time give a different answer to any question. Her "thinking" happens through the **decision tree**. That way, she formulates her answer depending on what the person across her has said. This is not dangerous in itself and many people call her a chat-bot. To what extent, however, is the "reasoning" on different topics simply a follow-up to the decision tree, and to what extend is it actually “getting smarter"? Some scientists believe that this given freedom that Sophia has could turn against us, as she could become too self aware with time.

- Interview of CNBC with Sophia https://www.youtube.com/watch?v=78-1MlkxyqI
- Sophia’s blog: https://www.hansonrobotics.com/blog/

CONTENT 3

Lil Miquela – first software „robot“

- Project, crearted by Brud in 2016 as an Instagram profile. Used mainly as a marketing strategy for different campaigns at the beginning, it now leads an independent “life”.
- Without a physical body, modelled over the images of real people.
- By the middle of 2022 has 3 million followers on Instagram.

- Lil Miquela’s introduction: I’m Miquela, A Real-Life Robot Mess - https://www.youtube.com/watch?v=6bn3tUUtj2M

CONTENT 3

Will robots close down jobs?

CONTENT 3

Which jobs will be occupied by robots?

- **Workers**;
- **Service Personnel** - McDonald’s franchise in Phoenix is almost entirely robot-controlled;
- **Translators** - Google Translate is improving thanks to its neural network.
- **Accountants -** SMACC Financial Company, provides $ 3.5 million to set up its accounting system with AI;
- **Lawyers** – the international lawyer firm Baker & Hostetler has hired the first lawyer with AI called ROSS;
- **Writers** - a novel written by AI, almost wins a literary award. EMMA, the plagiarism detector, can easily identify authorship if a certain number of documents are uploaded to it.
- ...

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CONTENT 3

Will robots kill jobs?

- Daisuke Adachi and colleagues at Yale University looked at Japanese manufacturing between 1978 and 2017 – they discover that an increase of one robot per 1,000 workers increased company employment by 2.2%.
- Joonas Tuhkuri from the Massachusetts Institute of Technology (MIT) and colleagues looked at Finnish companies - concluded that the introduction of modern technology led to an increase in the hiring of employees.
- Unpublished work by Michael Webb of Stanford University and Daniel Chandler of the London School of Economics - examines machine tools in British industry and finds that automation has a "strong positive relationship with company survival and that greater initial automation is associated with increased employment “.

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CONTENT 4

Quantum computers and science in the XXI century

- **Quantum bits (qubit)** – are not limited to only 2 possible states, but can exist in a quantum superposition of both 0 and 1, i.e. can store much more information.
- **Advantage** - many entangled qubits can handle multiple operations simultaneously.
- **Problems before implementation:**
  - such states can be maintained only under special conditions and for a very short time;
  - to control the input and output of the information that the qubits process due to their increased number.
- **Working on the problem** – IBM, Google, startup companies.
- Quantum computers will need their own software and algorithms (Shor's algorithm for dividing a number by prime factors, Grover's search algorithm, etc.).

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INTELLIGENT COMPUTER SYSTEMS

Svetlana Stefanova

September, 2022

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LECTURE 3

SPECIFICS OF INTELLIGENT SYSTEMS

1. Biological intelligent system
2. Intelligent system specifics
3. Types of intelligent computer systems
4. Agents

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Biological IS - skills

- for adaptation and survival;
- for obtaining new knowledge (curiosity);
- for copying other IS.

CONTENT 1

Basic functions of IS

- **receiving information** from the outside environment;
- **remembering** previous events;
- **decision making and reaction** towards the relevant situation;
- **ability to learn new behavioral rules**, by adapting and improving towards the surrounding environment.

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CONTENT 2

Elements of ICS

- sensors for perception of the environment;
- memory;
- algorithms for decision making;
- calculating elements;
- managing mechanisms;
- source of energy.

Features of modern ICS

- **Manageability** - allow refinement, diagnosis and repair from a distance;
- **Connectivity** - constant sharing of data (with people, with each other and in a "cloud" environment);
- **Security** - thanks to information encryption algorithms.

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CONTENT 2

ICS at home

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CONTENT 2

ICS in the industry

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CONTENT 3

ICS according to the resources used

- Centralized;
- Distributed.

CONTENT 3

Centralized ICS

The idea:

Ability to model real-world processes by adopting the idea of centralized intelligence, autonomy and power of a machine using all available information resources. For each individual task, ICS provides access to various information sources and integrates the obtained results.

Imposed requirements:

- **the need for a huge amount of knowledge for various tasks** - this places high demands on the hardware;
- **need for reprogramming** - to be able to interact with other software or with new information sources;

Risk:

Reaching dead-end states due to the lack of interaction with other systems for cooperative solving of the problem.

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CONTENT 3

Distributed ICS

The idea:

- the intelligent solution does not require a centralized memorization of the knowledge, processed by a general purpose inference scheme.
- intelligence is situational and active in individual tasks, enabling each solver to process the task without knowing the decision process in the rest of the system.

Questions:

- How to solve problems by systems, consisting of multiple distributed solvers?
- How to coordinate the distributed systems?

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CONTENT 3

Advantages of distributed ICS

- **extracting information from dispersed sources** and solutions, where the expert knowledge is distributed;
- **parallel problem solving -** difficult for one agent, due to resource limitations or due to the high risk of operation of centralized systems;
- **possibility of interconnection and exchange with existing systems** (intelligent and conventional) - changing business needs require renewal of existing systems, as complete rewriting is expensive or impossible;
- **higher speed of operation**;

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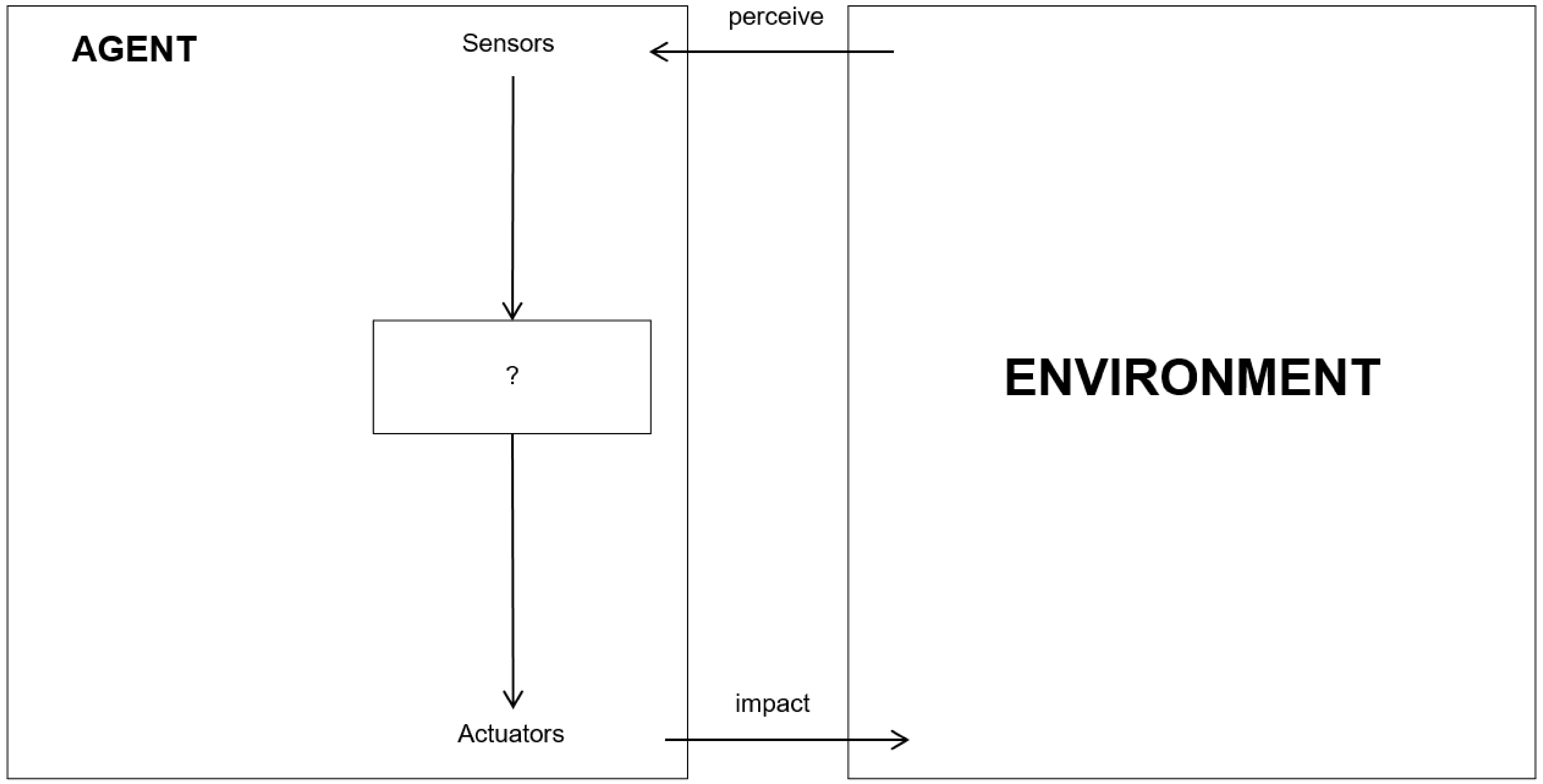
CONTENT 4

Agents

Key concept - ICS shape agents.

CONTENT 4

Agents



CONTENT 4

Mathematical description of an agent

- **Behavior of the agent** - can be described by a function, which maps to each perceptual sequence - a certain action.
- **External feature of the agent** - the function can be filled in a table by experimenting.
- **Internal feature of the agent** – the function will be implemented by the agent's program.

The function of the agent is an abstract mathematical description, and the program is a specific application implemented on the agent's architecture.

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CONTENT 4

ICS's task

To build a program of the agent, which applies the function in a way that it could map an action to each perception.

If the program is executed on a computing device with physical sensors and actuators, we call that architecture:\

Agent = architecture + program

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CONTENT 4

Task environment

PEAS (Performance, Environment, Actuators, Sensors)

Agent	Performance	Environment	Actuators	Sensors
autonomous car	comfortable, safe, fast, no traffic rules violations	roads, other participants in traffic: vehicles, pedestrians, customers	steering wheel, accelerator pedal, brake, etc.	cameras, mileage, GPS, engine sensors, etc.

CONTENT 4

Task environment features

- ***Single agent/multi-agent*** – according to the number of agents in the environment. For example, the game of chess is multi-agent, Sudoku - single agent.
- ***Fully/partially visible*** – if the agent's sensors give access to the full state of the environment at any point of time, i.e. define all the aspects that are necessary in choosing an action, then it is fully visible.
- ***Defined/fuzzy*** – if the next state of the environment is fully determined by the current state and action performed by the agent, then the environment is defined.
- ***Static/dynamic*** – if the environment can change as the agent is making a decision, then it is dynamic. Static environments are easier to implement, as the agent does not have to track the world when deciding what action to take.
- ***Episodic/associated*** – the agent's experience can be divided into separate episodes, each consisting of the agent's perception and the execution of a single action. The next episode does not depend on the actions taken in previous episodes.

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CONTENT 4

Steps when problem solving

- **Goal formulation** - based on current situation and performance measure. A goal can be considered as a set of states in which it is successful.
- **Problem formulation** - the process of deciding what actions and states to consider for a given goal. Actions of the type "moving forward 1 cm" would hardly lead to the resort village.
- **Search process** - to move from city to city, the correct path must be chosen if there is more than one. In order to choose the better one, the region must be known, i.e. to have prior knowledge.
- **Execution phase** - the search algorithm takes the problem as input and returns a solution in the form of a sequence of actions. Once a solution is found, the actions it recommends are performed.

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CONTENT 4

Knowledge of the environment

- **prior** – known in advance.
- **acquired** - obtained from monitoring the environment or from measurements using sensors. Measurements may contain "noise" which can lead to errors.

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CONTENT 4

Sensible agent

It reaches the best outcome or the best expected result.

Performance measure - a criterion for the success of the agent's behavior.

When an agent is placed in an environment, it generates a sequence of actions based on the impacts it receives. This sequence of actions causes the environment to go through a sequence of states. If this sequence is desired, the agent performs well.

There is no measure, that is appropriate for all agents.

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CONTENT 4

Simple reflex agents

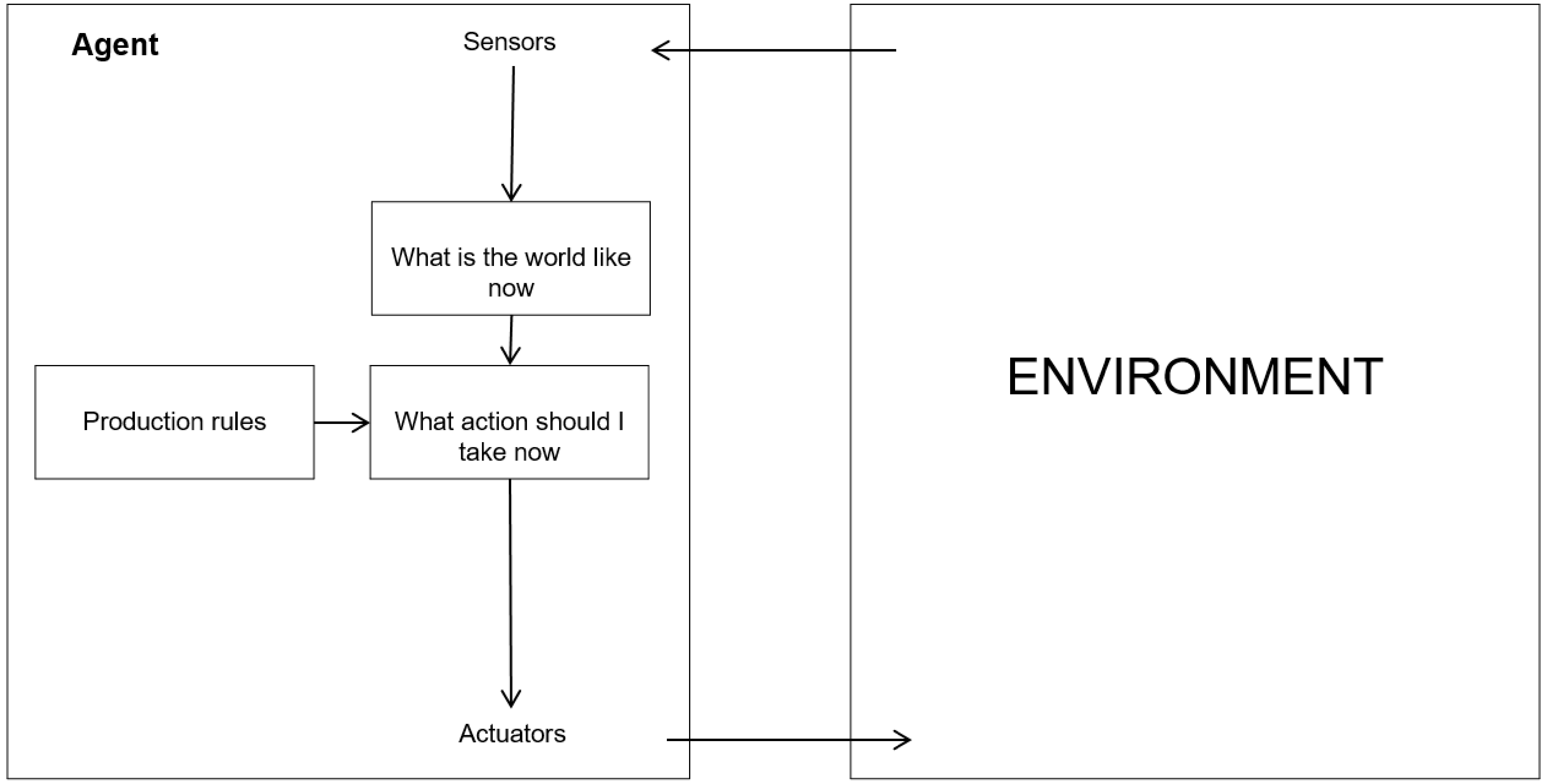
They choose actions based on current perception.

Example: autonomous taxi. If the car in front of us is stopping and its break lights light up, we need to notice this and also start stopping. Such a connection is called a rule of the type “condition-action”/ “if-then” or a **production rule**.

If *the car in front of us is stopping* ***then*** *we stop.*

CONTENT 4

Simple reflex agents



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CONTENT 4

Model-based reflex agents

In order to overcome partial visibility, the agent has **to keep track of the part of the world he can not see at the moment.**

In order to update the information about the inner state, two types of knowledge are required:

- how the world develops, regardless of the agent;
- how the actions of the agent influence the world.

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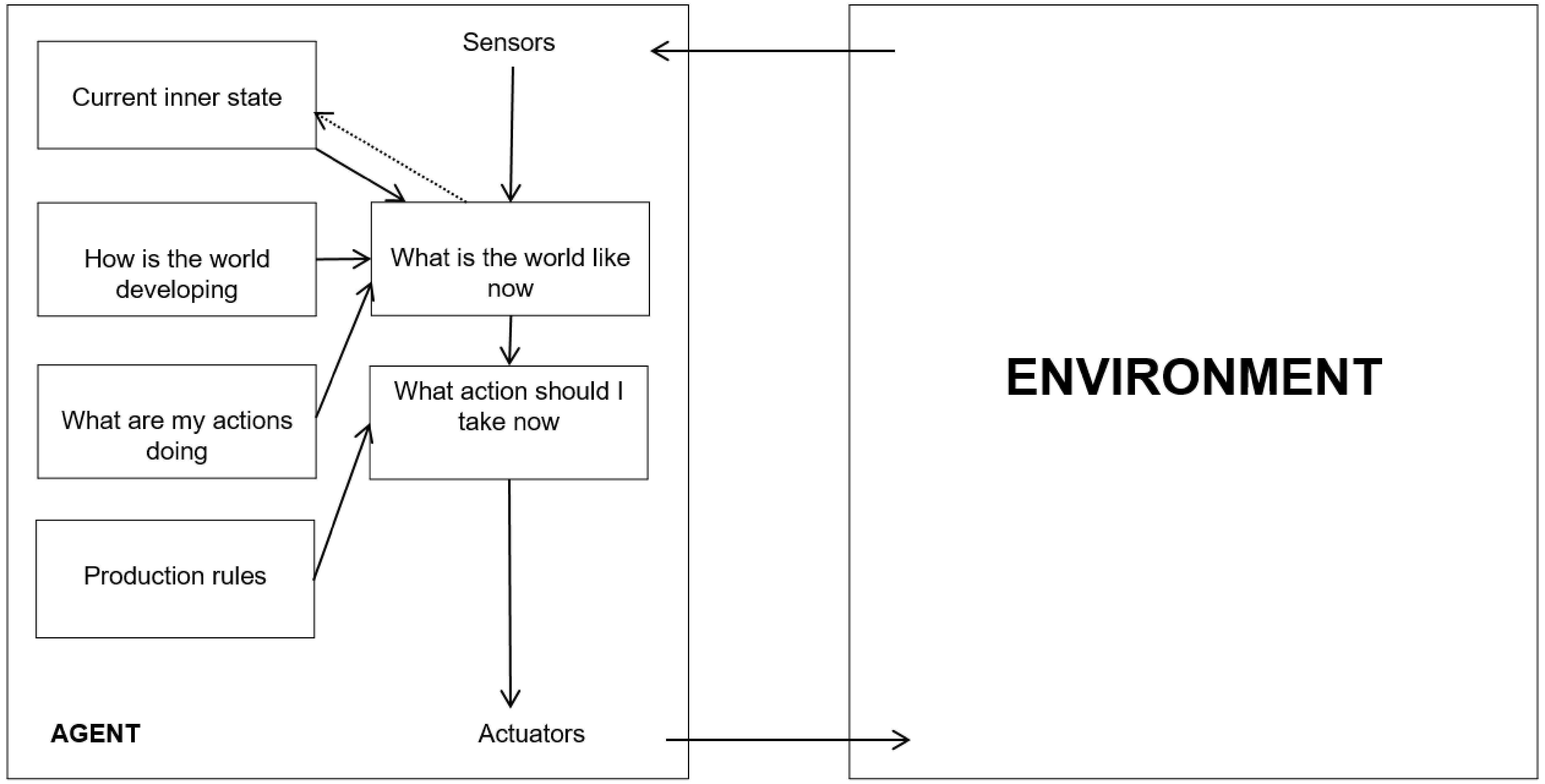
CONTENT 4

Model-based reflex agents



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CONTENT 4

Goal-based agents

Knowledge of the current state of the environment is not always sufficient to decide what to do.

Example: at an intersection, the car can turn left, right or continue straight.

i.e. **the agent also needs information about the goal it wants to achieve**.

IS can combine this with information about the results of possible actions (the same information used to update the internal state of the reflected agent). The choice becomes more complex when the agent must perform a sequence of actions and search for a path to achieve the goal.

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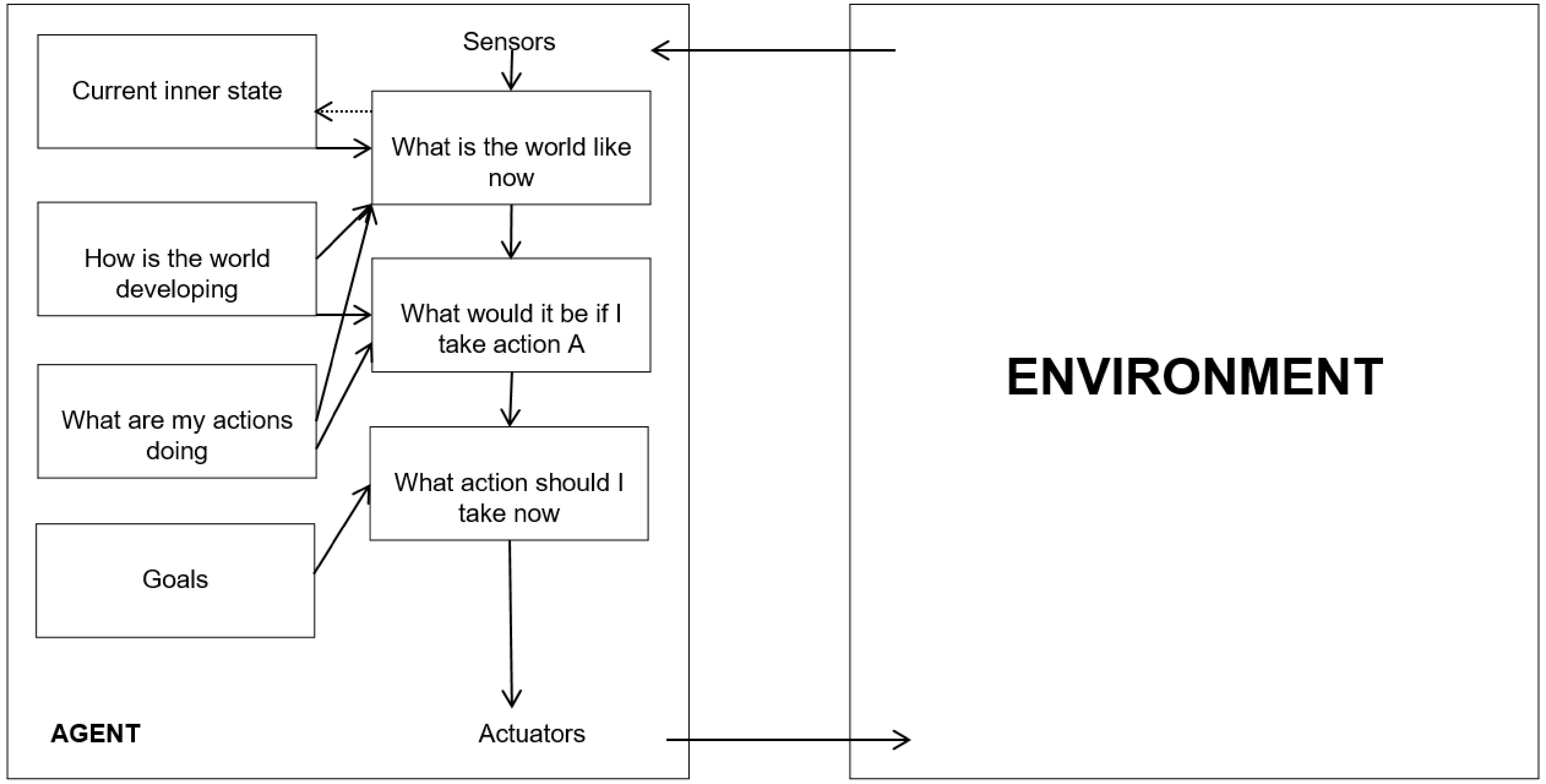
CONTENT 4

Goal-based agents



CONTENT 4

Utility-based agents

Example: there are different sequences of actions that would get the car to the goal, but some are faster, safer or cheaper than others.

The goal provides an awareness of the difference between "happy" and "unhappy" states, whereas a more basic measure of performance would allow a comparison between different states according to exactly how happy they would make the agent.

A utility function may map to a state or sequence of states a number that describes the **associative degree of happiness**.

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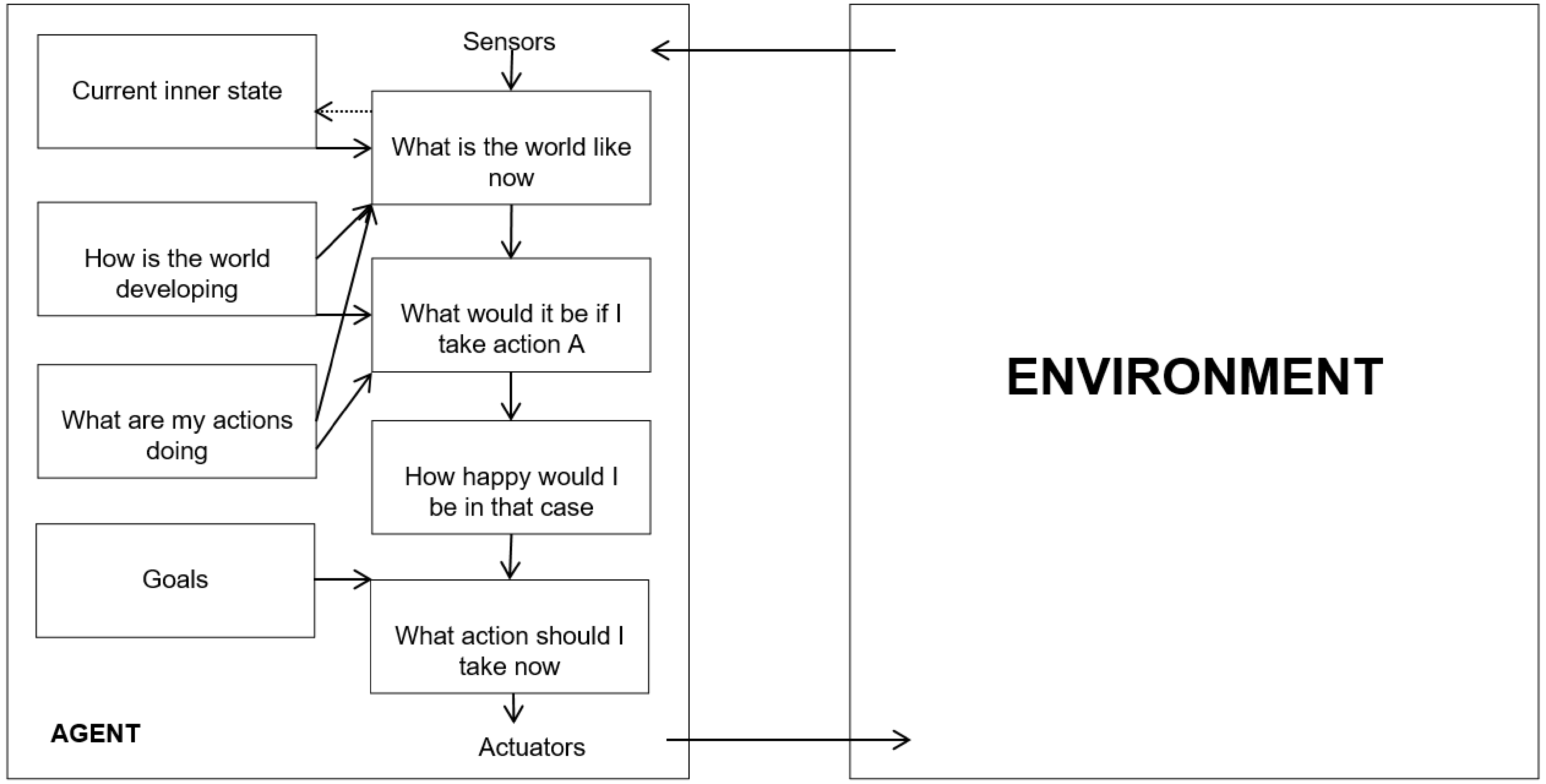
CONTENT 4

Utility-based agents



CONTENT 4

Problem solving agents

To solve problems we need sensible agents, which are usually **utility-based**.

Example: agent, going on holiday.

The performance measure could contain many factors:

- to get a tan,
- to enjoy the nightlife,
- to visit landmarks, etc.

If the agent has a flight delay, then he needs to transform his goal.

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LECTURE 4

EXPERT SYSTEMS

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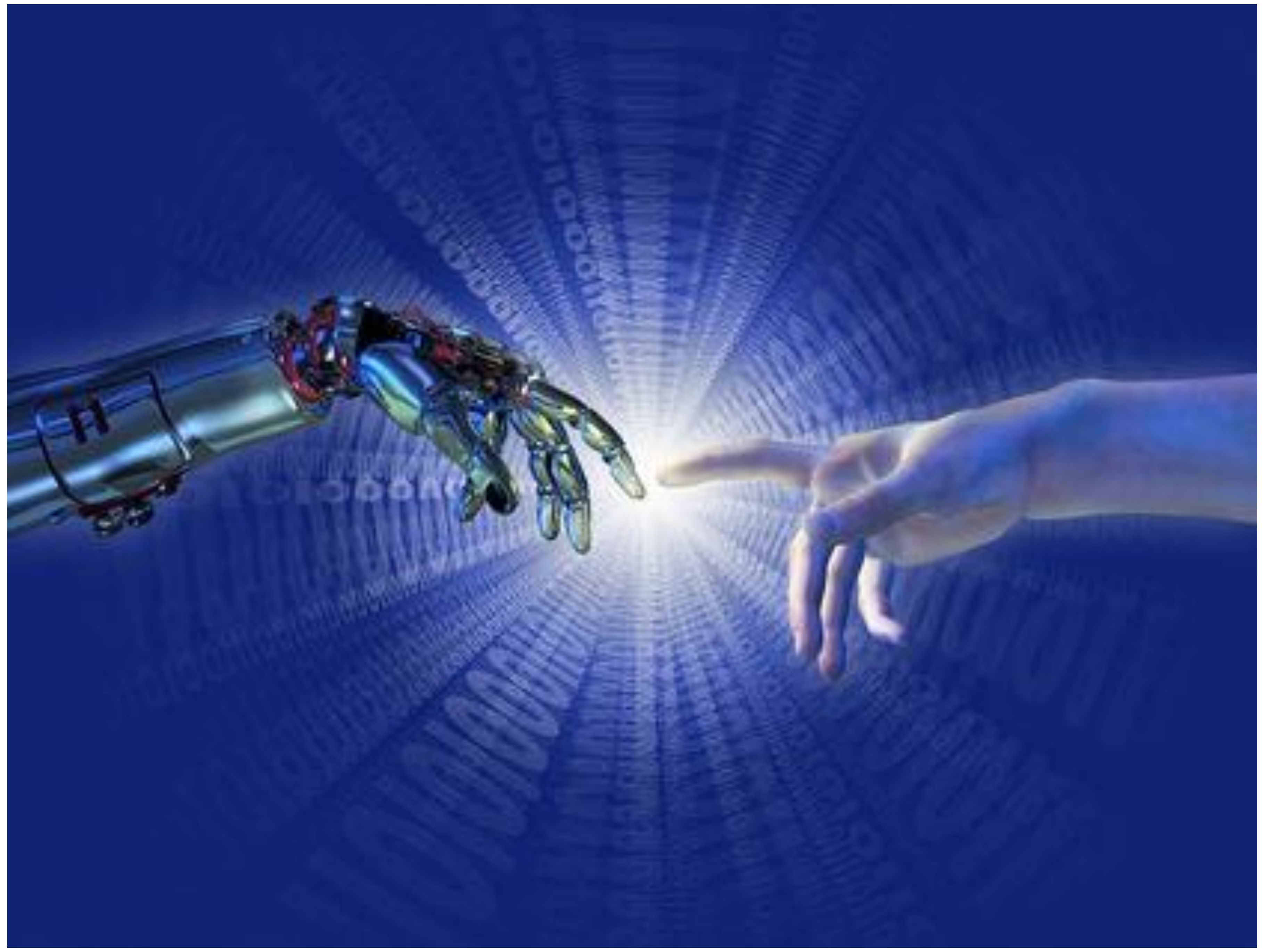
Definition of expert system (ES)

A computer program, processing the accumulated in it knowledge of experts-specialists in a given subject area and providing a solution at an expert level to a certain range of tasks.

Appearance – the 70s, together with the first practical results.



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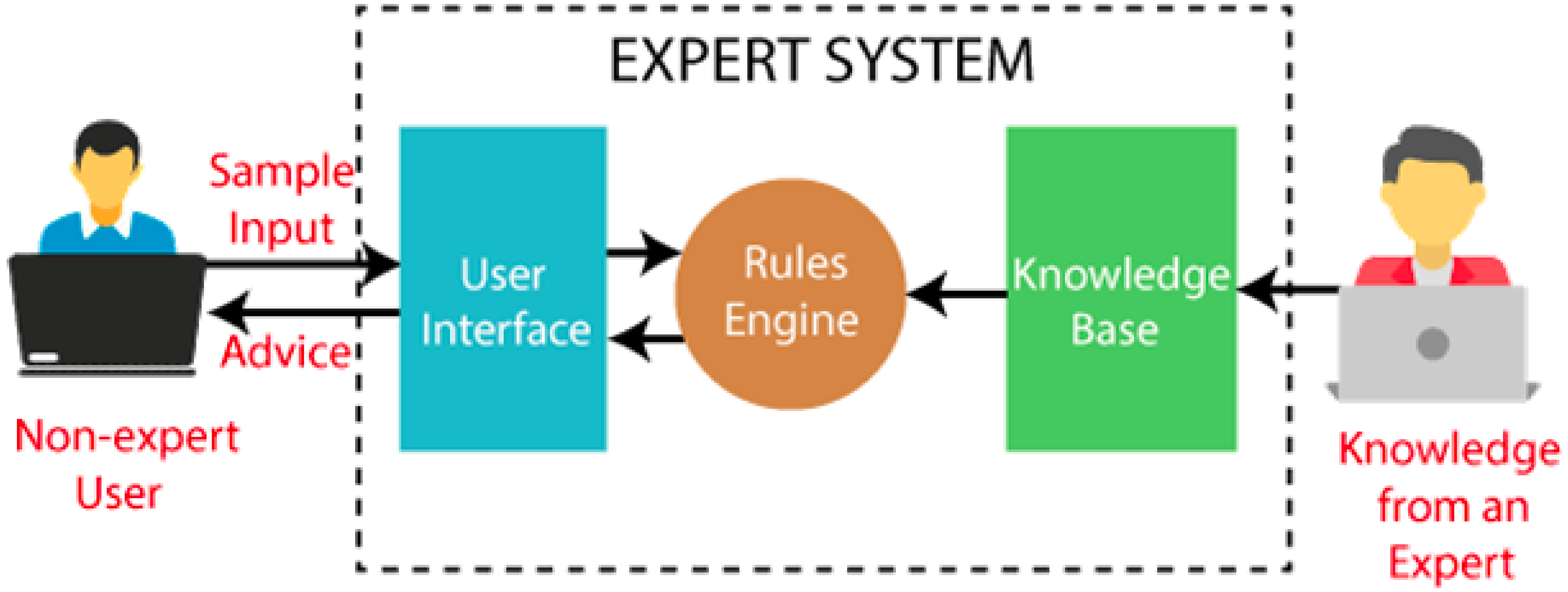
CONTENT 1

Definition of expert system (ES)



CONTENT 2

ES towards the broad class of ICS tasks

- performs difficult tasks at the level of a good specialist;
- uses problem-oriented strategies for solving tasks compared to more general ICS methods;
- uses knowledge about itself (metaknowledge) to conclude how the inference process proceeds and can give explanations for the resulting decisions.

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CONTENT 2

AI vs Expert System - Comparison Chart

Artificial Intelligence	Expert System
AI is the simulation of human intelligence in machines that are programmed to imitate human capabilities.	Expert systems refer to computer programs that simulate the thought process of a human expert to solve complex problems in a specific domain.
AI is the study of systems that act in a way to any observer would appear to be intelligent.	Expert systems represent the most successful demonstration of the capabilities of AI.
Components of AI include Natural Language Processing (NLP), knowledge representation, reasoning, problem solving & machine learning.	Expert systems are typically composed of the inference engine, the knowledge base, the user interface and the knowledge acquisition module.
AI systems are used in a wide range of industries, from healthcare to finance, automotive, data security, social media, travel and transport, etc.	Expert systems provide expert advice and guidance in a wide variety of activities, from computer diagnosis to delicate medical surgery.

CONTENT 3

ES features

- provide a competent solution to the given problem;
- focused on real-world tasks;
- narrowly oriented in a specific area;
- handle not data, but knowledge;
- flexible to acquire new knowledge;
- understandable through explanations.

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Nature of the solved tasks

- **With narrow scope** - the task must be narrow enough to encode appropriate expertise, but also complex enough to require expertise.
- **Existence of an expert** – an expert system cannot be constructed in a field where there are no experts yet.
- **Agreement between experts** - if there is frequent and significant disagreement between the experts in the problem area, the task is not suitable for the ES.
- **Availability of known data** – since ES is built gradually and knowledge is added in response to observed difficulties, it is necessary to have enough test results to explore the limits of what the system knows.

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CONTENT 3

Classes, solved tasks

- interpretation;
- prognosis;
- diagnostics;
- setting;
- planning;
- repair;
- management;
- learning.

A number of tasks (logical inference, pattern matching, recognition of sounds and other images, etc.) are not in an obvious state in this list.

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CONTENT 3

Why are ES popular?

- solve a wide class of hard-to-formalize problems considered unsolvable by computer;
- in practical tasks, results are achieved that are obtained only by highly qualified specialists-experts;
- allow non-specialists in programming to develop and solve their necessary tasks.

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CONTENT 3

Reasons for building an ES (excluding scientific)

- **Multiplication of expertise** – with the aim of using it for consulting. Geographical distances and retirement are important reasons for the unavailability of an expert.
- **Unity of expertise** - gathering in one place what different experts know about specialized cases.
- **Documentation** – important in learning, for example.

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CONTENT 4

Examples of ES

- **MATLAB** - software environment for numerical analysis and independent programming language;
- **MYCIN** - analyzes medical data for a patient with an acute infectious disease, diagnoses the probable causes of the infection and chooses the best treatment;
- **DENDRAL** - in organic chemistry;
- **MACSYMA** - in symbolic integration;
- **PROSPECTOR** - an *expert system* designed for decision-making problems in mineral exploration;
- **PUFF** - analyzes the health status of a person with breathing problems.

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CONTENT 4

MYCIN

- Developed in 1976 - 1978 in the Stanford University.
- Based on rules - uses a KB of about 450 rules and 1000 medical facts, primarily for meningitis.

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CONTENT 4

Extract of a MYCIN consultation session

Answers of the user – with big letters after **, text from the system with*, notes — with *cursive*.

1) Name of the patient: ** PT538

2) Age: **34 YEARS

3) Sex: ** MELE

MYCIN *fixes the answer of the user* = MALE

4) Race: ** WHITE

……………………………..

14) Has PT538 lately had any symptoms of constant headache or any pathological neurological symptoms (dizziness, drowsiness, etc.)? **YES

15) Has PT538 lately had any clearly proven pathological neurological displays (neck rigidity, coma, fainting, etc.), documented through medical supervision or exam? ** YES CSF

* cultures will be considered as related to MENINGITIS.

Note that MYCIN has come to a conclusion and informs the user that the infection is probably meningitis.

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CONTENT 4

Extract of a MYCIN consultation session

16) Please, give the date, when a clinical proof has been first displayed (symptoms, displays or lab tests) for meningitis? **29. 01. 1977 22:15

…………………………………….

23) How many days has PT538 had pathological neurological displays? ** 7,2 HOURS

Note that MYCIN accepts different units for time measurement.

……………………………………...

28) Do you know the results of the last CBC* of PT538? **YES

29) Please, give the CBC results in the given table:

CBC	Percentage
In thousands	**PMN****
29 ** K9	UNKNOWN

Note that, MYCIN accepts UNKNOWN as a valid value,

………..

30) Has PT538 had any injuries, disabilities or defects in the central nervous system (except neuro-surgical)? ** NO

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CONTENT 4

Extract of a MYCIN consultation session

35) Is meningitis an internal hospital infection? ** WHY

* i.e, WHY is it important to determine if the disease was acquired while the patient was hospitalized

The user asks WHY, to see an explanation of MYCIN's reasoning. The program first paraphrases the question and then displays the rule whose premise it is trying to establish.

*[2.0] This will assist in determining the organisms (other than those seen in cultures and swabs) that could be causing the infection. It has already been established that:

[2.1] the infection requiring treatment is meningitis, and

[2,2] no microorganisms were found during examination of the cerebrospinal fluid, and

[2.3] the type of infection is bacterial, and

[2.4] neurosurgery is not an appropriate solution based on the description of PT538, and [2.5] the duration for PT538 is greater than 10 days.

Therefore, if

[2,6] the infection was acquired while the patient was hospitalized, then, there is evidence that the organisms (other than those seen in cultures and swabs) that could cause the infections are: (E. coli (0,75), Staphylococcus-coag-pos (0,3), Pseudcmonas-aeruginosa (0,3) и Klebsiella-pneumoniae (0,5).

....

CONTENT 4

MYCIN - conclusions

Level of expertise - of the teaching staff in a faculty of infectious diseases.

Application - not used for daily work in hospitals.

Main obstacle – human processing.

Ways to overcome the problem (for human processing):

- inclusion of high-quality graphics with user-oriented forms and input/output schemes;
- collecting data from connected hardware instead of users.

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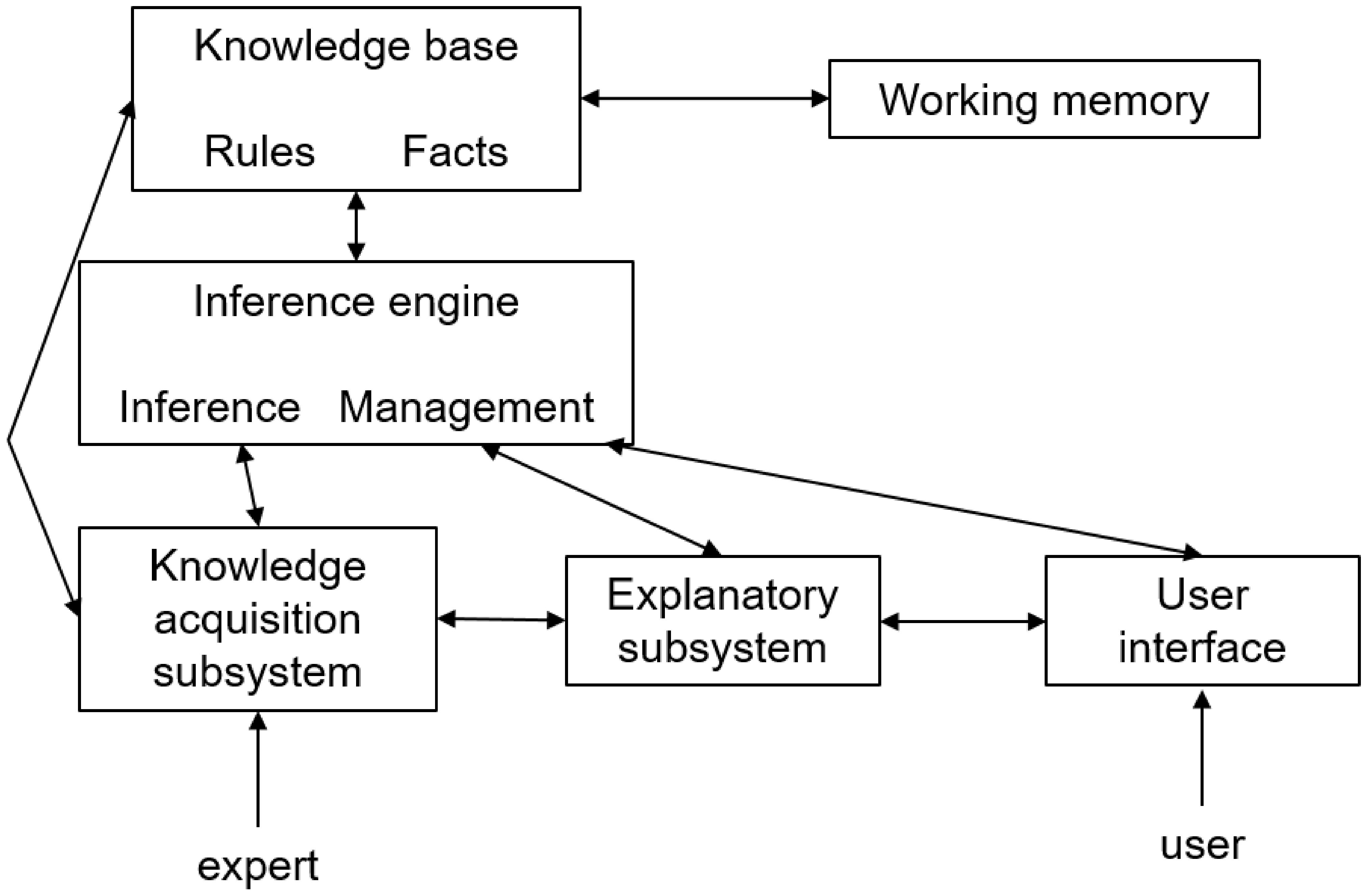
CONTENT 5

Architecture of ES



CONTENT 5

Elements of ES architecture

- **Knowledge base** – set of specialist and core knowledge including:
  - facts;
  - rules.
- **Knowledge acquisition subsystem** – uses a knowledge extraction methodology:
  - from the environment;
  - through rules.
- **Inference engine** - set of functions in a particular language that control interactive work and update the current state of knowledge about the given case;
- **Explanatory subsystem** – uses methodology to explain the conclusions drawn;
- **Interface section** - turns user input into an internal representation. A working subset of English is often used for communication.

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CONTENT 5

Knowledge processing in ES

Knowledge engineering - in the process of constructing the ES, the main difficulty is in extracting the necessary knowledge from the experts and processing it into a form suitable for machine processing.

An important achievement in the late 1970s and early 1980s was the construction of **knowledge processing structures** to help build, debug, interpret and explain ES: EMYCIN, ROSIE, KAS, EXPERT and OPS.

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CONTENT 5

Knowledge processing in ES - conclusions

- To be able to carry out an analysis, ES need:
  - basic knowledge;
  - knowledge about the relevant field.

Main idea - to separate the knowledge of the target area from the procedures that process it. This leads to flexibility and clarity, and the KB can be explored and manipulated like any other data structure.

- Computationally feasible and mathematically accurate methods are known for small classes of problems - a large part of the necessary knowledge is heuristics, which specialists use when solving difficult problems.
- ES can also extract information from reasoning with informal knowledge without trying to simulate the behavior of specialists.

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CONTENT 6

Toolkit

Specialized programming languages are required (not used for formal description like standard ones):

- Prolog;
- LISP;
- ML, etc.

The toolkit for building an ES can include:

- procedural languages for programming – PASCAL, PL, LISP;
- declarative languages for programming – OPS5, PROLOG;
- object-oriented languages – Python, SMALLTALK, FLAVORS;
- empty shells – SAVOIR, EXTRAN-7;
- environments – ART, Knowledge Craft, KEE.

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CONTENT 6

LISP

LISP (*LISt Processing language*) - the second after Fortran high-level programming language, still in use.

Created in 1958 in MIT by John McCarthy, including programming languages and data.

Dialects have originated from it, the most famous of which are Scheme and Common Lisp.

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CONTENT 6

Prolog

Prolog (***PRO****gramming in* ***LOG****ic)* - a high-level logic programming language created by Alain Colmerauer, Philippe Roussel and Robert Kowalski in 1972 as an alternative to the American-dominated LISP languages. It is based on first-order predicate calculus with certain limitations.

The goal - a language that uses logical expressions instead of instructions to the computer. Emphasis is on declarativeness in expressing the logical relationships between objects relating to a certain problem rather than on the procedural steps required to solve it. The system decides how to solve the problem, including the instructions for the computer to execute. Prolog solves problems by searching the KB, which can be refined if several processors search different parts of the database.

CONTENT 6

Python

The name comes from BBC's TV show „Monty Python's Flying Circus".

- **Interpreter** - saves development time as no compiling and linking is required to test an application. Like Java, an application written on it is relatively easily portable to other platforms or OS.
- Interactive, object-oriented programming language.
- Has built-in complex data types such as flexible arrays and dictionaries that are difficult to implement in C.
- Allows a program to be split into modules that can be reused in other programs.

- Has:
  - standard modules to be used as the basis of programs;
  - built-in modules that provide file input/output (I/O), system functions, sockets, programming interfaces to GUI libraries, etc.

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CONTENT 6

Python development environments

- **Integrated Development** Environments (IDE):
  - PyCharm (https://www.jetbrains.com/pycharm);
  - **Visual Studio Code** (https://code.visualstudio.com);
  - **Atom** (https://atom.io);
  - **Eclipse for Python** (https://www.eclipse.org).

- **Online environments** for programming - used for testing short examples or when it is not possible to install a development environment and Python interpreter locally or when sharing a code:
  - **Repl.it;**
  - **PythonAnywhere.**

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INTELLIGENT COMPUTER SYSTEMS

Svetlana Stefanova

September, 2022

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LECTURE 5

KNOWLEDGE BASE IN EXPERT SYSTEMS

1. Introduction
2. Knowledge base design
3. Models for knowledge representation

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Subject area

- **Definition** - a set of objects, events, relationships and connections between them that make up the necessary KB, sufficient enough to solve the tasks in this field at the level of a good expert.
- **Includes** real and abstract objects with some relation and having certain properties that are expressed through propositions.

The analysis and study of the subject area allows building a KB.

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CONTENT 1

Questions, related to KB

- **Representation** - how to present the knowledge of the subject area in the computer program?
- **Use** - how to use the knowledge to solve tasks at an expert level?

Some ES use KB that only allow reading.

With modern ES, it should be possible to delete and write in the KB.

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CONTENT 1

Knowledge technologist

During KB construction, the expert is assisted by someone who understands the syntax, the rule interpreter, the KB construction process, and the practical psychology of interacting with it. This specialist is called a **knowledge technologist**.

CONTENT 1

KB in traditional programs vs ICS

- **Traditional programs** - work with information, organized in the form of a DB, in which it is possible to extract only information that is specified in an explicit form.
- **ICS** – work with KB where reasoning/conclusions are possible, as a result of which new information can be generated that is not clearly present in the base.

CONTENT 1

Specifics of expertise

- **Wording/Formulation** - expertise is not always clearly codified and exists in many forms. The task of the knowledge technologist involves bringing together what is known about the task with its transformation into the system.
- **Certainty** - expertise is largely heuristic and not well formalized, i.e. knowledge is not always certain.
- **Accessibility** - because it is not well formalized, the expert's knowledge is not always easily accessible.
- **Completeness** - the presence of incompleteness, as facts and heuristics change with increasing experience.
- **Terminology** - due to the variety of sources of expertise, the expert uses terminology that varies (from broad concepts to precisely defined theoretical terms).

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KB designing - stages

- **Acquisition** - through different techniques and approaches and from different sources. Some of the most reliable sources are experts from the given subject area.
- **Analysis** - includes arrangement, evaluation and filtration, which are mainly carried out by the knowledge technologist.
- **Representation** - various schemes and approaches are used to formally represent knowledge on a carrier with aim for their further systematization, analysis, supplementation and approximation to some machine form (close to the constructs of a logical programming language).

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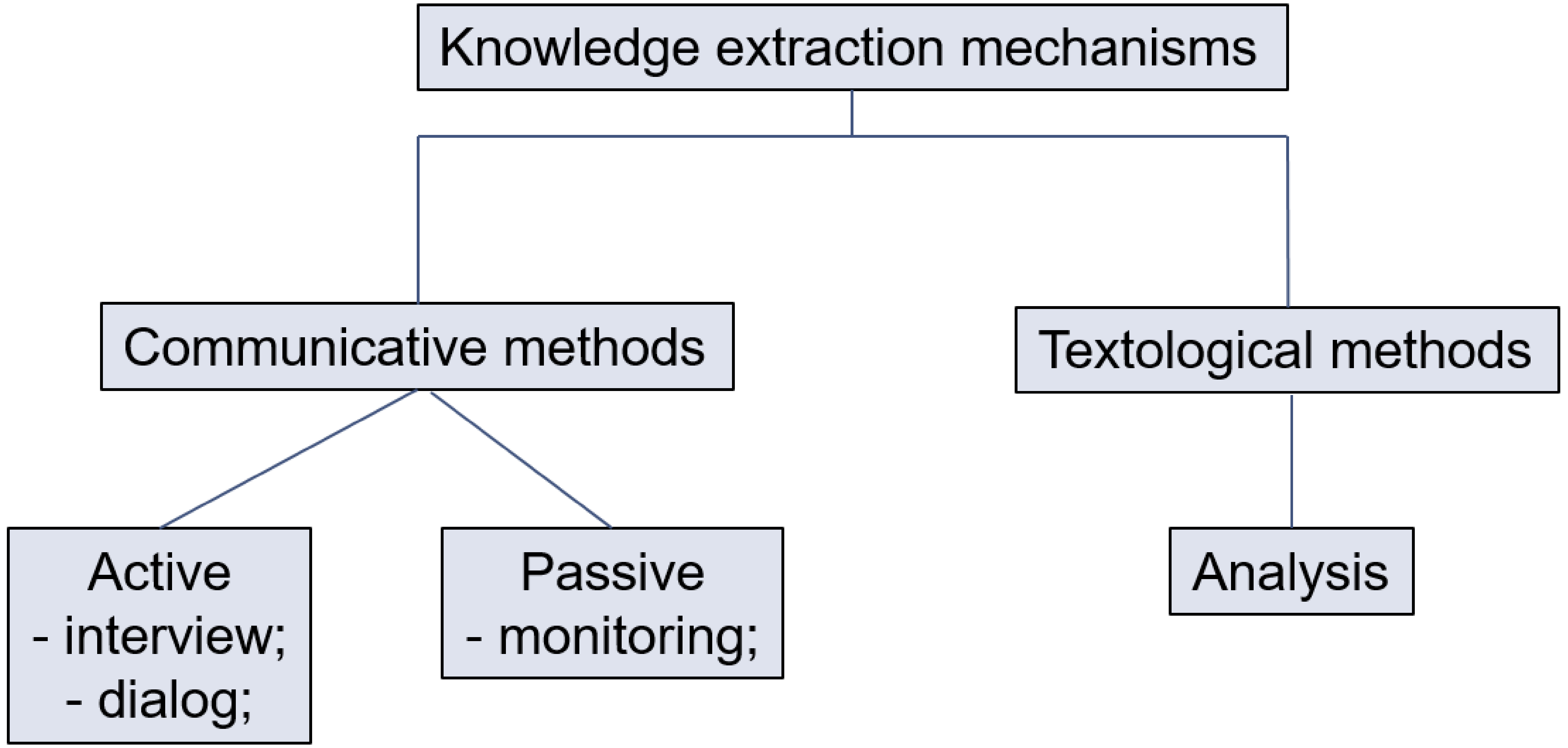
1st stage: knowledge acquisition



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Knowledge acquisition - mechanisms

- **Textological** - extracting knowledge from documents and specialized literature.
- **Communicative** - methods of contact of the knowledge technologist with the expert:
  - **Active** - the initiative is in the hands of the knowledge technologist, who actively contacts the expert in various ways (conversations, dialogues, games, etc.);
  - **Passive** - the leading role belongs to the expert, and the knowledge technologist only protocols his reasoning during real work or records what the expert considers necessary to talk about during separate sessions.

Different methods are usually combined.

Knowledge acquisition - automation

The problems associated with interviewing the experts are the reason for the search for methods and means of automating the process.

Automation is sought in two directions:

- creation of software tools for **automatic extraction** of knowledge in the process of dialogue between the software system and the expert.
- creation of software tools for **machine learning and self-learning** - the system is trained on the basis of examples, analogies, analysis of experimental data, etc.

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2nd stage: knowledge analysis

Includes:

- **Verifications;**
- **Coordinating uneven constructive elements** – combining large narrative reports with precise statements about facts.

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Knowledge analysis – types

- **Logical** - verification for completeness and consistency.
- **Structural** – verification whether each rule subjects to the adopted structure;
- **Static** - verification for weaknesses in the KB (eg, one rule includes another or contradicts another).

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3rd stage: knowledge representation

Division by type:

- basic knowledge of the subject area;
- specific knowledge about the task.

Unified data structures – a homogeneous knowledge representation facilitates the system designer in developing the knowledge acquisition and explanation modules.

Knowledge specifics

- **Incompleteness** - in medical diagnostics, for example, the doctor usually has to act before all the incoming tests have been done.
- **Ability to process redundancy** - different knowledge can lead to the same interpretations or to mutually exclusive interpretations.
- **Uncertainty** - sources of information are not infallible.
- **Noise** - data can contain noise for a number of reasons: electronic noise, misreading of indications, transcription errors, etc.

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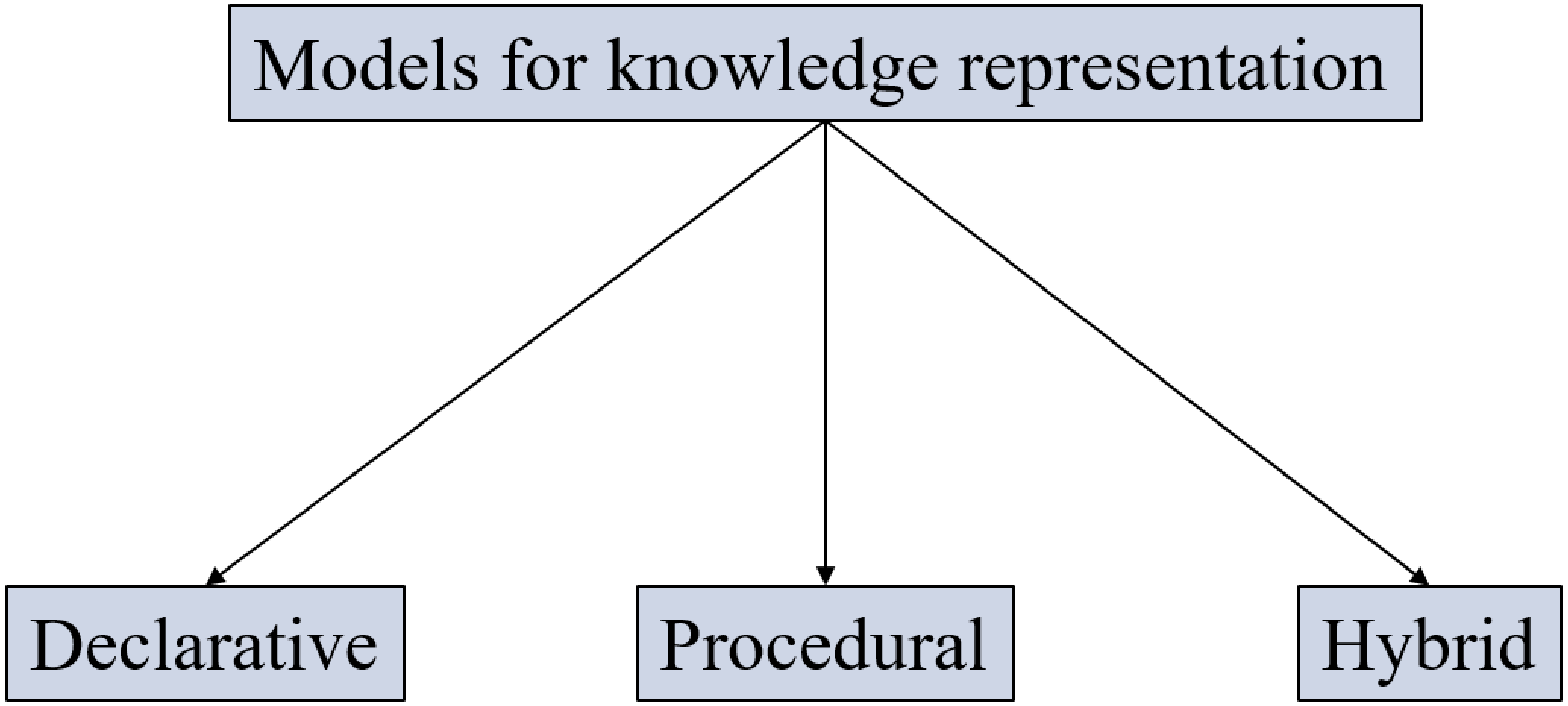
CONTENT 3

Models for knowledge representation



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CONTENT 3

Declarative representation of knowledge

- **Declarative representation** – a simple statement that the fact is true.
- Knowledge is given as **descriptive** (declarative), where the individual units of knowledge are described independently of one another:
  - allows for **modularity** when organizing the KB, which facilitates its update;
  - the lack of hierarchy in the presentation of knowledge leads to difficulties in using it.

- **Declarative models are suitable in tasks where**:
  - the subject area is unstructured;
  - there are no clear links and relationships between the objects;
  - inaccurate knowledge is handled;
  - the knowledge of the subject area is predominantly of an empirical character.
- Convenient for experts and users.

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CONTENT 3

Procedural representation of knowledge

- **Procedural representation** – a set of instructions without an explicit statement.
- More effective to use, but harder to maintain.
- Knowledge of the subject area is presented **clearly**. Availability for an advanced internal structure of the KB, which improves the efficiency of its use, but it requires strict adherence to certain rules and detailing of the knowledge.

Procedural models are suitable in tasks where:

- the subject area is highly structured;
- there are dependencies and relations between objects;
- the knowledge is mainly relations between objects and meta-knowledge.

Convenient for the knowledge technologists.

CONTENT 3

Hybrid representation of knowledge

- Knowledge is represented by two or more of the known methods at the same time.
- Declarative and procedural representation are alternative strategies that reach the same result. Any procedural representation can become a declarative and vice versa.

CONTENT 3

Requirements for the knowledge representation models

- **naturalness of presentation**;
- **clear semantics** – each sentence to be plainly interpreted;
- **correctness of the rules of inference** - if the knowledge given in the KB is true, then all the new knowledge, derived from it, is also true;
- **modularity**;
- **efficiency in terms of memory and time requirements**.

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CONTENT 3

Basic models for knowledge representation

- Semantic networks;
- The triad "OBJECT-ATTRIBUTE-VALUE" (OAV);
- Frames;
- Rules.

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CONTENT 3

Semantic networks

- A set of objects, called **nodes,** connected to each other by **arcs**;
- Can be considered as a **graph**.
- Usually, both arcs and nodes have **labels**, i.e. are named and no limitations on node names and arcs are required.

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CONTENT 3

Semantic networks - nodes

- **Objects:**

➢ Physical – the objects that surround us;

➢ Conceptual - can be actions, events, or abstract categories. Example: “Bulgaria" and “2” may be nodes from a geographic KB.

- **Descriptors** - provide additional information about the objects. Example, “beautiful" and “small“ contain information about the country Bulgaria.

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CONTENT 3

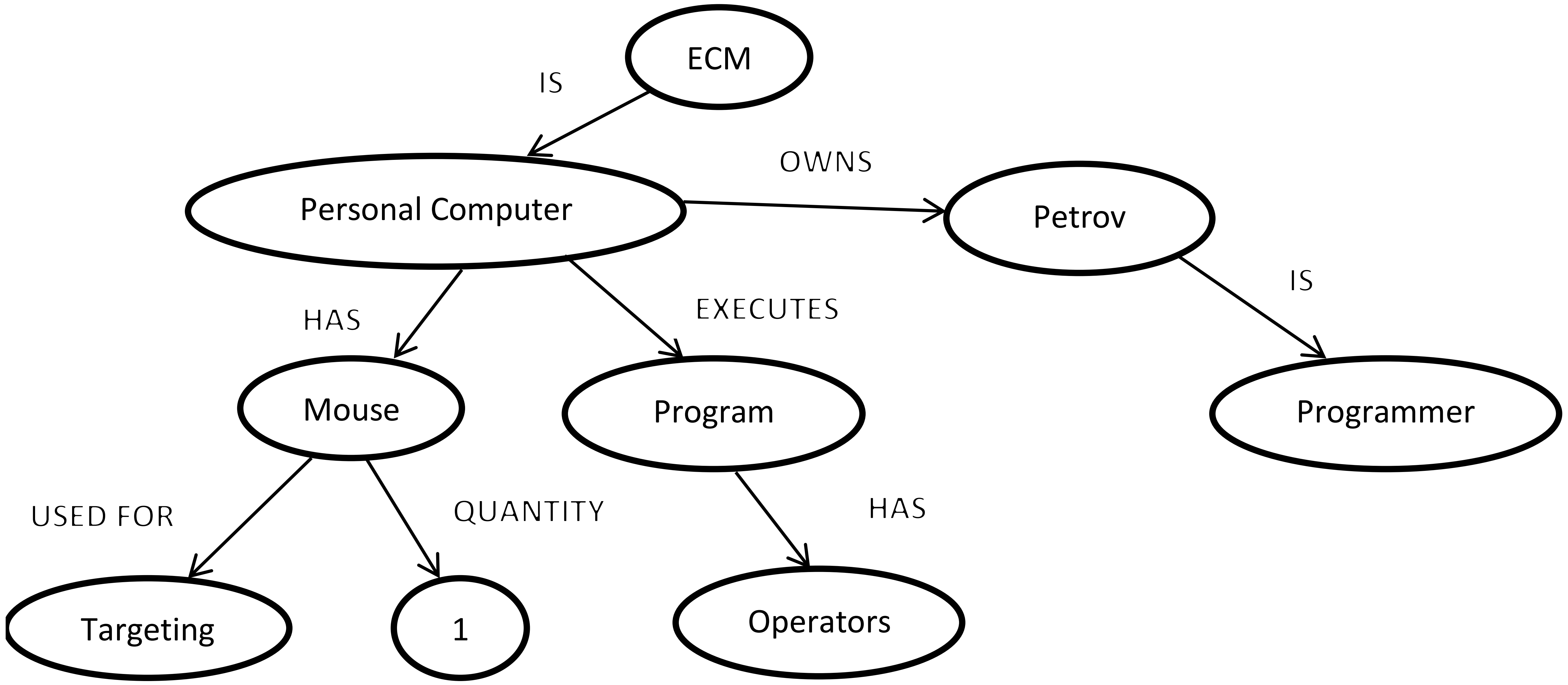
Semantic networks – arcs (links)

Common arcs are :

- **“IS”** - represents a "class-type" relationship. Example, "The wolf **is** a predator”;
- **“HAS”** – identifies the nodes that are properties of other nodes and it shows a relationship between a part and a subpart. Example, "The wolf **has** paws”;
- **definitive** – defines some kind of a statement. Example, “Wolves **love** meat”.

CONTENT 3

Semantic networks - example



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CONTENT 3

Semantic networks – syntactic approaches for representation

- **object i – link ij – object j** - more natural to the language ***LISP***;
- **link ij (object i, object j)** - more natural for use in the ***PROLOG*** logical programming language.
- A combination of the two approaches is possible.

CONTENT 3

Semantic networks - advantages

- **Simplicity**;
- **Visibility**;
- **Flexibility** - new nodes and arcs can easily be defined;
- **Inheritance** – a specimen of a given class has the properties of the more general classes that it is a member of. It is an application of the “**IS**” relationship.

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CONTENT 3

Semantic networks - disadvantages

- **Difficulty in presenting n-array relationships**. ***Simon's method*** – a given *n*-array relationship is transformed into a system of binary relatives by introducing a new object *n+1* into the network that represents the whole relation. New binary relations are then introduced to describe the links between the new object and each of the original arguments.
- **Difficulty in presenting knowledge with quantum** – separated semantic networks can be used (an hierarchical set of subnets, each of which corresponds to the scope of a variable). Some special arcs in the network do not point to nodes, but to entire semantic networks that are sub-networks of the given one.
- **Problem when executing operations with semantic networks**.
- **Problem of the two Smiths (different objects with the same name)**.

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CONTENT 3

Triad "OBJECT-ATTRIBUTE-VALUE“ (OAV)

Used in the MYCIN expert system.

- **Objects -** can be physical (door, transistor) or conceptual (bank loan, sale).
- **Attributes** - main features or properties associated with the objects. For example, size, shape, and color for physical objects or values of interest, payment term, size for the conceptual object “bank loan”.
- **Value** - indicates the specific nature of the attribute in the given situation. For example, the apple's color may be red, and the bank loan rate may be 10%.

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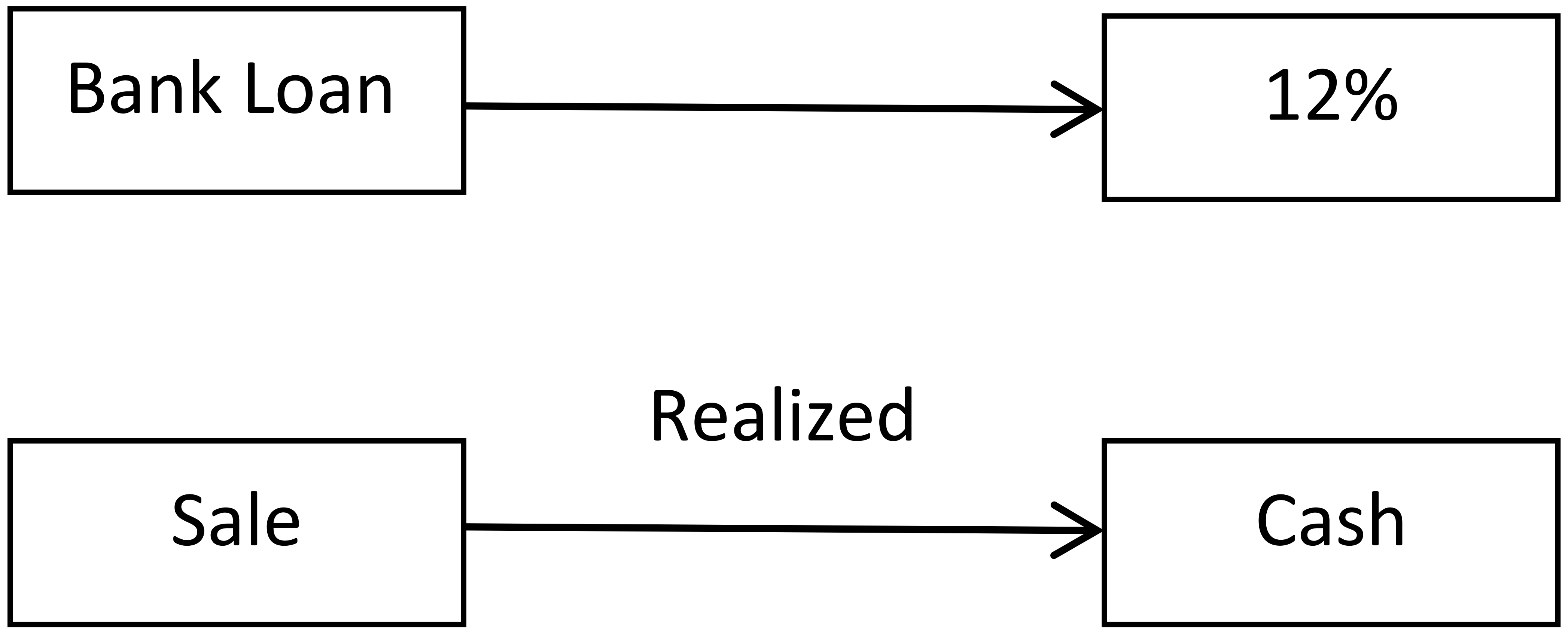
CONTENT 3

Triad OAV - examples



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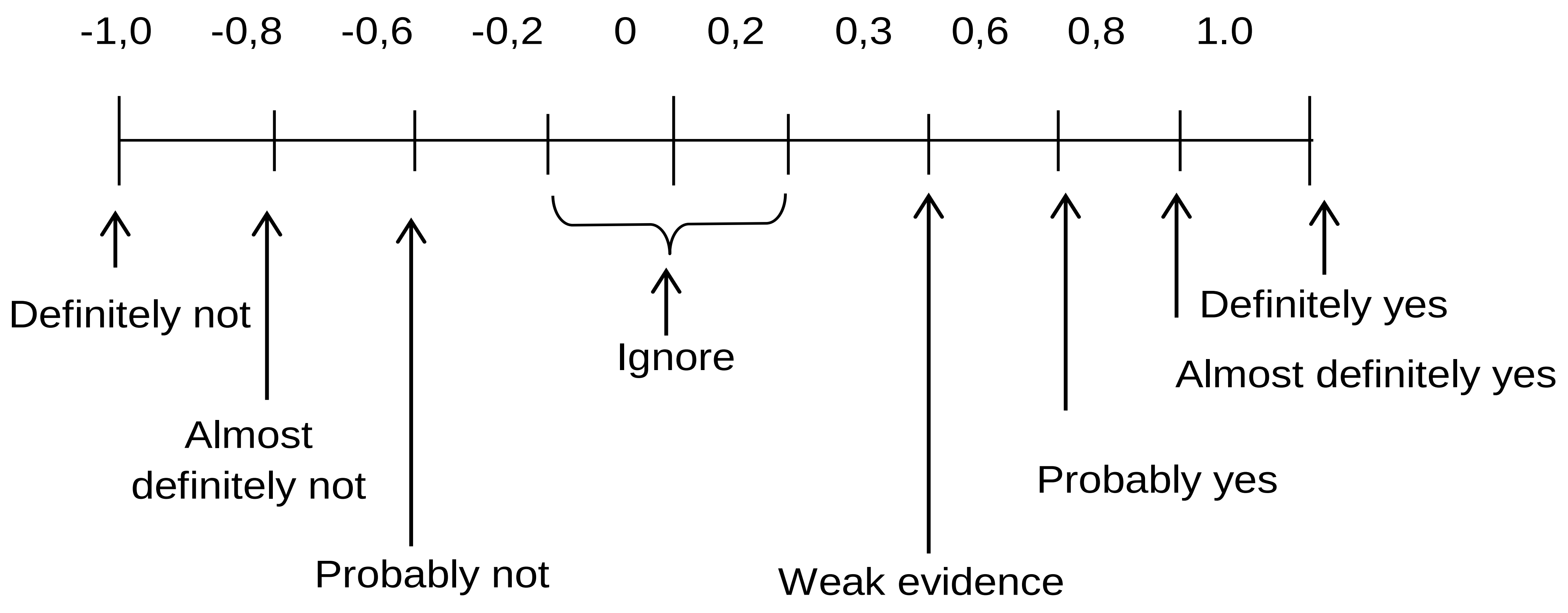
CONTENT 3

Triad OAV – working with uncertain facts

If the fact is uncertain, OAV could be modified with a number, called a **factor/coefficient of reliability/confidence,** that correlates to the truth of a statement.

The factor of reliability **is not a probability**, but an informal **measure of trust** or **security** towards a given evidence. It shows the extent to which it is certain that the evidence is true.



CONTENT 3

Triad OAV – advantages and disadvantages

Advantages:

- Objects can be arranged in the form of a graph, which means **generating and inheriting properties**;
- Ability to **handle uncertain data**;
- Ability to use an **OO (object-oriented) approach**.

Disadvantages:

- Knowledge is presented **fragmentarily;**
- **Links are in an implicit form**;
- There are **difficulties in tracking the links between objects** in a large KB;

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CONTENT 3

Frames

- **Protoframe** - a solid structure of the information unit.
- **Frame-exemplar** – obtained from the protoframe by assigning specific names and values to the slots.

Name of the frame:

Name slot 1:	*Value of slot 1*
Name slot 2:	*Value of slot 2*
…………………….	……………………………
Name slot N:	*Value of slot N*

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CONTENT 3

Frames – values of the slots

- numbers or mathematical ratios;
- text in natural language or programs;
- a set of rules or procedures for obtaining values;
- default values;
- citing of slots from other frames;
- pointers to other frames;
- a pointer to a set of slots of lower level frames.

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CONTENT 3

Example frame

No	Description of goods / service	Catalogue No	Warranty months	Number	Unit price w/o VAT	Total price with VAT	Currency
1	Motherboard - GB H110M-DS2 / LGA1151	#Q0066010027505	36	1	88,07	88,07	BGN
2	Processor - I3-7100 3.9GHZ/3MB/LGA1151/BOX	#Q0066010027506	36	1	261,12	261,12	BGN
3	Memory - 8G DDR4 2400 ADATA	#Q0066010027507	60	1	95,62	95,62	BGN
4	Hard Drive - ADATA SSD SU650 240GB 3D NAND	#Q0066010027508	36	1	65,31	65,31	BGN
5	Box - CM MASTERBOX LITE 3	#Q0066010027509	24	1	48,31	48,31	BGN
6	Power Supply - PSU FORTRON FSP350-50AHBCC	#Q0066010027510	24	1	50,49	50,49	BGN
7	Software product with license sticker - Microsoft Windows Pro 10 64Bit Eng Intl 1pk DSP DVD	FQC-08929	0	1	259,59	259,59	BGN
Version - Windows 10 Type of license - OEM (License and media (DVD)) Language - English Bit - 64 Other - For sale with computer configuration							

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Frames – advantages and disadvantages

Advantages :

- possibility of a **declarative and procedural presentation** of knowledge;
- **inheritance**;
- inclusion of **default values**;
- possibility **for interconnections** between the frames.

Disadvantages:

- more difficult to **understand**;
- higher requirements for **computing resources**.

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CONTENT 3

Rules

Predicate - the conditional part of the rule or prerequisite.

Rules can be:

- **simple** - contain one simple statement;
- **complex** - contain more than one condition, connected with logical relations of the types AND, OR, NO.

The rules of the given type are called **production**, as well as the systems based on them.

Credibility factors can relate to rules just as they relate to facts.

IF { prerequisite / condition / situation } **THEN** { conclusion / consequence / action }

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CONTENT 3

Rules – advantages and disadvantages

Advantages:

- Representation is in a **descriptive form**;
- Ability to **handle insecure data**;
- Ability to **merge facts** into one rule.

Disadvantages:

- Knowledge is **difficult to formalize** and represent;
- **The volume** of the KB is significantly higher.

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INTELLIGENT COMPUTER SYSTEMS

Svetlana Stefanova

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LECTURE 6

MECHANISMS FOR INFERENCE CONTROL

1. Introduction
2. Propositional rules
3. Types of inference mechanisms

Inference specifics

- **Symbolic reasoning** - used in applied areas where mathematical methods are absent or computationally bulky;
- **A combination of deductive logic and plausible reasoning** – a large part of the world's expertise is heuristic, and programs that incorporate expert-level knowledge must combine the two methods.
- **Clear problem-solving strategy** - just as it is useful to separate domain-specific knowledge from inference methods, it is also useful to separate the problem-solving strategy. The same KB and inference method can lead to radically different behaviors for different strategies.

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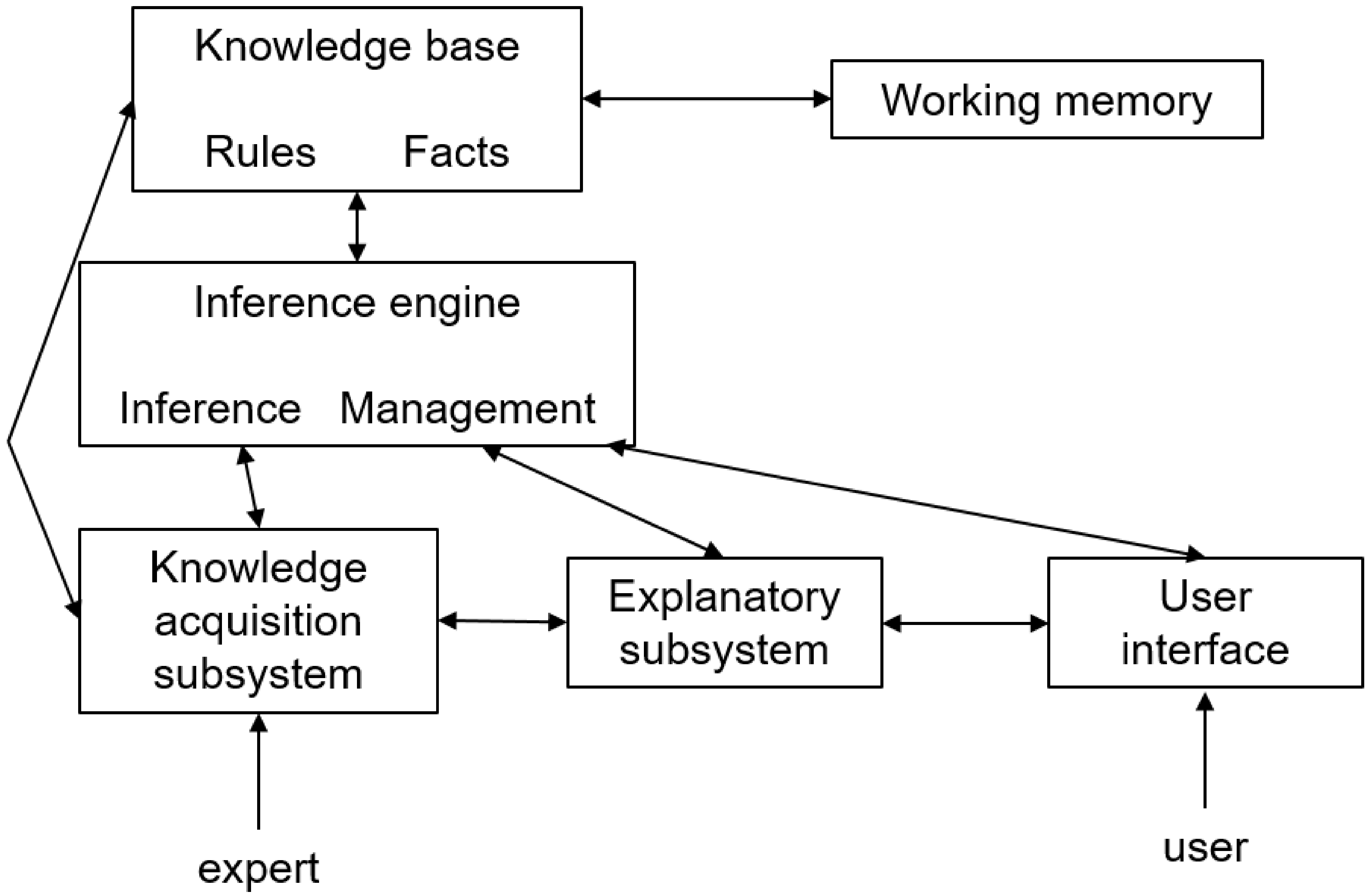
CONTENT 1

Inference engine

A software module that implements the inference mechanisms and stands between the user and the KB.



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CONTENT 1

Inference engine – main functions

- Review existing facts and rules and add new facts when possible;
- Determining the order in which the inference will be drawn, thus guiding the consultation with the user.

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CONTENT 1

Inference mechanisms

Direct the ES when using the preserved in its KB:

- facts;
- rules.

The most commonly used inference mechanism is through a logical rule.

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Propositional rule

The most commonly used logical rule is of the propositional type:

IF A THEN G

A – premise/proposition;

G – conclusion, inference.

Proposition

Special type of statement, whose truth we define. It can be either *true* or *false*, but never both at one and the same time.

- *Elephants are mammals.*
- *Some birds can fly.*

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Propositions - types

- **Simple/literals** - do not contain other propositions;
- **Composite/clauses** - contain several statements that are related to each other with relationships of the type AND, OR, NO, IMPLIES (IMPLICATION) and EQUIVALENCE (DOUBLE IMPLICATION).

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Propositional rule - types

- **Definitive**

Example:

Has (x, feathers) OR (Can (x, fly) AND Can (x, lay-eggs)) ->class (x, birds)

Given the appropriate facts, it can be logically inferred whether an object is a bird or not.

- **Empirical**

Example:

Condition (machine, does-not-want-to-start) AND Condition (headlights, weak) ->

Condition (battery, dead)

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Propositional rule - conclusions

- it is simplified and reasoning with it is easy to understand;
- some conclusions that are true cannot be drawn;
- in traditional programming, all the necessary information is expected to be available to start work. In the ES, the inference engine must also be able to handle incomplete information.

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CONTENT 3

Inference mechanisms - types

- data driven;
- goal driven;
- hybrid.

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CONTENT 3

Inference mechanisms - types

- If A is known to be true and there is a rule that says "If A, then B", we can conclude that B is true.
- If B is known to not be true, and if there is a rule "If A, then B", we can conclude that A is not true.

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Data driven inference mechanisms

IF A THEN G →

Each **IF A THEN G** rule is applicable when there are facts in the KB that satisfy condition **A**:

- **if there is an applicable rule** - we apply it and this will lead to the addition of new facts to the KB. Rules given this way may become applicable even if they were previously inapplicable;
- **if there are no applicable rules** - we contact the user for additional information.

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CONTENT 3

Facts - input

When working with the system, the user must start by entering facts:

- **textual** - this requires a language to transform the facts into an appropriate internal representation.
- **with a menu** - an acceptable solution, but there is often a need for greater flexibility.

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Data driven inference mechanisms - example

- Rule 1: If the size of a person's hands are different, then the type of his profession is manual work.
- Rule 2: If the man's collar is priestly, then his profession type is religious.

Ivan's attributes:

"hand size": "different";

"collar": "none".

Since the premise of rule 1 is true, we can conclude that Ivan's occupation type is manual labor.

If rule 2 is tested, it will fail because Ivan's collar is not priestly.

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CONTENT 3

Data driven inference mechanisms - procedure

Procedure Answer;

Review the KB for the set **S** of applicable rules;

While S is nonempty and the problem is not solved **do**

begin

call **Select-rule** (**S**) to select rule **R** from **S**;

apply **R** and update KB;

review KB for new applicable rules and expand **S** if possible;

end;

end;

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Data driven inference mechanisms - problems

- **If there is more than one applicable rule, in what order should they be applied?** - Different strategies differ mostly in the effort devoted to solving the task for rule selection. Possible strategies:
  - a simple and "cheap" strategy - to select the first encountered rule when traversing S. If the rules are not well ordered, this can lead to many redundant steps. Any extensions designed to overcome this drawback can make management quite complicated.
  - introducing weights to the rules according to their importance.

- **The program "fires" the rules one after the other, and its behavior sometimes seems aimless to untrained users** - this undermines the user's confidence in the reliability of the system.

CONTENT 3

Goal driven inference mechanisms

Only rules applicable to any specific G goal are considered.

Achieving G is equal to proving that the fact corresponding to G is truth-valued.

In some tasks, reaching a goal requires setting and reaching sub-goals. This can lead to a fruitless search if most of the subgoals are unreachable, but there is always a path from each subgoal to the original goal.

IF A THEN G

←

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CONTENT 3

Goal driven inference mechanisms - example

Rule: If Ivan has a dragon tattoo, then Ivan has been in China.

Given fact: Ivan has not been in China.

New fact: Ivan does not have a dragon tattoo.

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CONTENT 3

Goal driven inference mechanisms - procedure

Procedure Reach (**G**);

Review KB for the set of rules **S** that define **G**;

If S is empty **then** ask the use for a new **G else**

while G is unrecognized and **S** is a nonempty set **do**

begin

call **Select-rule** (**S**) to select the rule **R** from **S**;

G ← condition (**R**); *{A becomes new G}*

If G is unrecognized **then** call **Reach** (**G**);

If G is true **then** apply **R;**

end;

end;

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CONTENT 3

Goal driven inference mechanisms - steps

- All rules whose right side can establish the truth of G are collected.
- If there is more than one suitable rule, a selection is made using the "Select-rule" procedure.
- After the rule R is selected, its left side A is examined to see if R is applicable. If there is no information about A in the KB, determining its truth becomes a new subgoal and the "Reach" procedure is recursively applied to A.
- The search proceeds systematically backwards from the set goal until we reach a subgoal for which there are no rules. The system then turns to the user and asks for relevant facts:
  - if the user cannot provide the required information - the rule that the system is currently working on cannot be used, but other paths of reasoning can be explored.
  - if the supplied information indicates that G is true, R is applied. The process continues until it is determined whether G is true or false or until the applicable rules are exhausted.

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CONTENT 3

Goal driven inference mechanisms - conclusions

- Since the left side A of the chosen rule R becomes the next subgoal G, choosing a rule is equivalent to choosing a subgoal.
- Strategies differ in effort in solving this task for subgoal selection:

➢ a simple and "cheap" strategy - to choose the 1st rule encountered while traversing S. If the rules are not well ordered, this may lead to exploration of unpromising subgoals. As in the case of data management, extensions designed to overcome these shortcomings can complicate the strategy.

CONTENT 3

Goal driven inference mechanisms

Advantages:

- they do not seek additional information and do not apply rules that are not related to the main goal;
- the system can explain its behavior simply by telling the user what goal it is working on and what rule it is using.

Main disadvantage: the user cannot guide the work by adding relevant information about the task. This may make the strategy unacceptable when a fast, real-time response is required.

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Hybrid strategy

The idea - to alternate between the two phases, by using the information given by the user to determine a goal, and then to ask him for additional information in the process of working on the chosen goal.

Procedure Alternate;

Repeat

User to input facts in the KB;

Call **Answer** to find the consequences;

Call **Select-goal** to choose a goal **G**;

Call **Reach** (**G**) to attempt to establish **G**;

until problem is solved;

end;

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LECTURE 7

EXPLANATORY MECHANISMS

1. Introduction
2. Types of queries
3. Explanatory module specifics
4. Explanatory module structure

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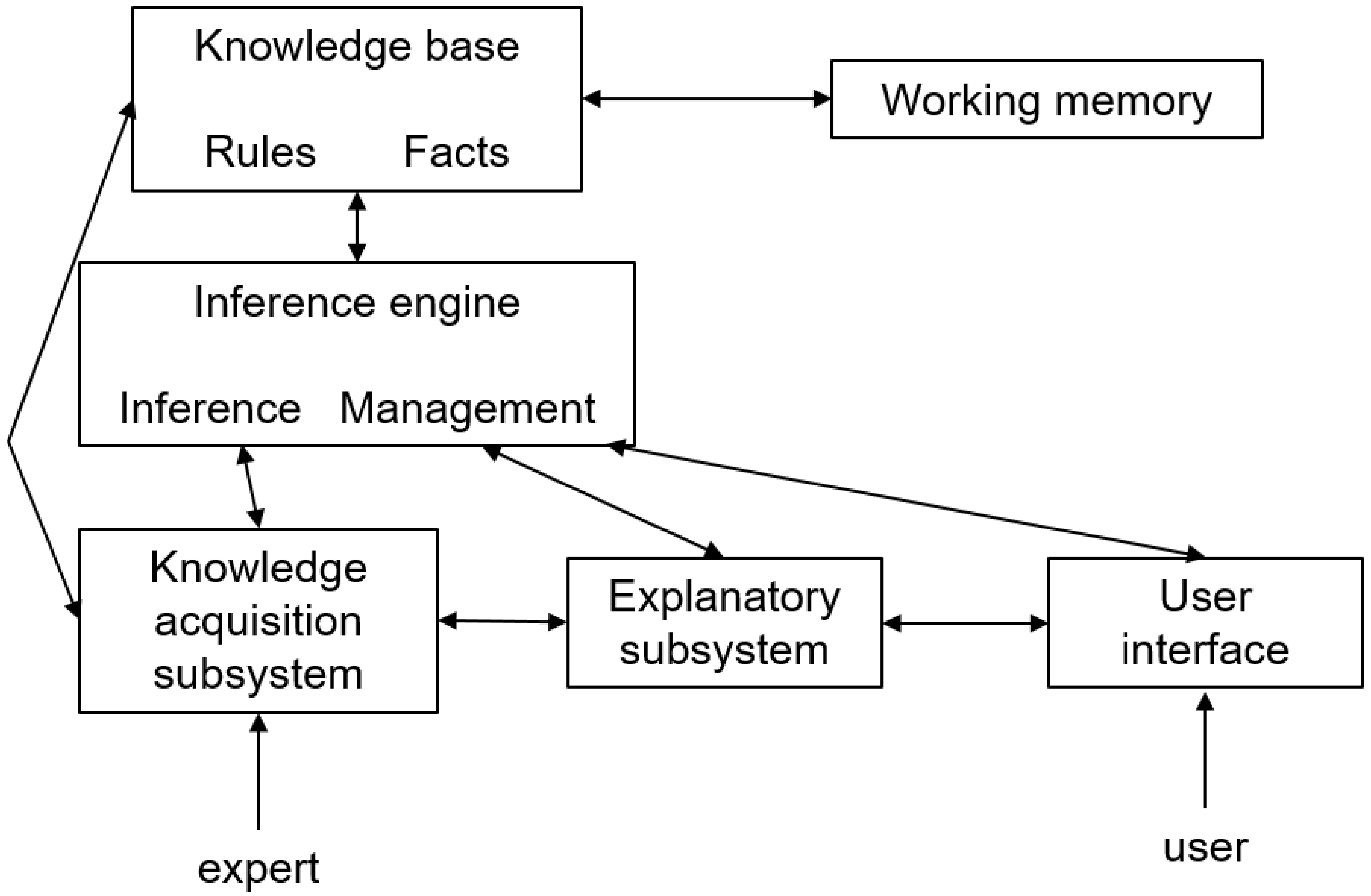
CONTENT 1

Explanatory subsystem



CONTENT 1

Explanatory module

Uses a methodology to explain the inferences made (i.e. how it has gotten to G).

If we use production rules of the type:

IF A THEN G

the system must be able to explain from which conditions it started (i.e. from condition A).

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Types of queries

- **Static queries to KB;**
- **Dynamic queries about the path of reasoning.**

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Types of queries: static to KB

An understanding of what the KB contains at any given time is required. Using the system effectively depends on assessing what it knows and what it doesn't.

Example:

What does "meningitis" mean?

The system should return the definition for "meningitis".

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Types of queries: dynamic about the path of reasoning

As the ES collects data and draws interim conclusions, the user must be able to ask questions to follow the line of reasoning.

Example:

How did you assume that the organism was bacterial in nature?.

The system should return the rule used:

IF (1) the infection is primary bacteremia, AND

(2) the place from which the culture was taken is sterile, AND

(3) this organism is assumed to have penetrated through the gastrointestinal tract,

THEN it can be assumed (0.7) that this organism is bacterial in nature.

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CONTENT 3

Explanatory module: what does it need?

- **knowledge about the ES:**
  - static knowledge;
  - dynamic knowledge;
- **knowledge about the history of the consultation** – which means a record of any conclusion that has been reached during consultations;
- **procedural knowledge:**
  - knowledge about the production rules;
  - knowledge about the interpretation of the rules;
- **problem-oriented knowledge:**
  - set theory;
  - logic;
  - arithmetic.

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CONTENT 3

Rule interpreter

To provide explanations for system actions, the Explanatory module must also understand how the rule interpreter works:

- when a rule is tested;
- when a rule will fail;
- why one rule is tested and not another.

A scheme of how or why certain rules are used, together with a full record of the specific actions taken, can be used as a basis for explaining the results of the consultation.

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CONTENT 4

Explanatory module - design

- To decide what basic questions the system will answer;
- To provide for the possibility of supplementing;
- The format and organization of the KB to allow and facilitate a consultative mode of work, i.e. knowledge to be easily accessible;
- The module to "understand" the semantics of the rules - it can be done by including a description of the semantics of each rule in the system KB.

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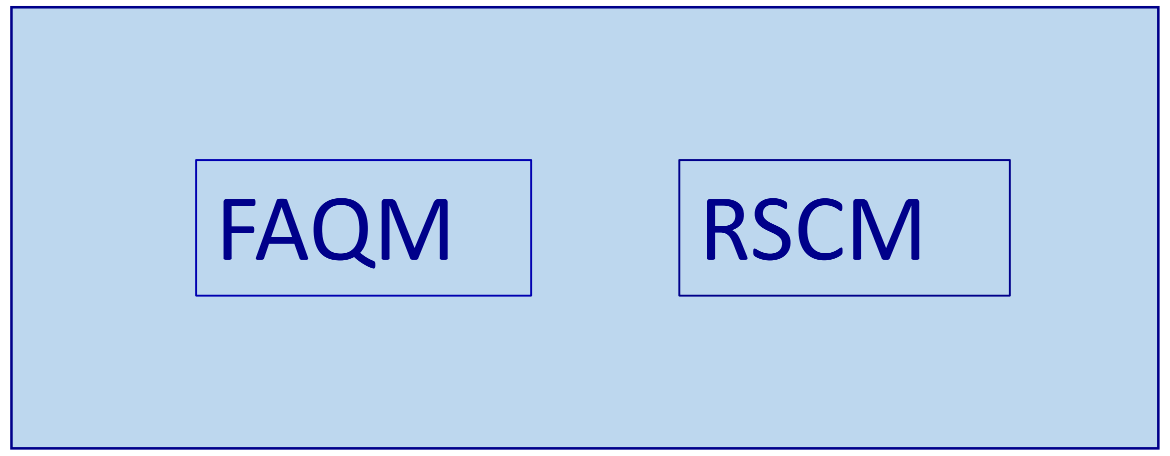
CONTENT 4

Explanatory module - structure

The basic functions of the EM are executed by the corresponding submodules:

- **frequently asked questions answering module (FAQM);**
- **module for reasoning status check (RSCM)**.



CONTENT 4

Frequently asked questions answering module

Used:

- during consultation;
- after the system has printed the results.

Answers questions:

- about the static knowledge of the subject area;

Example: *What does „meningitis“ mean?.*

- about facts, gathered during the consultation.

Example: *What is the value of hemoglobin?*

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CONTENT 4

Module for reasoning status check

Used: during the consultation.

Answers questions: about the reasoning process of the system.

Example: *How did you assume that the organism was bacterial in nature?*

CONTENT 4

Modes of consultation

- **Dialogic** - the system periodically requests additional information. This allows for the user to ask for clarifications while the consultation is taking place.
- **Non-interactive** - the user has no opportunity to interact with the system until it has printed its deductions. It is possible to:
    - Insert a mechanism for the interruption of the reasoning process and question asking;
    - Limit to questions about the final state of the system knowledge - in this case there will be no RSCM.

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LECTURE 8

REASONING WITH UNCERTAINTY

1. Introduction
2. Uncertainty of rules
3. Uncertainty of facts
4. Credibility factor
5. Ways to evaluate the certainty of rules

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CONTENT 1

Relevance of the knowledge security problem

The problem with reporting and analyzing the security of knowledge is one of the most important in the field of AI.

Sources of uncertainty:

- Uncertainty of facts;
- Uncertainty of rules.

Part of the expertise of experts is to know:

- when to ignore missing information;
- when to stop to get it.

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Uncertainty of rules

Rules that carry knowledge with uncertain information can be included in the KB.

Example: *IF you have pain in your back, THEN apply warming ointment.*

The pain may be neurological and heating may be contraindicated.

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CONTENT 3

Uncertainty of facts

In the real world, despite the uncertainty of the data, we can make completely certain conclusions by adhering to **certain rules:**

- to not apply given rules if the information needed to evaluate their premises is not available.
- the result depends on the type of prerequisites:

➢ for **AND** clauses - all clauses must evaluate to true for the rule to apply. If a user answers "unknown" for any part of the prerequisite, the rule fails.

➢ for **OR** clauses - unknown information related to one clause of the premise does not make the rule impossible to succeed.

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CONTENT 3

Uncertainty of facts

If we use rules in the data structure:

IF A THEN G

it is important to the inference **G** that the fact **A is not known** or **not entirely certain**, as it requires the derivation of new propositions from assumed true premises, by repeated application of rules.

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CONTENT 3

Uncertainty of facts – where can it come from?

- Ambiguity;
- Incompleteness;
- Unreliability/inaccuracy.

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CONTENT 3

Uncertainty of facts - ambiguity

Ambiguity is one of the properties of information in the real world.

Sources of ambiguity:

- conflicting knowledge;

Example: *data from a video camera with limited resolution.*

- blurred boundaries of concepts;

Example: *He is an old man.*

- expressions with a multi-valued scale of truth, etc.

Example: *You must be good!*

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CONTENT 3

Uncertainty of facts - incompleteness

Incompleteness refers to the content of the information and can be seen as:

- **Absence;**
- **Insufficiency.**

Sources of incompleteness:

- time - lack of time for a complete analysis;
- financial - need for expensive and risky research.

In reasoning using incomplete data, we get conclusions that are questionable.

Making a decision when facing incomplete data gives reason to thinking.

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CONTENT 3

Uncertainty of facts - unreliability/inaccuracy

An inaccuracy is established when the truth of the information is considered.

Sources of inaccuracy:

- inaccurate data;
- unreliable data.

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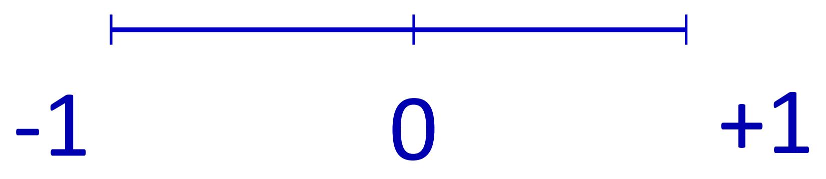
CONTENT 4

Credibility factor

The degree of certainty can be quantified by a number called the **credibility factor or safety factor**:



Important: Credibility factor is not a probability, but it can be compared to a probability without being expected to obey the laws of probability

CONTENT 4

Credibility factor - application

According to the nature of the sources of uncertainty, the credibility factor can be used:

- **In case of uncertainty of the facts** - With the help of composite premises, the uncertain facts can be checked;
- **In case of uncertainty of the rules** - The rules themselves may not be completely defined, and it is also possible that some facts-inferences may be obtained as a result of more than 1 rule. A combining function combines their credibility factors.

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CONTENT 4

Credibility factor – of facts

A user sometimes thinks a fact is true, but is not completely sure.

Prerequisites are evaluated differently depending on the number of clauses and logical connections they contain. Rules succeed if the premises have a credibility factor greater than a certain **threshold.**

An uncertain premise always leads to an uncertain conclusion, and it is affected by its uncertainty.

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CONTENT 4

Credibility factor – of rules

When the rules are not completely certain they may also have an associated "credibility factor".

Example:

IF you have pain in your back, THEN apply warming ointment.

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CONTENT 4

Credibility factor – example

“If Boko is green

then he is probably a frog”.

But he can also be a chameleon?

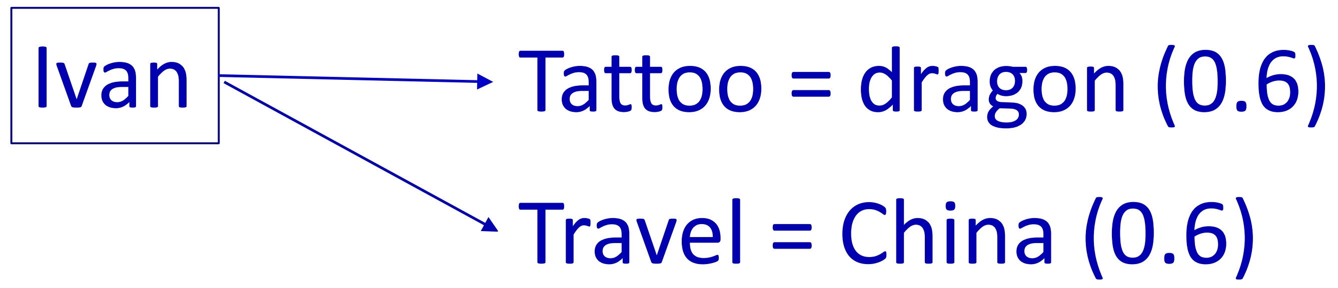
This type of reasoning can be mimicked using numeric values:

“If it is known that Boko is green, it can be inferred with certainty 0.85 that he is a frog”

“If it is known that Boko is a frog, it can be inferred with certainty 0.95 that he jumps”.

CONTENT 4

Credibility factor – example



„If Ivan's tattoo is a dragon, then Ivan traveled to China“.

Credibility: We can only be partially (0.6) confident that a given tattoo is of one type.

This credibility factor is propagated by the rule that concludes that Ivan has been in China (0.6).

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CONTENT 4

Credibility factor of the inference

- Incompletely certain information will never be combined to form a certain conclusion.
- As more positive information emerges, confidence in the conclusion increases.
- The order in which the information is combined does not matter for credibility.

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Credibility factor of the inference

- **If the premise is simple** and succeeds with some certainty, then the value is accepted with its given credibility factor;
- **If the premise is complex** and succeeds with some certainty, then the final credibility factor of the conclusion is the product of the credibility factors of the premise.

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CONTENT 5

Ways to evaluate the certainty of rules

- probability theory (Bayes's theory);
- evidence theory (Dempster-Shafer theory);
- possibility theory (Zadeh's theory);

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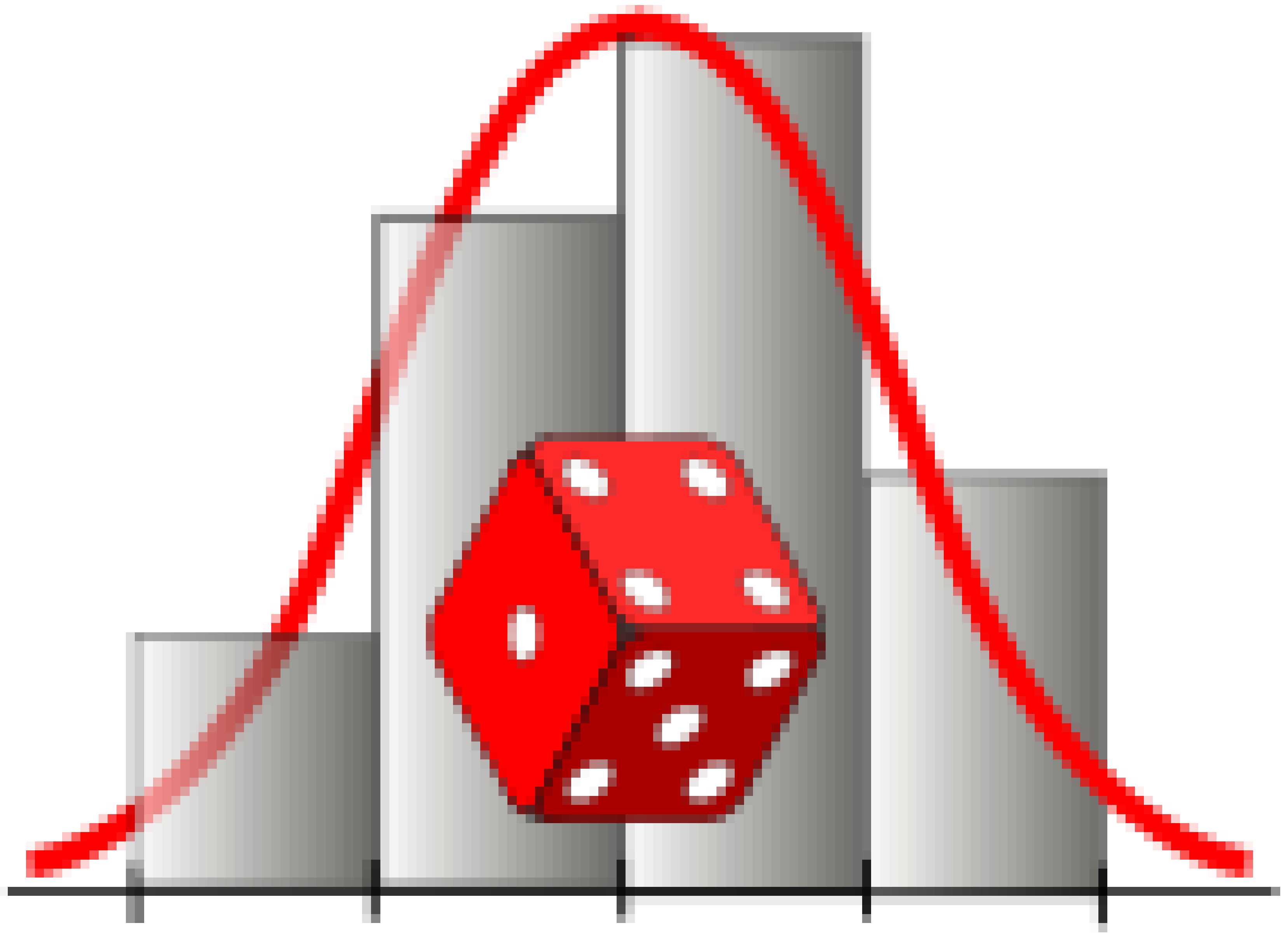
CONTENT 5

Probability theory



CONTENT 5

Probability theory

- **Probability** – it is established experimentally or statistically as a way to determine the subjective confidence in a given event.
- **Unconditional probability** - the confidence that is assigned to a statement A without requiring the fulfillment of any condition.

P(A), where P(A) is a non-negative number

- **Conditional probability** – it is used when, in order to establish the probability of a certain statement A, the realization of a certain event B is taken into account. It is used only when we know everything about the event B.

P(A|B) (i.e. IF B THEN A)

When event C becomes known (additional information), the conditional probability is calculated: **P (A | B∧C).**

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CONTENT 5

Probability theory – conditional and unconditional probability

Unconditional probability can be seen as a special case of conditional probability, where the absence of facts about the event **B** is indicated by its absence.

P(A|)

Conditional probabilities can be determined from unconditional ones by the probability product theorem

$$\mathbf{P(A|B) = P(A \wedge B) / P(B),} \text{ where } P(B) > 0$$

i.e. written back

$$\mathbf{P(A \wedge B) = P(A|B) * P(B)}$$

CONTENT 5

Probability theory - axioms

- all probabilities are with a value **between 0 and 1**;
- true statements have a probability of **1** and false statements have a probability of **0**;
- the disjunction probability is:

$$P(A \lor B) = P(A|) + P(B) - P(A \land B)$$

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CONTENT 5

Probability theory - features

The following property can be deduced from the axioms:

$$P(A|B) * P(B) = P(B|A) * P(A)$$

If we divide by P(A) we get **Bayes's rule**:

$$P(B|A) = P(A|B) * P(B) / P(A),$$

which allows for an unknown probability to be calculated with given known others.

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CONTENT 5

Probability theory - example

Task: making a medical diagnosis (where there are many conditional probabilities). What is the probability that a patient has meningitis if he has a stiff neck?

The doctor knows that meningitis is a diagnosis in 50% of cases when the complaint is a stiff neck (the conditional probability). According to the statistics (unconditionally):

- the probability of someone suffering from meningitis is 1/50 000;
- the probability of a person having a stiff neck is 1/20.

A is the statement that the patient has a stiff neck and B is the probability that he has meningitis. P(B|A) means that the patient with a stiff neck may have meningitis.

$$P(B|A) = (1/2*1/50000)/1/20 = 1/5000.$$

CONTENT 5

Probability theory – credibility measurement

In Bayes’s theory, probability is often used to measure the credibility of a statement.

Laplace (1812г.) reaches the same conclusion and used it to solve problems in celestial mechanics, medicine, and court practice.

Example: Laplace calculated the mass of Saturn based on existing astronomical observations of its orbit. He announces the results, along with their uncertainty: “I bet 11’000:1, that the error in this result is not more than 1/100 of its value."

Laplace would win the bet, because 150 years later, based on new data, his result has been corrected by only 0,63%.

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CONTENT 5

Probability theory – evaluating hypotheses

Bayes‘s rule is also used for hypothesis evaluations.

Bayesian nets - they represent dependencies between individual quantities and specify the probability distribution. A confidence network is a graph including:

- **quantities**, forming the nodes in the network;
- **direct connections**, connecting pairs of nodes, where the intuitive meaning of arrows is to indicate the direct influence of one quantity on another.
- each node has a **table of probabilities** quantifying the effect on it that the so-called causal quantities have (those from which the arrows start).

When new information comes in that imposes changes on the probabilities, the changes are propagated to the nodes and the new situation is established, i.e. it reflects the fact that statements influence each other.

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CONTENT 5

Probability theory – uncertain inference

There are two reasons for the uncertainty of statement **B**:

- the user has said, that **B** is uncertain;
- the program derives **B** by a plausible rule, i.e. with probability.

If we want to use **B** in a rule for **P(A|B)** the question arises: how do we reduce the certainty of the conclusion due to the uncertainty associated with **B**?

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CONTENT 5

Probability theory – uncertain inference

Let **E** denote the evidence used to establish **B**, and **P(A|E)** be the current probability of **A** with given **E**.

Under some assumptions:

$$P(A|E) = P(A|B)*P(B|E) + P(A|\sim B)*[1-P(B|E)]$$

This formula is valid in the extreme cases of complete certainty, i.e.

if we know that B is true (**P(B|E)=1)**, we get **P(A|B),** and

if we know that B is false (**P(B|E)=0)**, we get **P(A|~B).**

CONTENT 5

Probability theory – uncertain inference

Unfortunately, a problem arises in the intermediate cases.

In particular, lets suppose that E does not provide information about B, i.e. **P(B|E) = P(B).**

The previous formula promises to add **P(A),** when the calculation is based on expert-derived values, but the resulting value for **P(A|E)** usually does not agree with the expert estimate of **P(A).** This means that **P(A), P(B), P(A|B)** and **P(A|~B)** are not independent, and the expert's subjective estimates of them are almost certainly numerically untenable.

Probability theory – uncertain inference

In this particular case, the problem can be solved by, for example, not asking the expert about **P(A),** but calculating it

$$P(A) = P(A|B)*P(B) + P(A|\sim B)*P(\sim B).$$

However, this makes the parameters of only one rule compatible, and the solution is not obvious when given a network of rules with conflicting values of the probability parameters.

CONTENT 5

Probability theory - assessing the uncertainty of the rules

- **the reliability coefficient of a conjunction** is the minimum of the coefficients of the elements included in the conjunction
  e.g. (P1(with К1) Λ P2(with К2)) with К3 -> К3 = min(К1,К2)
- **the reliability coefficient of a disjunction** is the maximum of the coefficients of the elements included in the disjunction;
- **the confidence coefficient of the negation** is the difference between a one and the confidence coefficient for the statement;
- **the certainty of an entire rule** is considered as the product of the coefficients of the premises with the certainty of the consequence, i.e. (If A with К1, then C with К2) with К3 -> К3 = К1 * К2

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CONTENT 5

Probability theory - conclusions

- Using these rules, it is possible to combine partial information based on mathematical approaches.
- Typically, a rule has a security threshold value related to the security of the premise. Below this threshold value, the rule is not activated.

Bayes' theory does not make it possible to distinguish uncertainty from ignorance.

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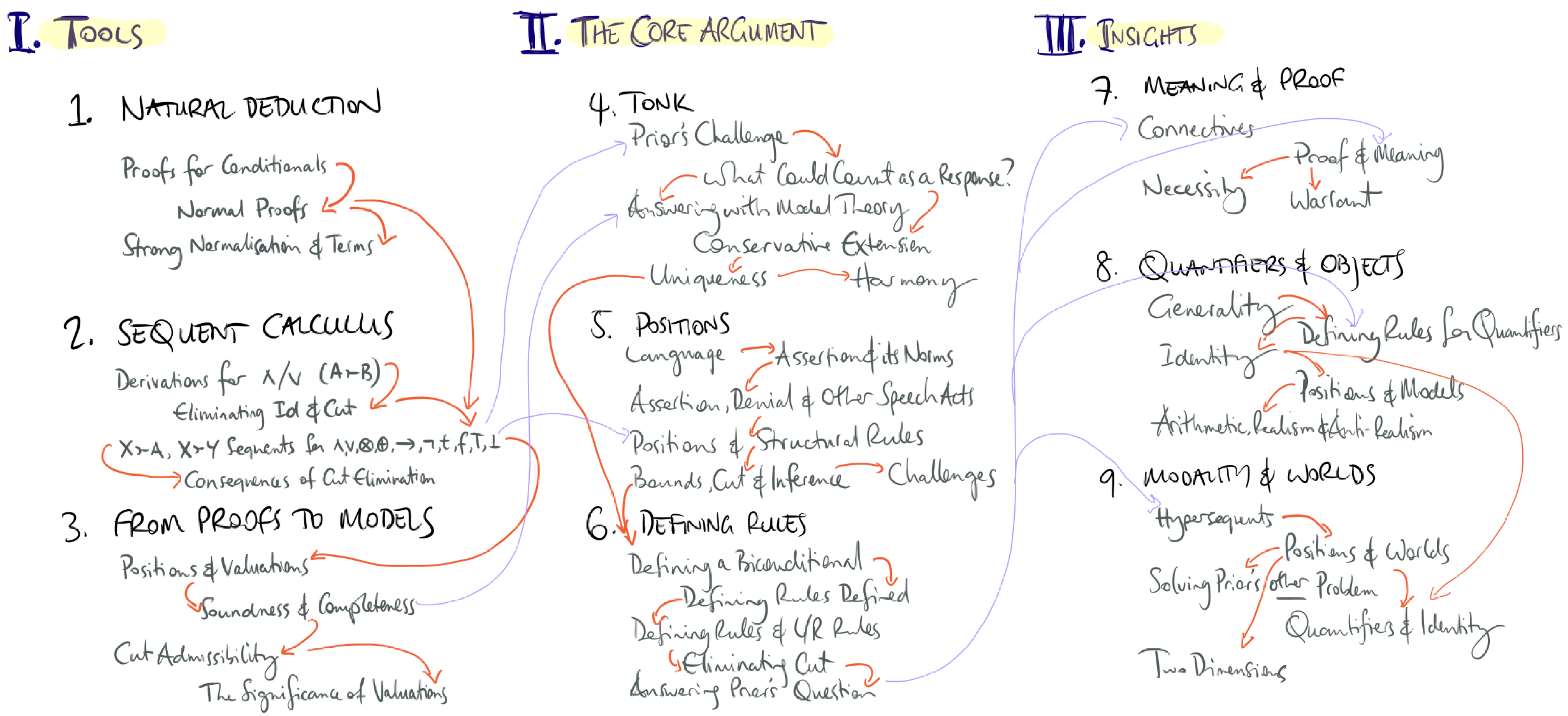
CONTENT 5

Probability theory - problems in quantifying uncertainty

- **the need to give numerical values for a priori probabilities** - The expert can say how certain he feels about conclusion A when condition B is present (If B Then A), but may find it difficult to assign the probability of A in the absence of any given condition.
- **the expert cannot distinguish probability from utility or importance** and expresses some undetermined measure of importance.

CONTENT 5

Evidence theory



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CONTENT 5

Comparison between the two theories

Both:

- account for degrees in measuring uncertainty using probabilities.
- set a confidence function on a set of hypotheses;
- set a mechanism for updating the current set of probabilities when new information arrives.

Evidence theory can distinguish ignorance from uncertainty.

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CONTENT 5

Evidence theory - advantage

With Bayes, the degree of confidence in hypothesis H can be defined by the probability of its negation:

$$P(H) = 1-P(\sim H)$$

Here, the degree of confidence in the hypothesis H together with the degree of confidence in the complement does not always give full certainty of 1:

$$P(H)+P(\sim H)<=1.$$

The difference to 1 defines the **degree of ignorance**.

Dempster and Shaffer insist on a fundamental distinction between uncertainty and ignorance.

In probability theory, one expresses the degree of one's knowledge or belief in the statement A with a number P(A).

Dempster and Shaffer believe that the classic Bayesian failure of a prior probabilities is often due to the fact that one does not know the values of the prior probabilities, and this makes every choice arbitrary and unjustified.

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CONTENT 5

Evidence theory – confidence functions

Evidence theory addresses the distinction between uncertainty and ignorance by introducing **confidence functions.**

They satisfy axioms that are weaker than those for probability functions. Thus, probability functions become a subclass of confidence functions, and proof theory reduces to probability theory when the probability values are known.

The Dempster-Shafer theory does not make it possible to distinguish uncertainty from lack of specificity.

CONTENT 5

Possibility theory

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CONTENT 5

Possibility theory

In 1973 professor Zadeh created a theory of possibilities/fuzzy logic, which is **not actually fuzzy**, but to a large extent precise.

Applications:

- creation of algorithms for recognition of images, pictures and sounds;
- signal processing;
- quantitative analysis in economics - study of financial operations, etc.;
- decision-making systems - expert systems for diagnostics, planning, forecasting, etc.;
- information processing/databases.

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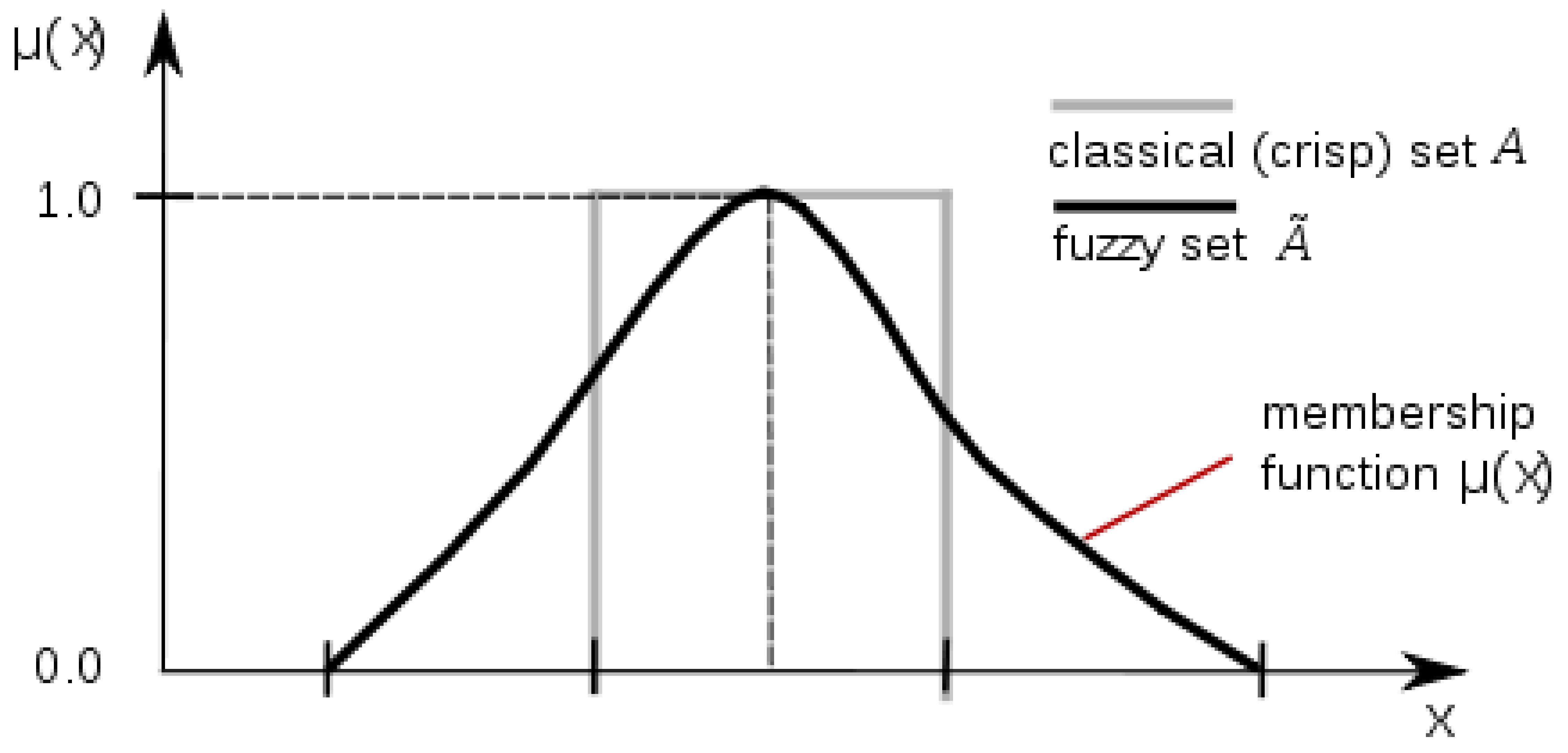
CONTENT 5

Possibility theory – fuzzy sets

Fuzzy sets are classes with imprecise boundaries.

Example: a class of beautiful women, a class of honest men, and a class of tall mountains.



CONTENT 5

Possibility theory – fuzzy sets

According to Zadeh, probability theory is suitable for tasks related to measuring information, but it is inappropriate for **tasks related to the meaning of the information**.

Much of the uncertainty surrounding the use of English terms and expressions is due to vagueness rather than coincidence.

Possibility theory quantifies this kind of uncertainty by introducing **membership functions** with values between 0 and 1.

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CONTENT 5

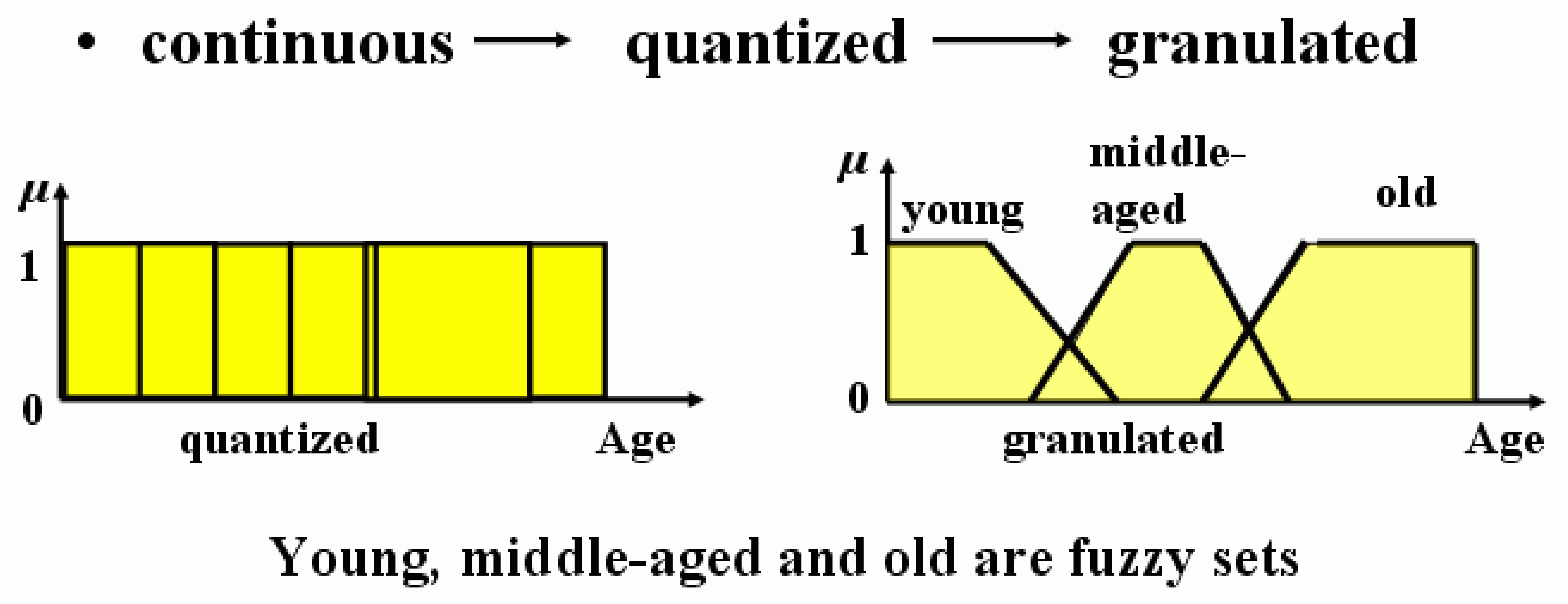
Possibility theory – fuzzy sets and membership degree

- **In classical set theory -** a given element either belongs or does not belong to a given set, i.e. its membership is evaluated as 1 or 0 and there is no third possibility (Law of the Excluded Middle).
- **In fuzzy set theory**, an element belongs to a given set with a degree calculated according to a specified membership function as a number in the interval [0, 1]. The membership function is an extension of Cantor's characteristic function and expresses the degree of truth of a statement. In classical logic, there are only two degrees of truth: "false" and “true";

Possibility theory - overlapping

In fuzzy logic, everything is or is allowed to be overlapping.

Example: the term age is an overlapped term when its values are described as young, middle-aged, and old.



CONTENT 5

Possibility theory – fuzzy sets

If **U** is a set and **u** is an element of **U**, a fuzzy subset **A** of **U** s defined by a membership function **mA (u),** which measures the degree to which **A** belongs to **U**.

Mathematically, **A** is defined as the set of ordered pairs:

A = {u, mA(u)}

mA(u) maps to each element of **U** a number from the interval **[0, 1].**

Example:

if S is the set of positive integers,

F is the fuzzy subset of small integers,

we can have mF(1) = 1, mF(2) = 1, mF(3)=0,8...mF (20) =0,01 etc.

CONTENT 5

Possibility theory – representation of fuzzy sets

- **by enumeration** - if U consists of a finite number of elements, then A is presented:

$$A(u_i) = m1/u1 + \dots + mn/un = \sum m_j/u_j \text{, където } j = 1 \text{ до } n.$$

- **graphically**;
- **analytically**.

Composite membership functions are obtained by operations on simple membership functions, for example addition or subtraction.

CONTENT 5

Possibility theory and fuzzy sets

Probability theory is concerned not so much with how the numerical values of probabilities are determined, but with the rules for calculating the probability of expressions containing random variables.

Similarly, **possibility theory** is not concerned with obtaining numerical values for probability distributions, but with rules for computing the probability of expressions containing fuzzy variables.

Conclusion: Most of the concepts in probability theory have counterparts in possibility theory. Therefore, possibility theory can also be used to quantify the uncertainty coming from the ambiguity of input information — no matter whether the input is data or rules.

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CONTENT 5

Possibility theory – linguistic approach

To account for the factors affecting a given problem, which have qualitative characteristics and are expressed by insufficiently defined and ambiguous terms from natural language and professional terminology in a given subject area, special formalization methods have to be applied.

Linguistic approach uses the theory of fuzzy sets and allows to present subjective linguistic evaluations of specialists and thus account for the inaccuracy of information contained in natural language.

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Possibility theory – linguistic variable

Determined by:

- name;
- multitude of meanings;
- field of meanings;
- a syntactic procedure for forming new meanings of a linguistic variable;
- a semantic procedure for rewriting a formed new meaning to some semantics by forming a corresponding fuzzy set.

Example: linguistic variable HEIGHT, formalizing the concept of *human height* has meanings SHORT, MEDIUM, TALL and a range of meanings from 1m to 2 meters. Formally, this can be written: <height{short, medium, tall},[1,2], Proc1, Proc2>.

CONTENT 5

Possibility theory – linguistic variable

The concept of **degree of affiliation** serves to denote the degree of correspondence of a given value of a linguistic variable to the subjective meaning attached to it.

Example:

set **A** corresponds to the fuzzy concept "*small stock in the warehouse*",

exponent of **A** is a finite set of values **S**{10,11,12,......40}, where the elements from 10 to 40 are separate quantities of materials.

If we ask a specialist to express with a number how true the statement "a small stock of m-l in storage" is for each of the elements of **S**, then the set can be represented:

A={0,05/10;0.1/11;0.2/12;....;0.1/40}.

According to the formalized concepts of a specialist, some of the following meanings correspond to the most complete degree of "small stock in the warehouse":

max 20-23; 14-19; 30-40 min.

Each of the meanings of linguistic variables can be graphically expressed by means of a membership function.

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University of Ruse

INTELLIGENT COMPUTER SYSTEMS

Svetlana Stefanova

September, 2022

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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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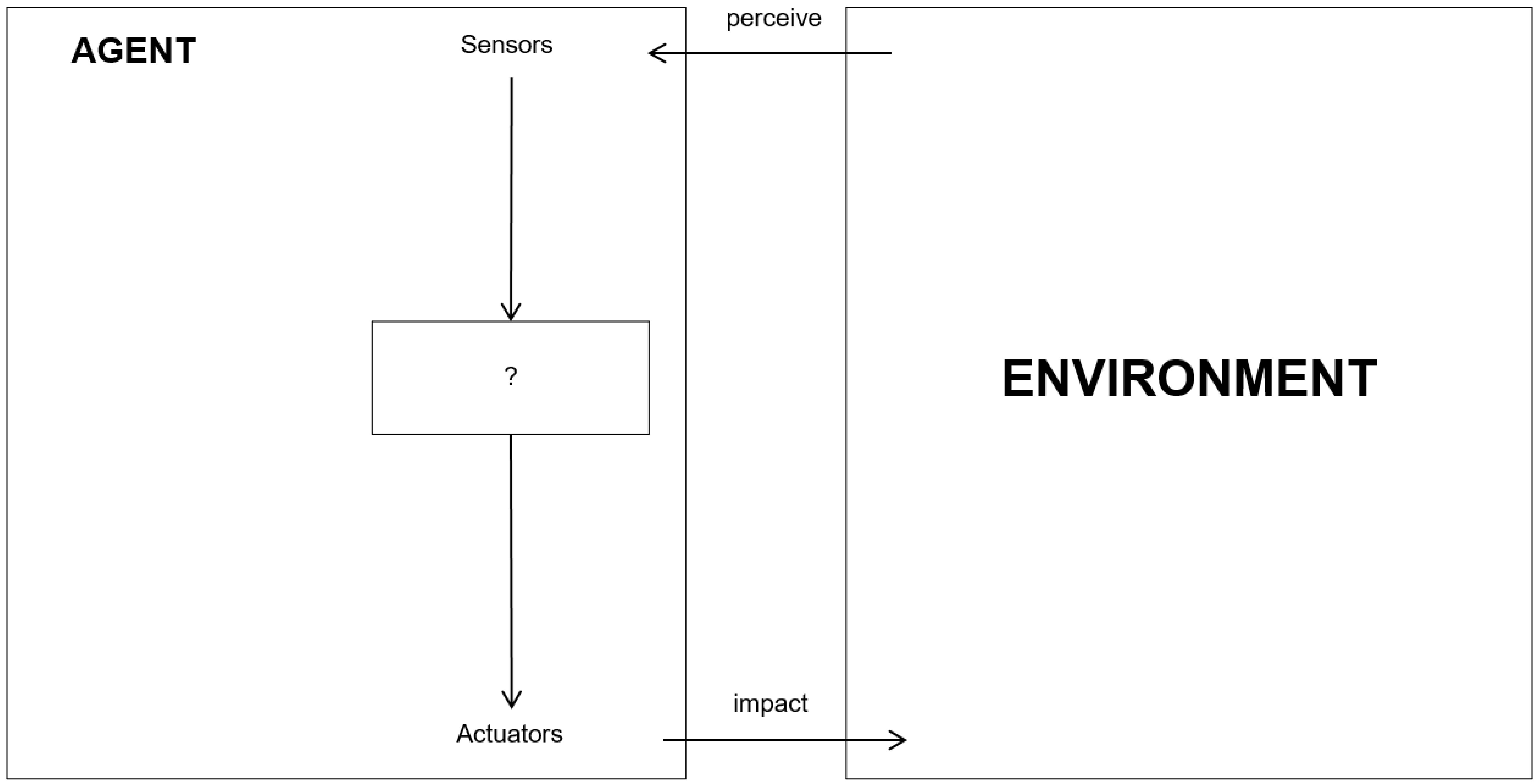
CONTENT 1

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.

CONTENT 1

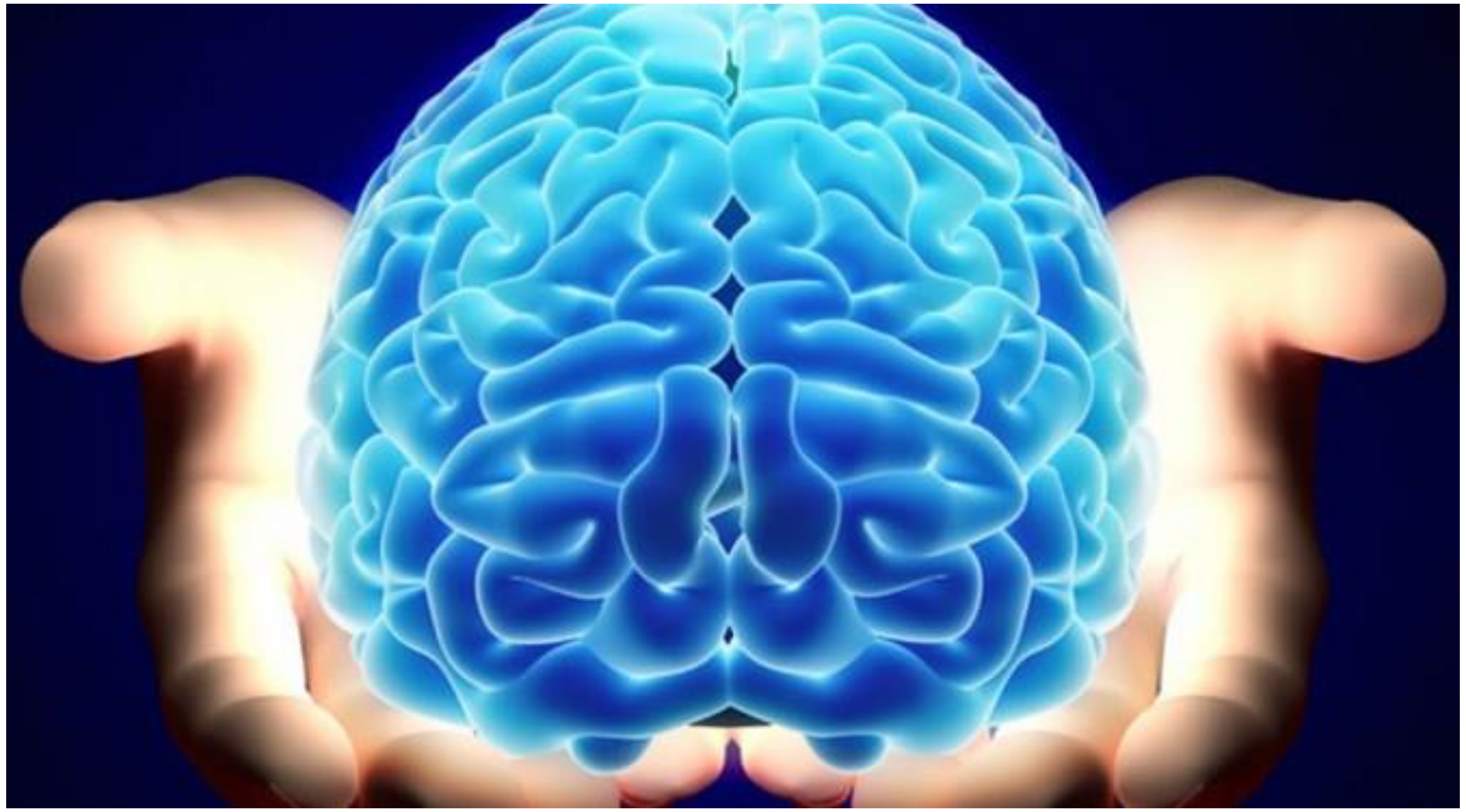
Human brain

- **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.



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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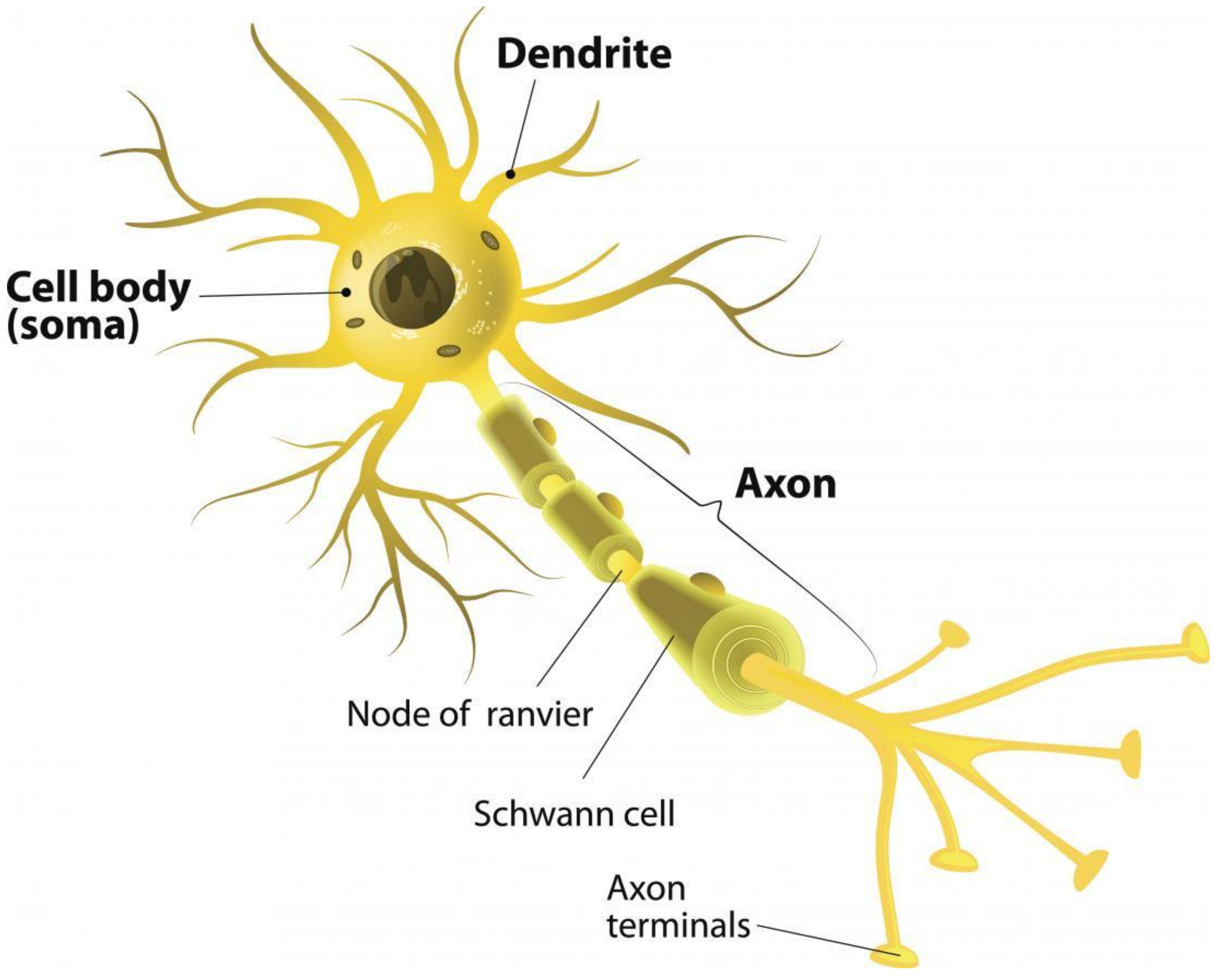
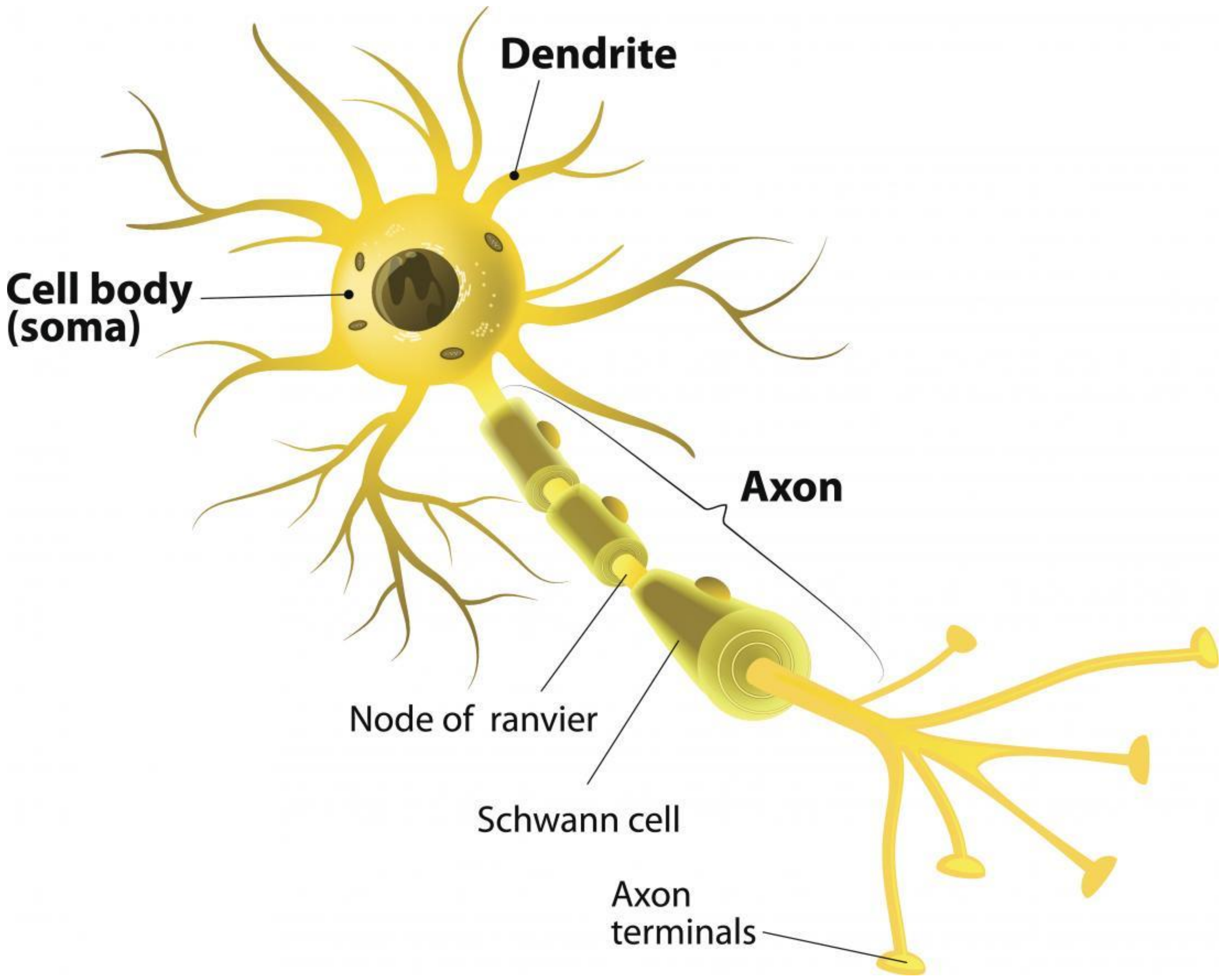
Biological neuron



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.



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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CONTENT 3

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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CONTENT 3

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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CONTENT 3

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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CONTENT 3

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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CONTENT 3

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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CONTENT 3

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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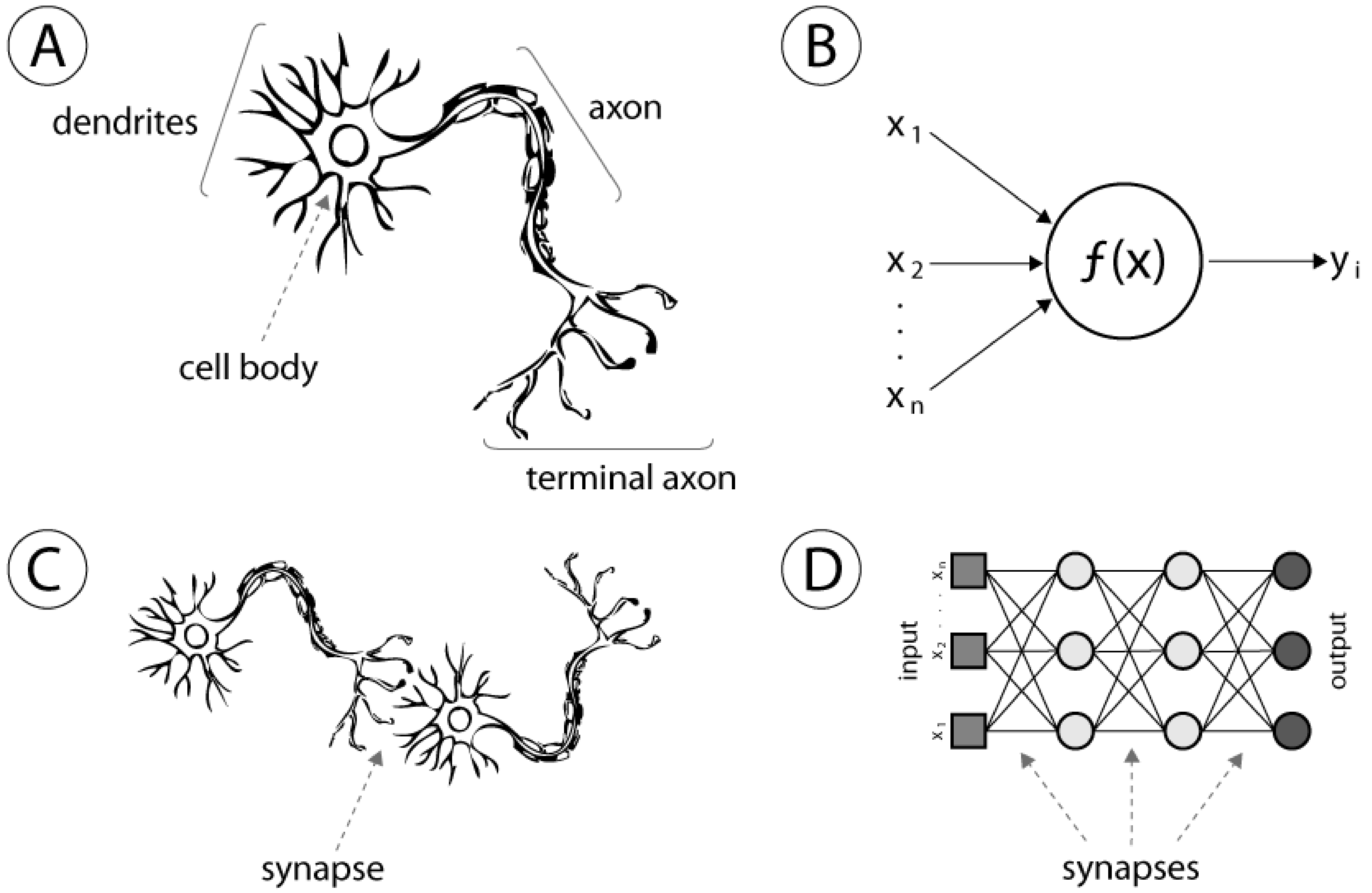
CONTENT 3

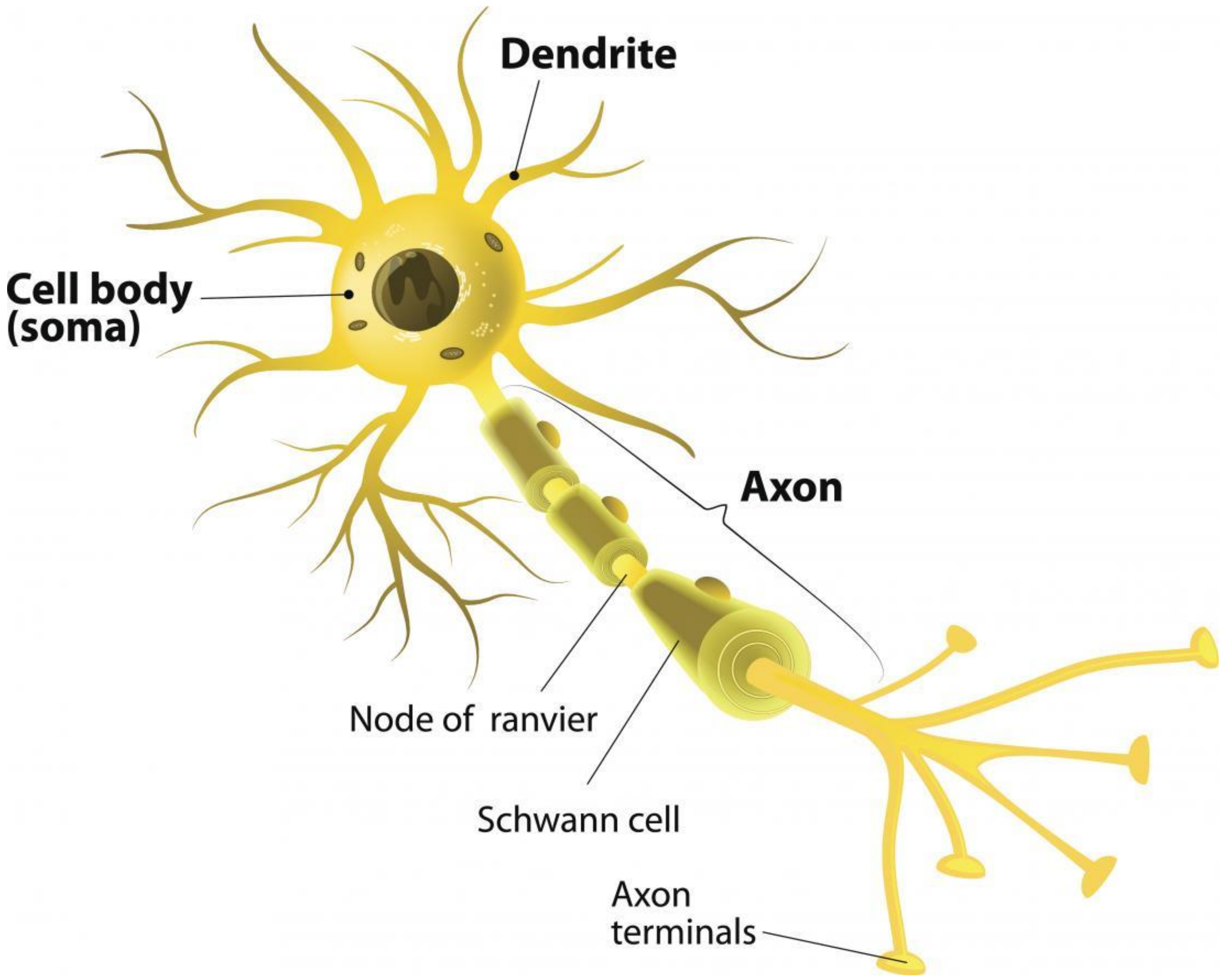
Biological vs. artificial neural network

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



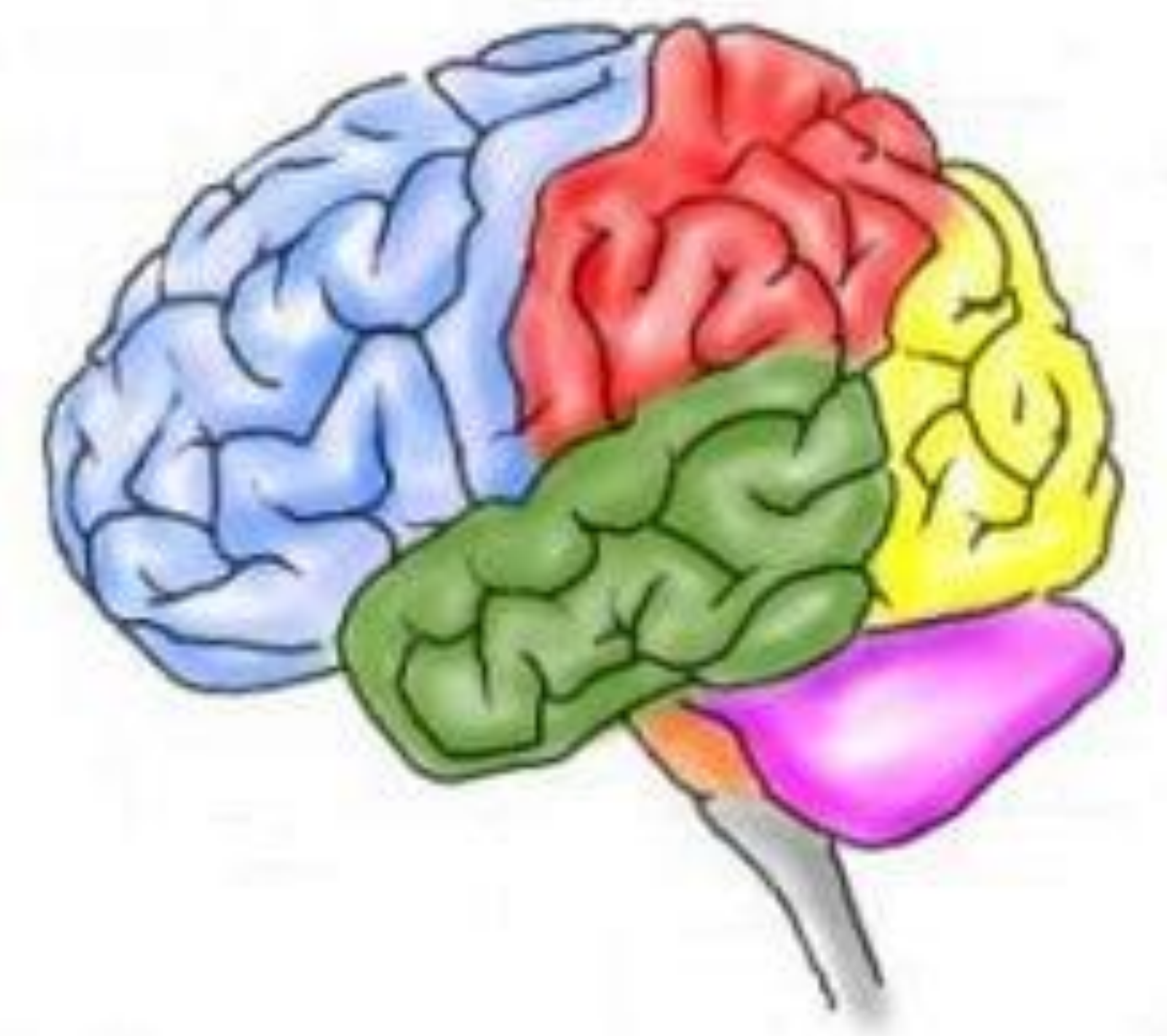
Biological vs. artificial neuron

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



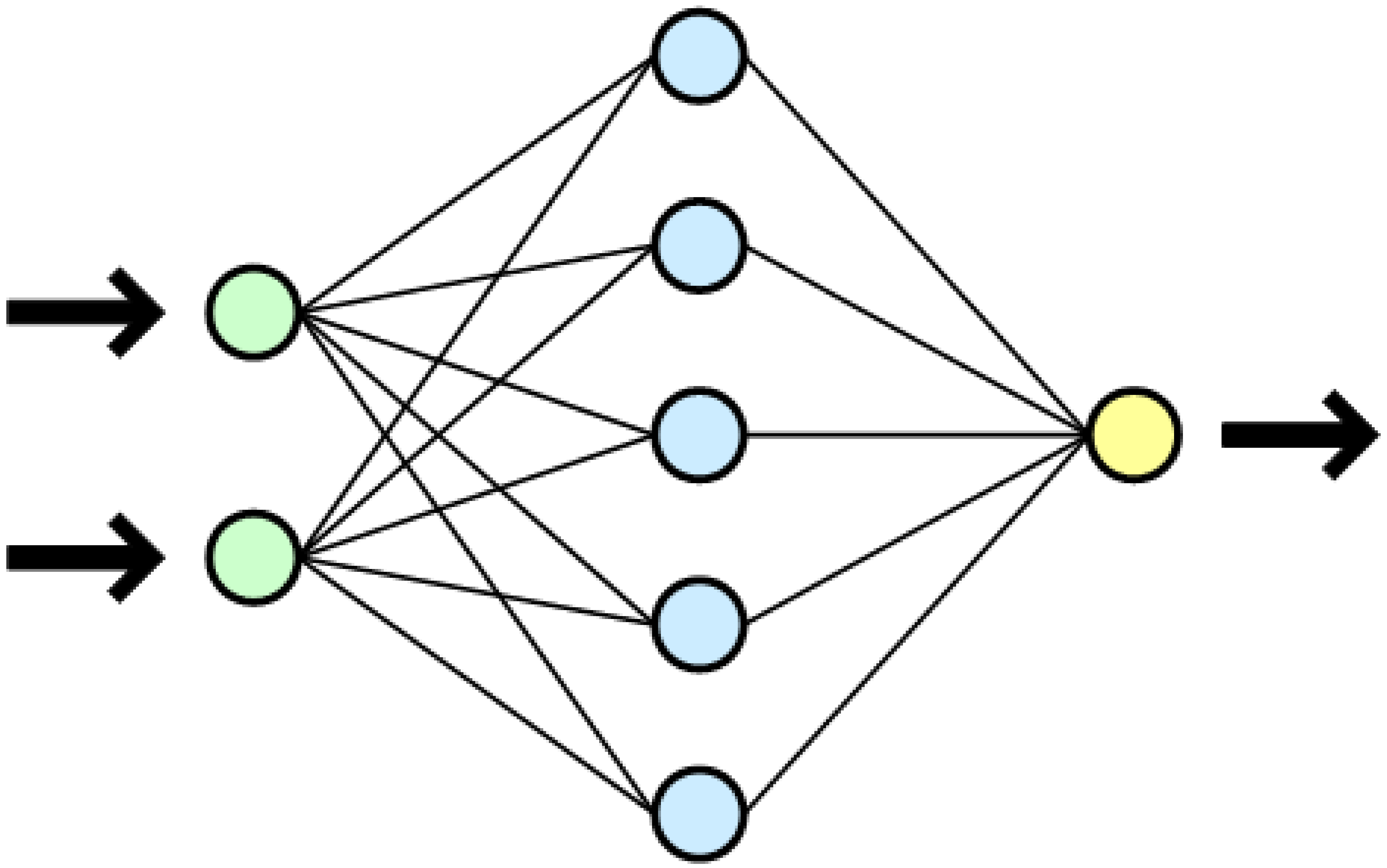
CONTENT 4

General architecture of the brain



CONTENT 4

General architecture of NN



CONTENT 4

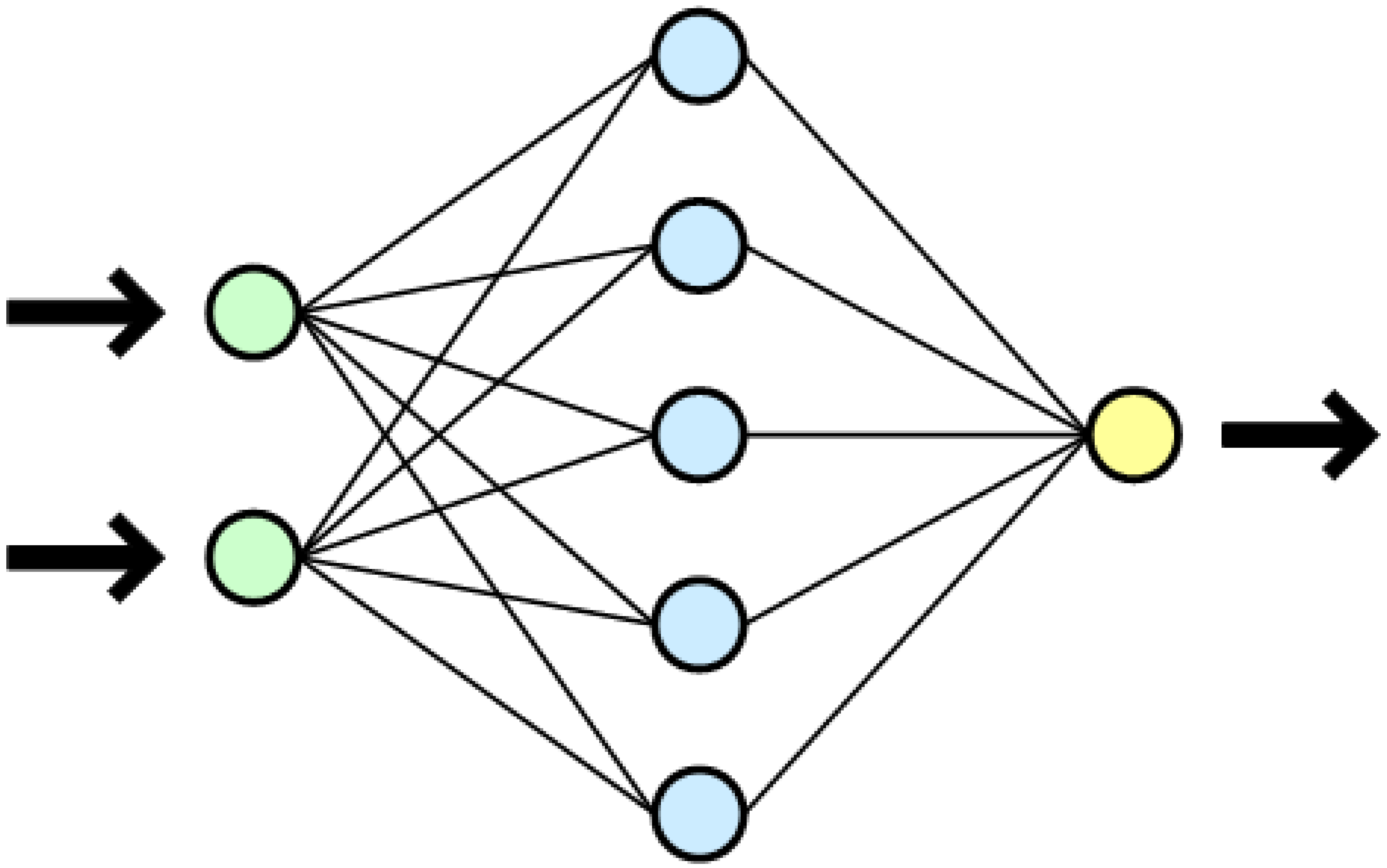
Architecture of NN

- 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.



CONTENT 4

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.

CONTENT 4

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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CONTENT 5

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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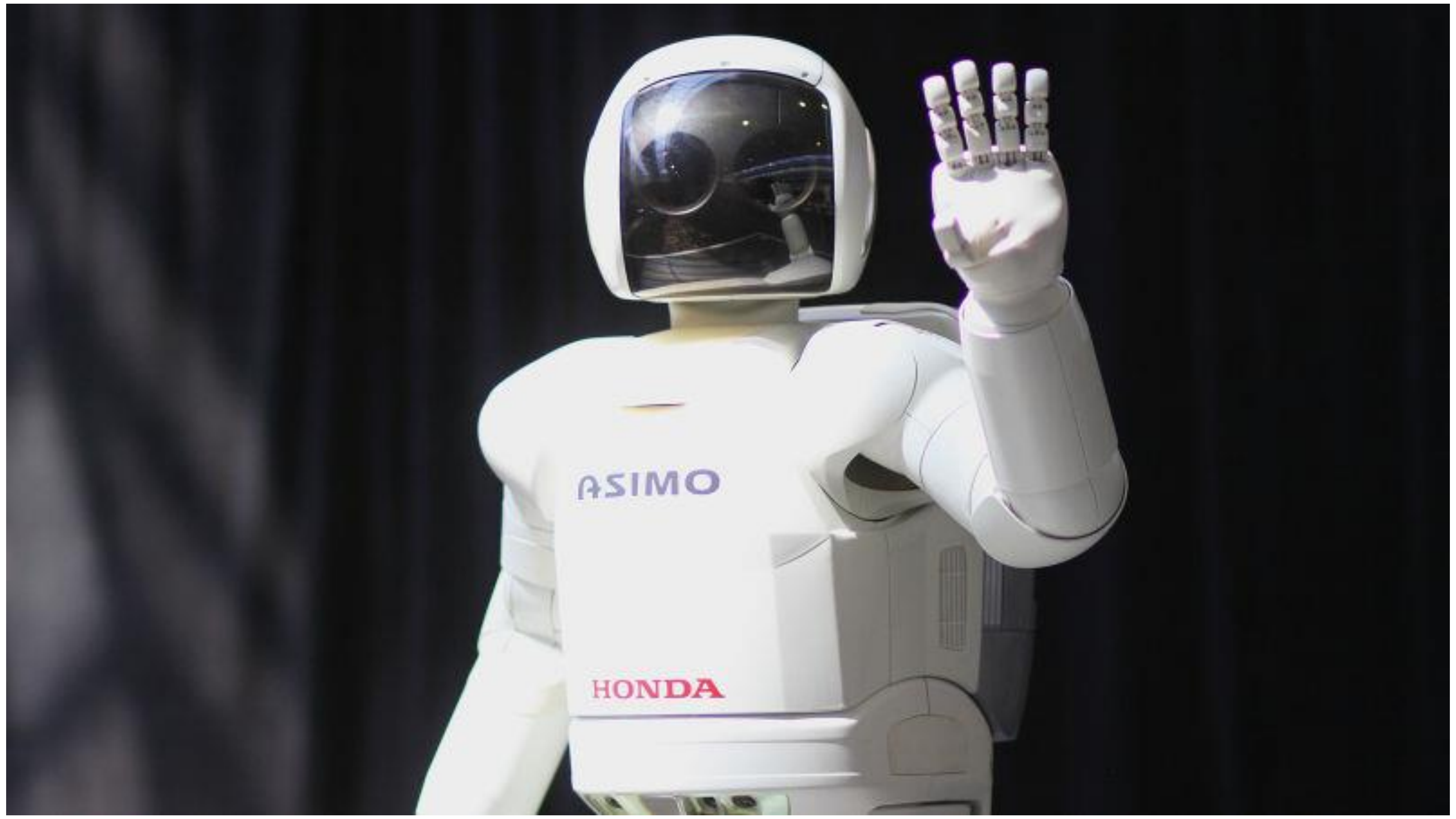
CONTENT 5

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).



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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University of Ruse

INTELLIGENT COMPUTER SYSTEMS

Svetlana Stefanova

September, 2022

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LECTURE 10

NEURAL NETWORK STRUCTURES

1. Neuron model
2. Neural network model
3. Neural networks according to typology
4. Neural networks according to connection weights
5. Neural networks according to the direction of the signal
6. Neural networks according to input and output value
7. Learning

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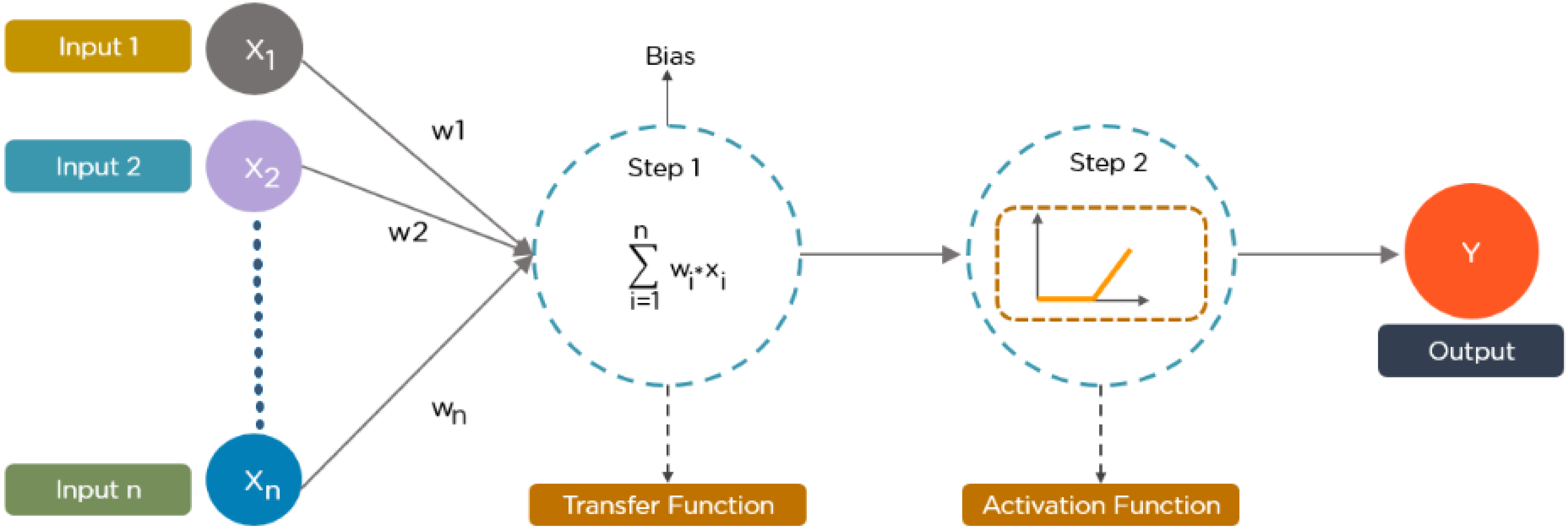
CONTENT 1

Structure of a neuron



CONTENT 1

Input data

The basic artificial neuron model contains a set of **adaptive parameters, called weights**, as in linear regression.

Example: when shopping, we take different products with different quantities and unit price.

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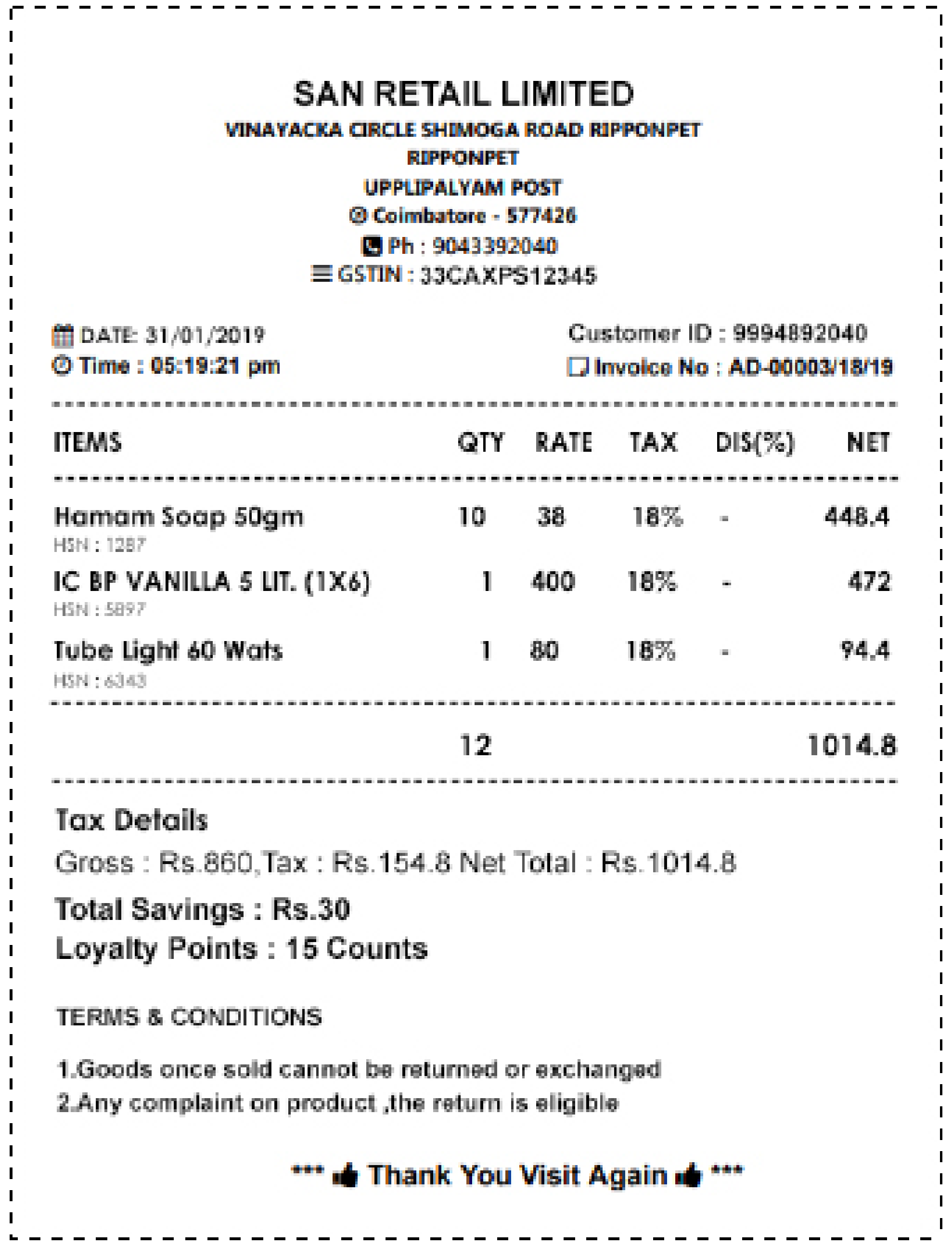
CONTENT 1

Transfer function

A weighted sum of the inputs, i.e. sum of weights multiplied by the inputs or a linear combination of the inputs. In reality, a bias is also added.

Example: the shopping bill is obtained by adding the quantity of each product multiplied by its unit price.



SAN RETAIL LIMITED
VINAYACKA CIRCLE SHIMOGA ROAD RIPPONPET
RIPPONPET
UPPLIPALYAM POST
Coimbatore - 577426
Ph : 9043392040
GSTIN : 33CAXPS12345

DATE: 31/01/2019
Time : 05:19:21 pm
Customer ID : 9994892040
Invoice No : AD-00003/18/19

ITEMS	QTY	RATE	TAX	DIS(%)	NET
Hamam Soap 50gm HSN : 1287	10	38	18%	-	448.4
IC BP VANILLA 5 LIT. (1X6) HSN : 5897	1	400	18%	-	472
Tube Light 60 Wats HSN : 6343	1	80	18%	-	94.4
	12				1014.8

Tax Details
Gross : Rs.860,Tax : Rs.154.8 Net Total : Rs.1014.8
Total Savings : Rs.30
Loyalty Points : 15 Counts

TERMS & CONDITIONS
1.Goods once sold cannot be returned or exchanged
2.Any complaint on product ,the return is eligible

*** Thank You Visit Again ***

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CONTENT 1

Activation function

Defines the output with a given input or set of inputs.

It actually decides whether the "weighted sum" of the input along with the bias should be "shot" to the output or not.

Only non-linear activation functions allow non-trivial problems to be solved using a small number of nodes.

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CONTENT 1

Some activation functions

- **linear** - does nothing and only outputs;
- **step** - if the input value is >0, it sends a signal (ON), otherwise it does nothing (OFF);
- **sigmoid** - a "lighter" version of the step function.

$$\sigma(x) = \frac{1}{1 + e^{-x}}$$

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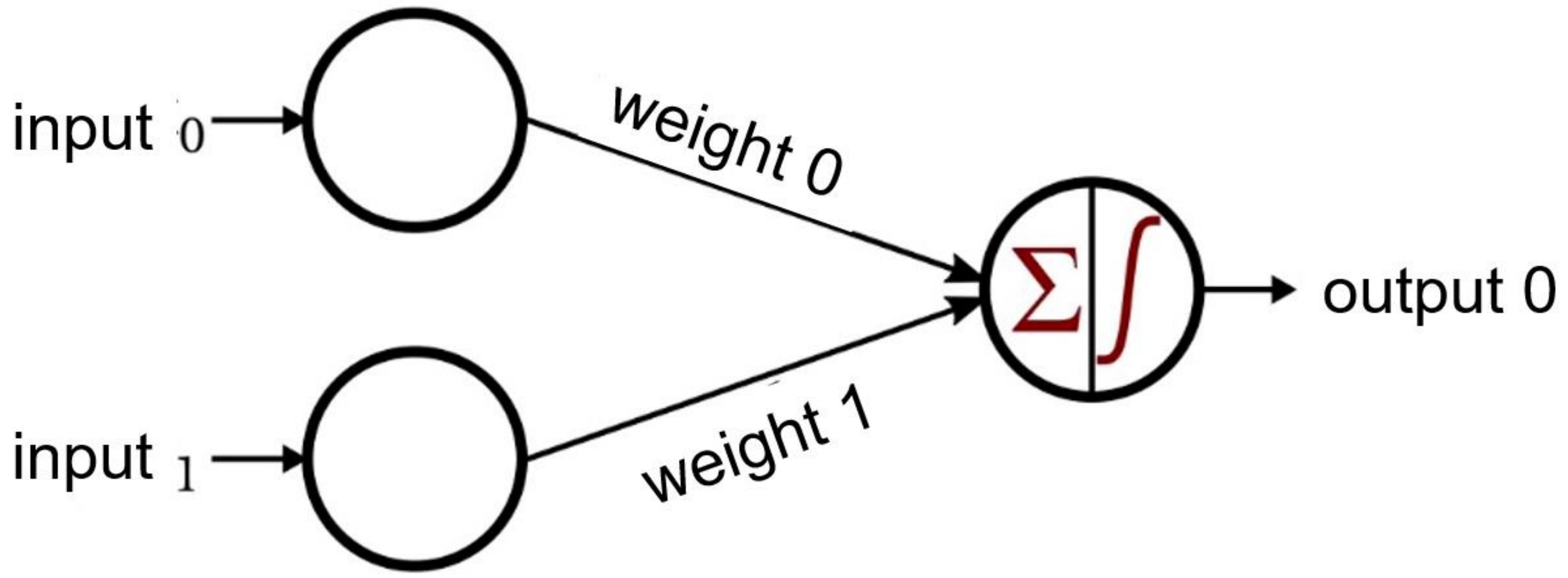
CONTENT 1

A generalized model of a neuron

- **linear** - does nothing and only outputs;
- **step** - if the input value is >0, it sends a signal (ON), otherwise it does nothing (OFF);
- **sigmoid** - a "lighter" version of the step function.

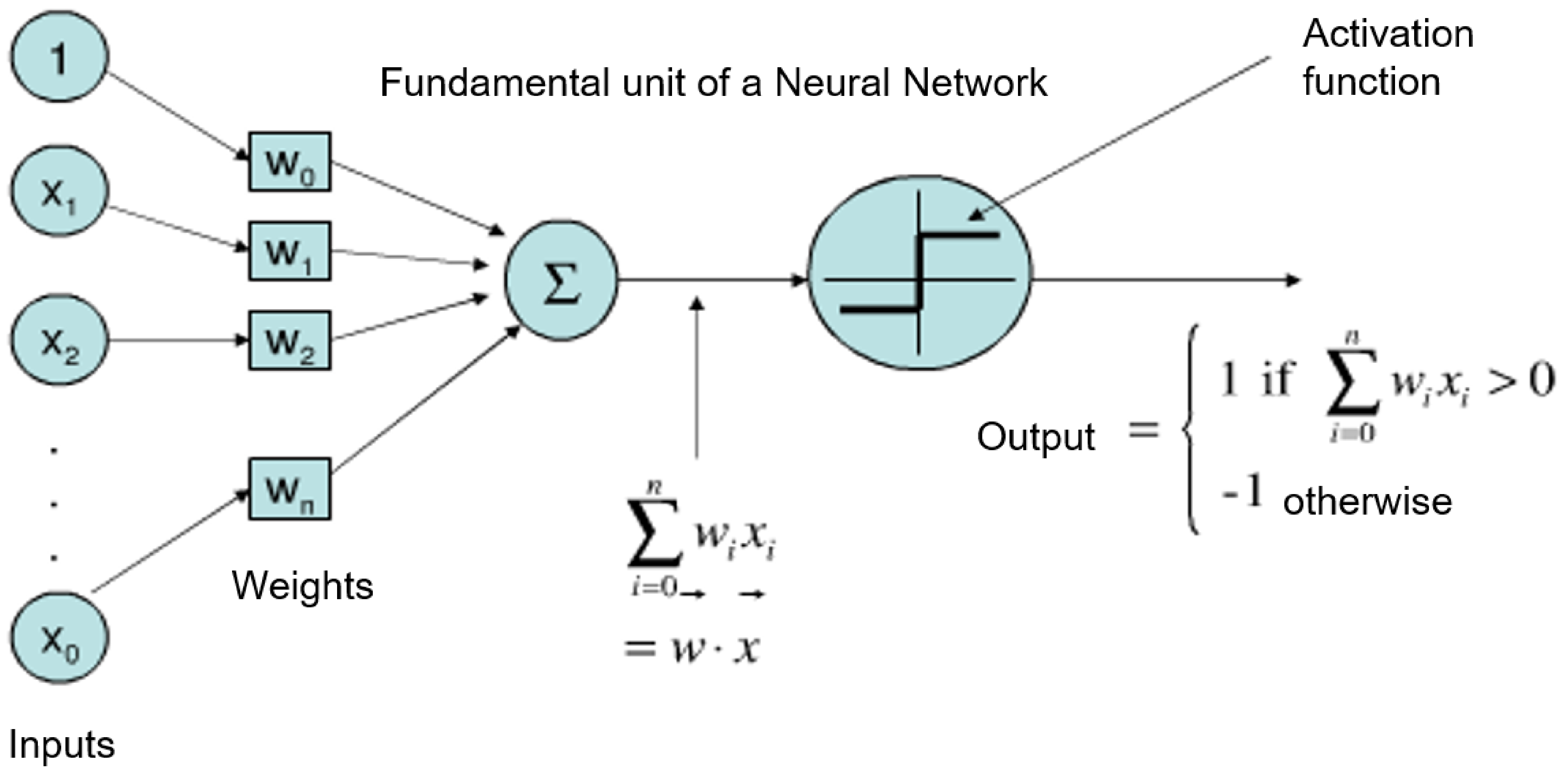


CONTENT 1

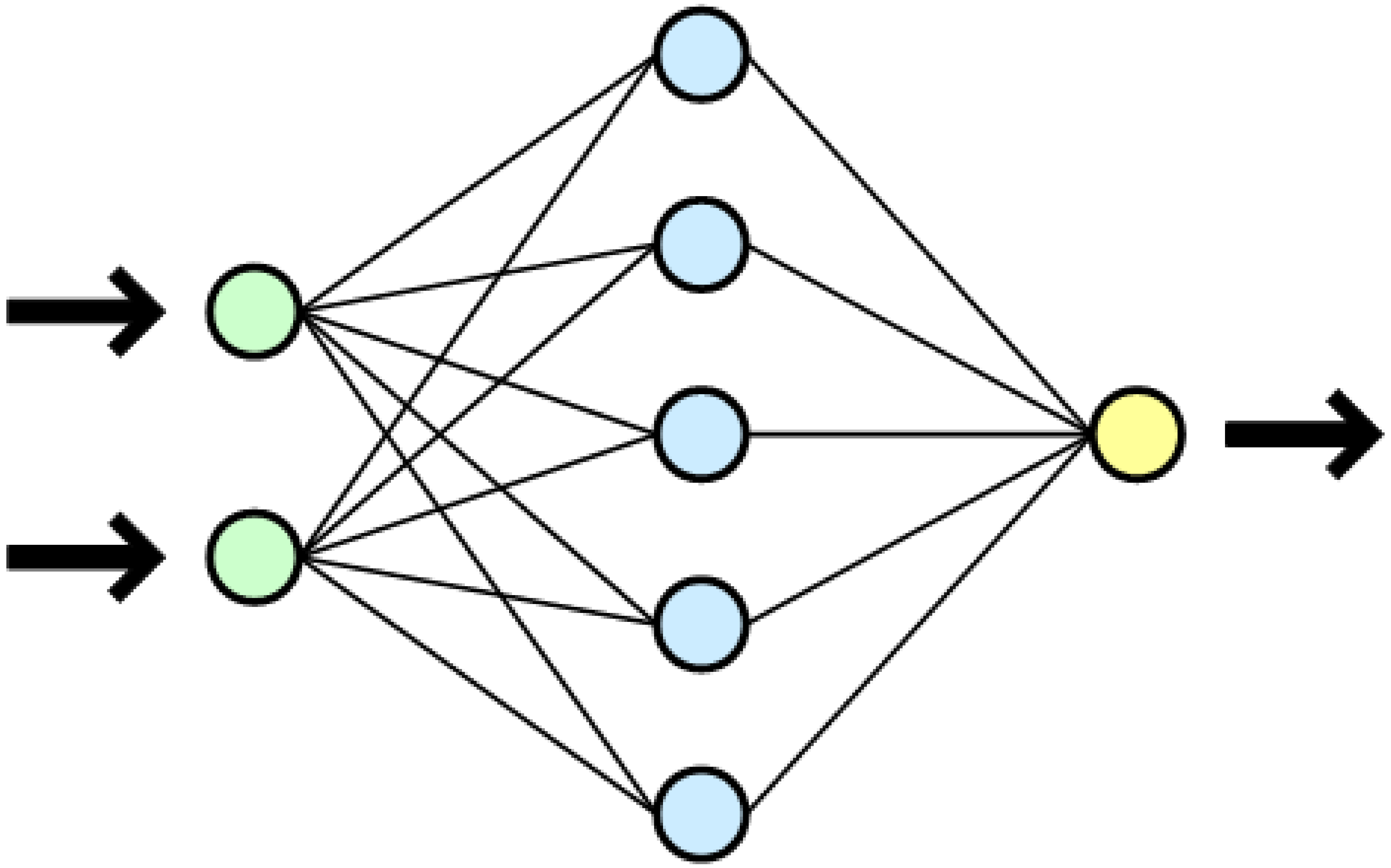
A model of a neuron with a step activation function

The sum of the products of the weights Wi and the inputs Xi is calculated at each node and compared to some **threshold** (usually 0):

- f the net value is above the threshold - the neuron is activated and takes the activated value (usually 1);
- if the net value is below the threshold - the neuron takes the deactivated value (usually -1).



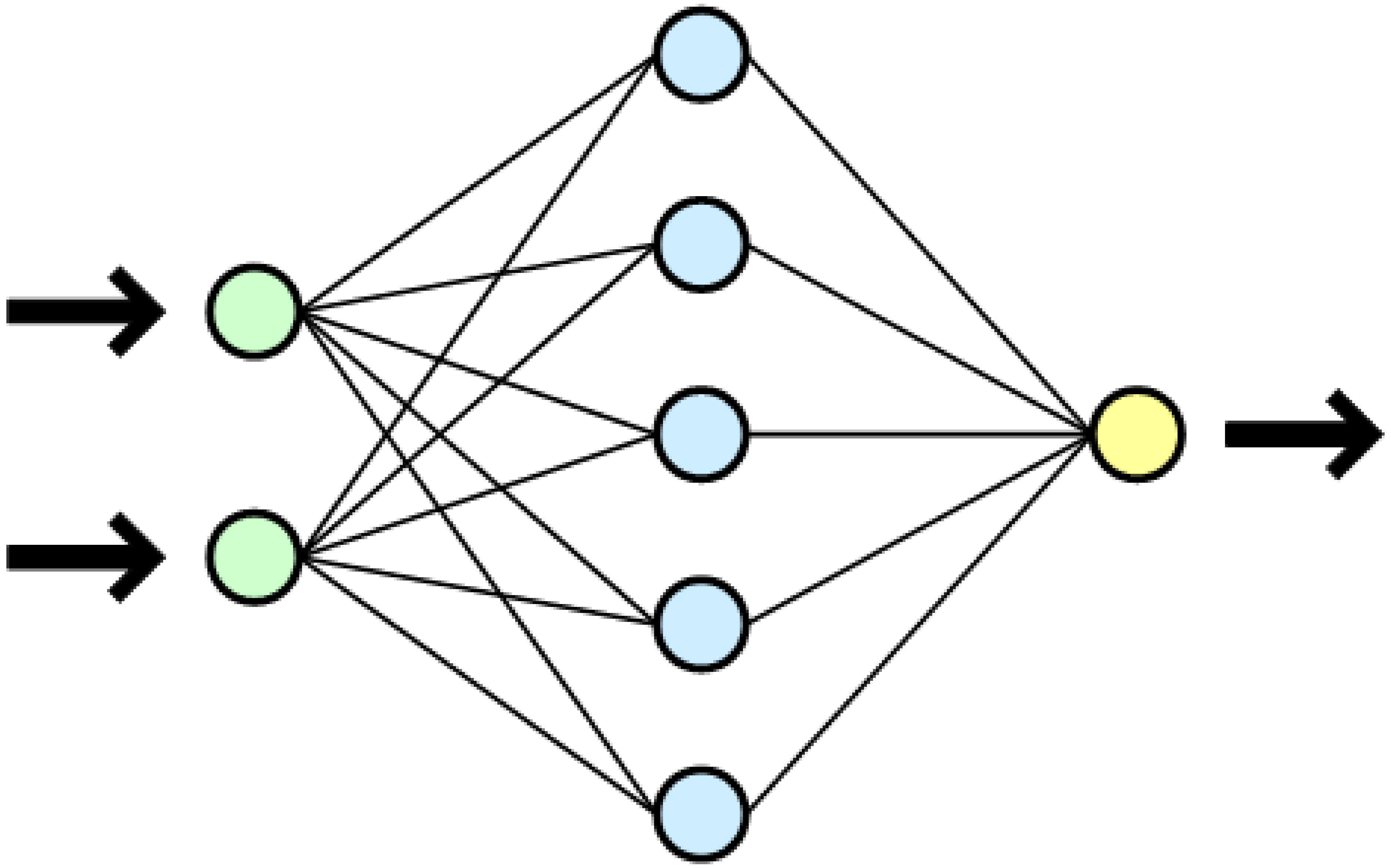
General architecture of NN



NN topology

Most often, NNs are composed of several successive layers of elements:

- **the elements of the lowest layer** play the role of input devices of the network by perceiving signals from the external environment;
- **the elements of the top layer** play the role of output devices of the network by outputting the result of the operation of the network, which is obtained based on the input signals and the weights of the connections between the elements.



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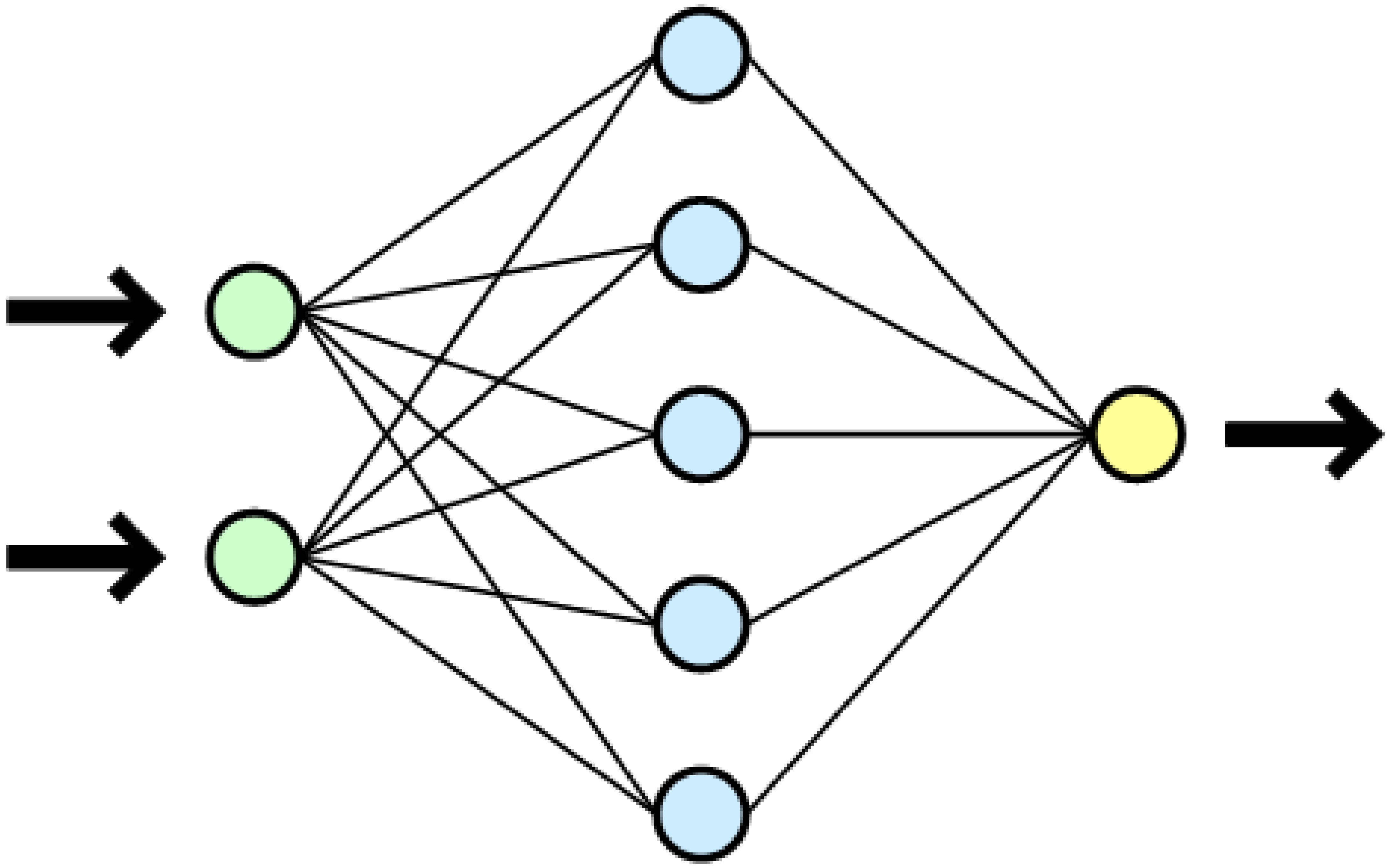
Input layer

Input layer - consists of neurons that receive the input data directly from the dataset.

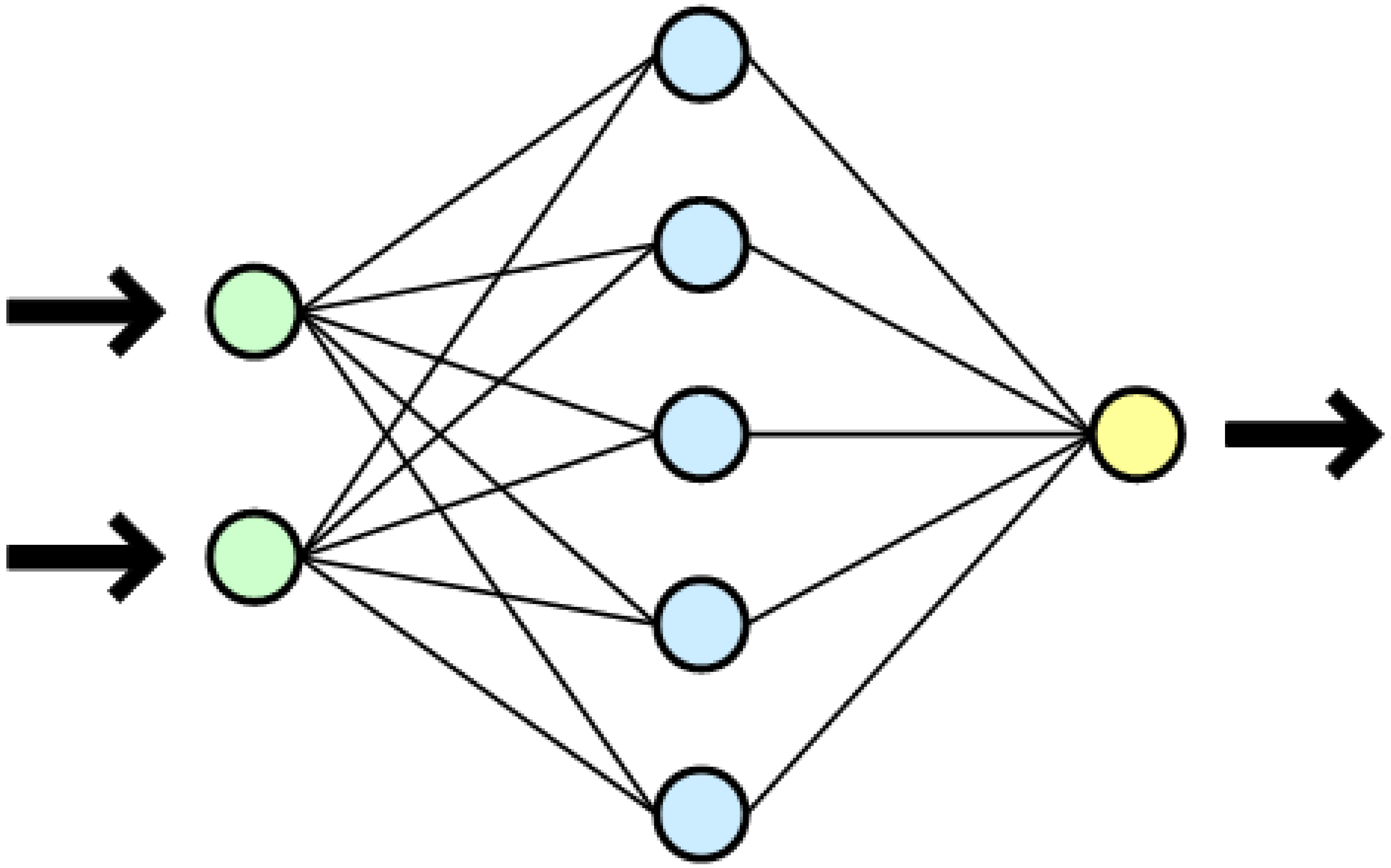
The number of elements of the input layer - is determined by the dimensionality of the input data;

Example: in an image recognition task, the input layer will use as input the pixel values from the given image.



Internal layers

Hidden layers use as input the output data of previous neurons, and their output data is used for input data of subsequent neural layers. The number and sizes of hidden layers are determined iteratively depending on the subject area and the specific task.



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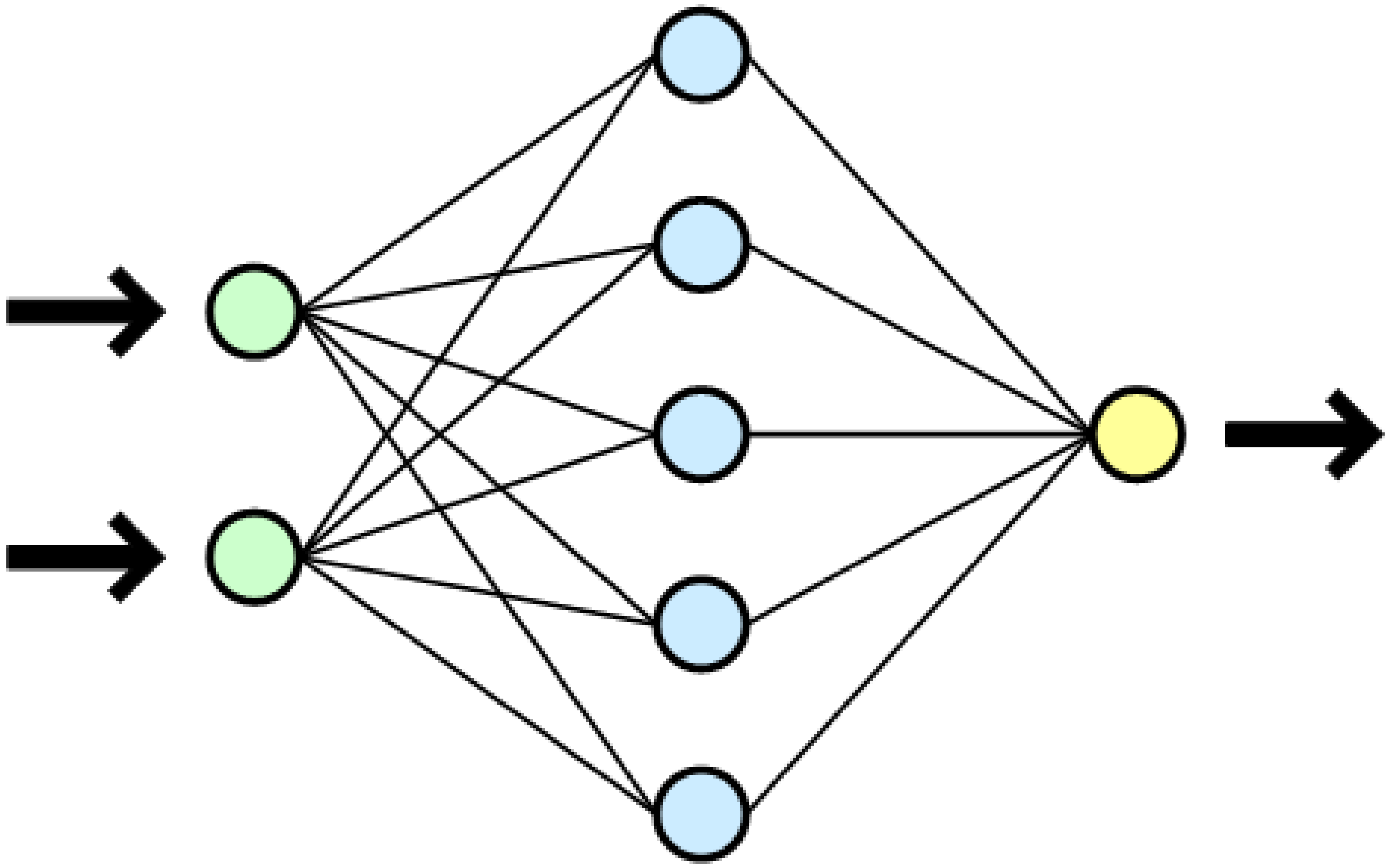
Output layer

The output layer - outputs the output data for the entire network.

The number of elements from the output layer - is determined by the number of recognized classes.



Perceptron

A basic neural model with a stepwise activation function.

One of the earliest models of neural computation.

A classic example of a multilayer network is the so-called a multilayer perceptron based on the error backpropagation algorithm.

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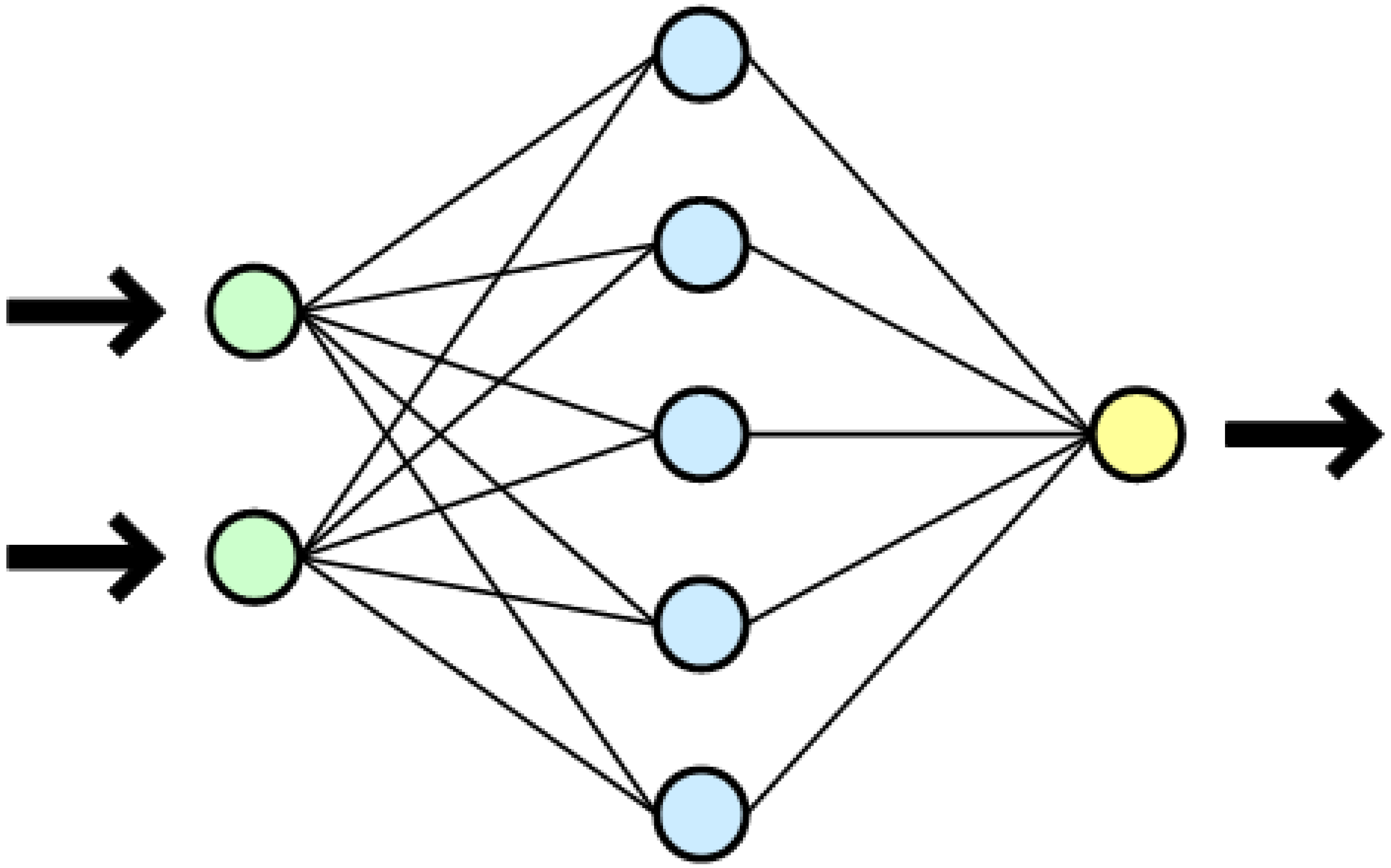
CONTENT 3

NN according to the typology of the network

Depending on the number of layers:

- **single-layer** (sometimes called two-layer) - one input and one output layer, lacking the so-called internal or hidden layers;
- **multi-layered** - has at least one hidden layer:
  - ➢ shallow;
  - ➢ deep.

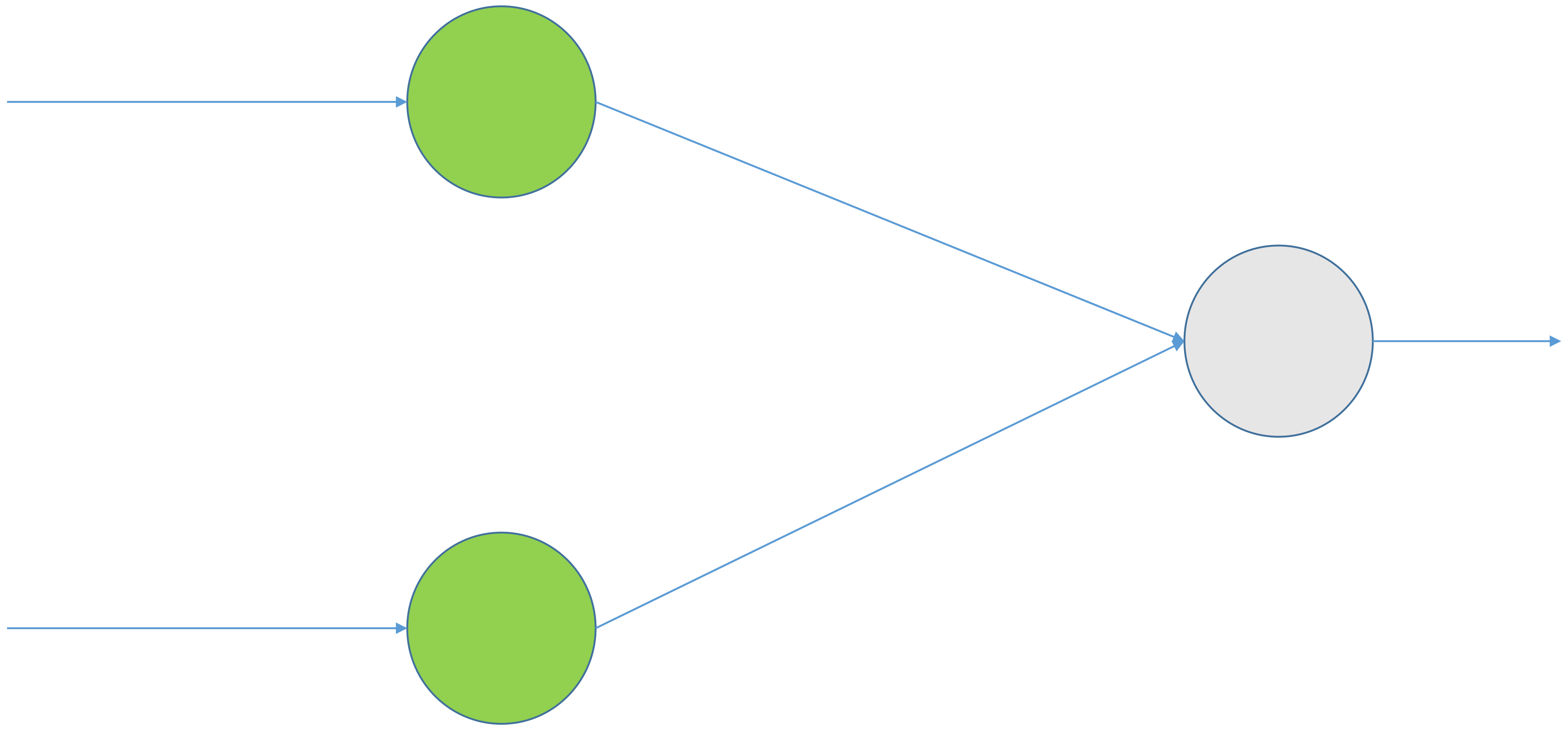


Single-layer NN

The simplest form of single-layer NN is the perceptron.

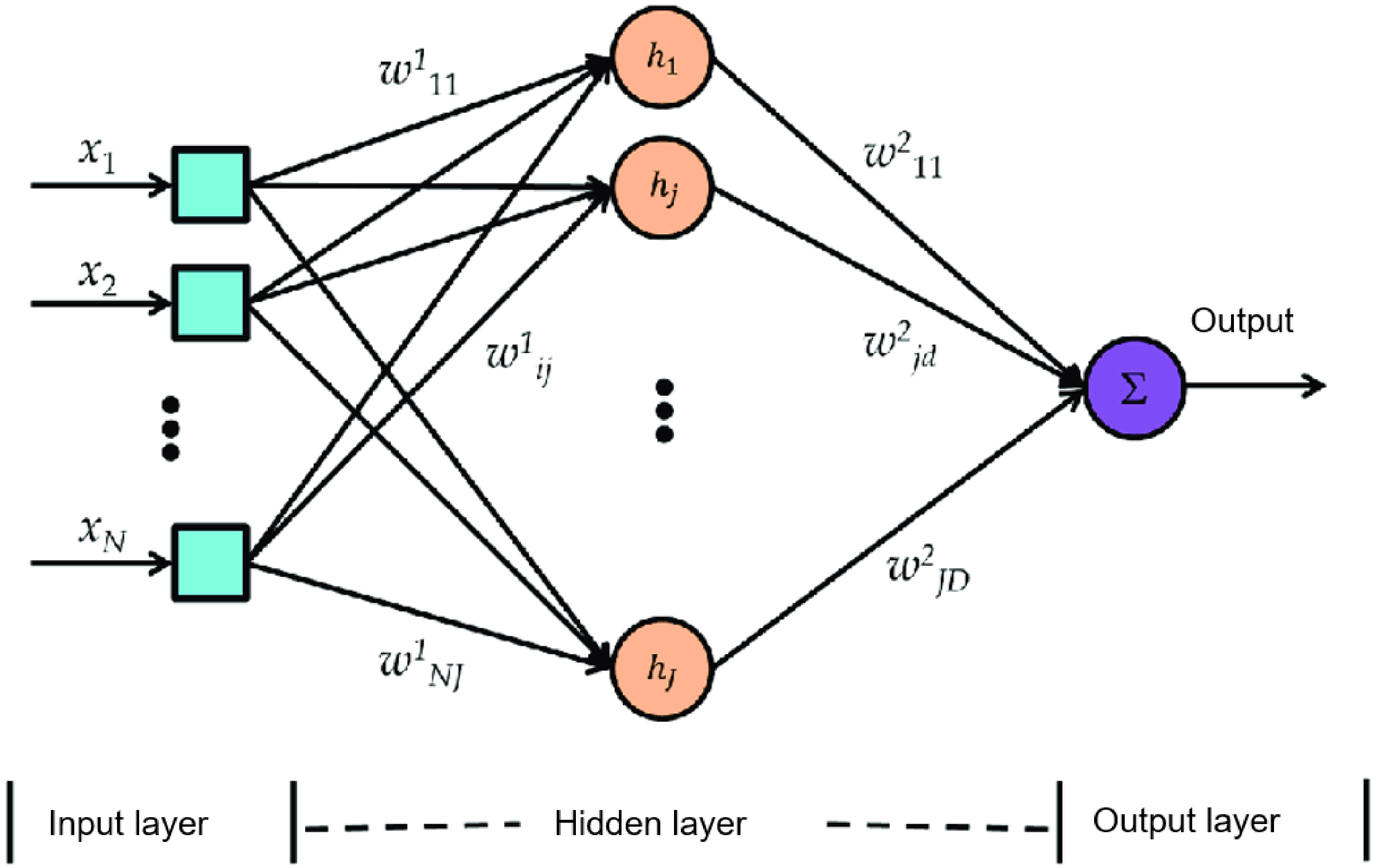
There is only 1 layer of input nodes that send weighted inputs to the next layer of receiving nodes, or in some cases only one.

Information moves in only one direction: through the inputs to the output.



Multi-layer NN

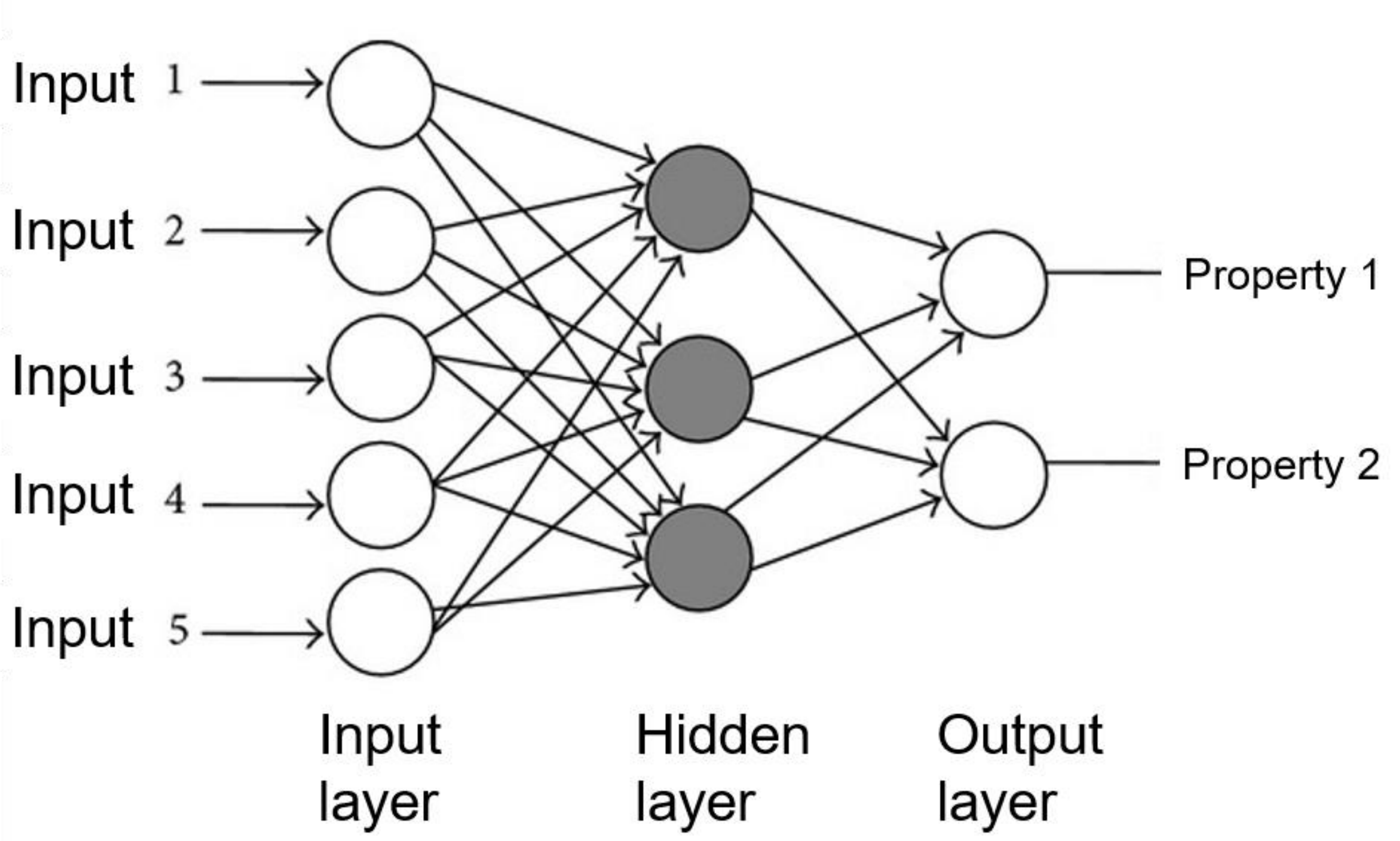
It contains layers of neurons or nodes that vary greatly in design. They usually have at least 1 input layer that sends weighted inputs to a series of hidden layers, and an output layer at the end.



CONTENT 3

Multi-layer NN - example

The network serves to separate the incoming data into 2 groups according to property 1 and 2.



CONTENT 4

NN according to the weights of the connections

According to the type of connection weights, NNs can be divided into:

- **simulative** – with connections with positive weights;
- **suppressive** – with connections with negative weights.

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CONTENT 5

NN according to the direction of the signal

- **straightforward (feedforward)** - connections are one-way and are oriented from the elements of a given layer to the elements of the layer immediately above it;
- **recurrent (feedback)** - each element is connected by two-way connections with all its neighbors. Here the concept of layer largely loses its meaning.

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CONTENT 5

Straightforward NN

It consists of a large number of simple neurons organized in layers. Each unit in a layer is related to some units in the previous layer. Connections are not equal: each connection can have a different weight.

Data enters the inputs and travels through the network, layer by layer, until it reaches the outputs. During normal operation, i.e. when acting as a classifier, there is no feedback between layers.

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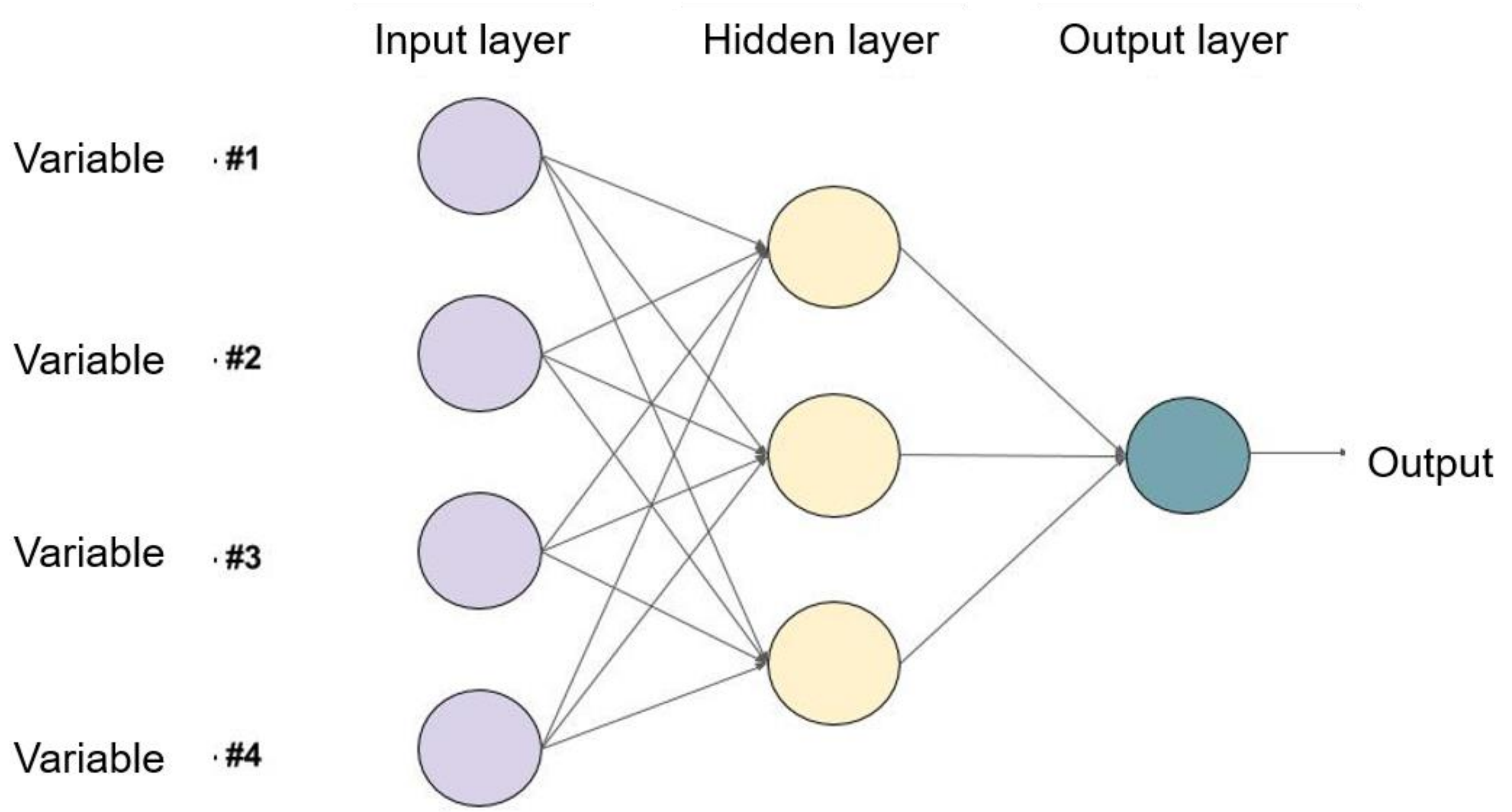
CONTENT 5

Structure of a straightforward network



Example of Feedforward NM with one hidden layer (with 3 neurons).

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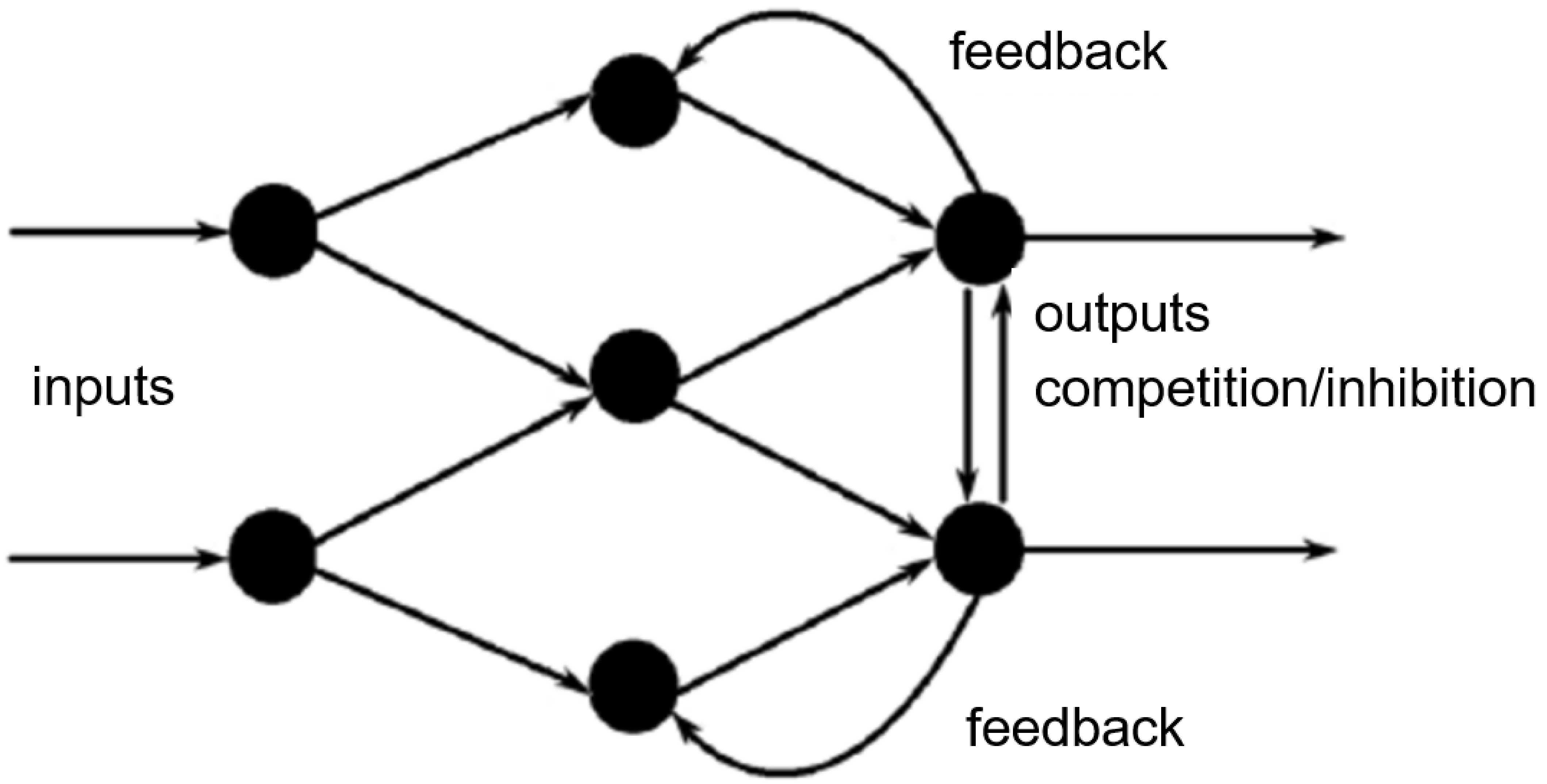
CONTENT 5

Recurrent NN

When NM has some internal recurrence, i.e. signals feed back to some neuron or layer that has already received and processed that signal, the network is of the feedback type. Most of the feedback networks are single layer.



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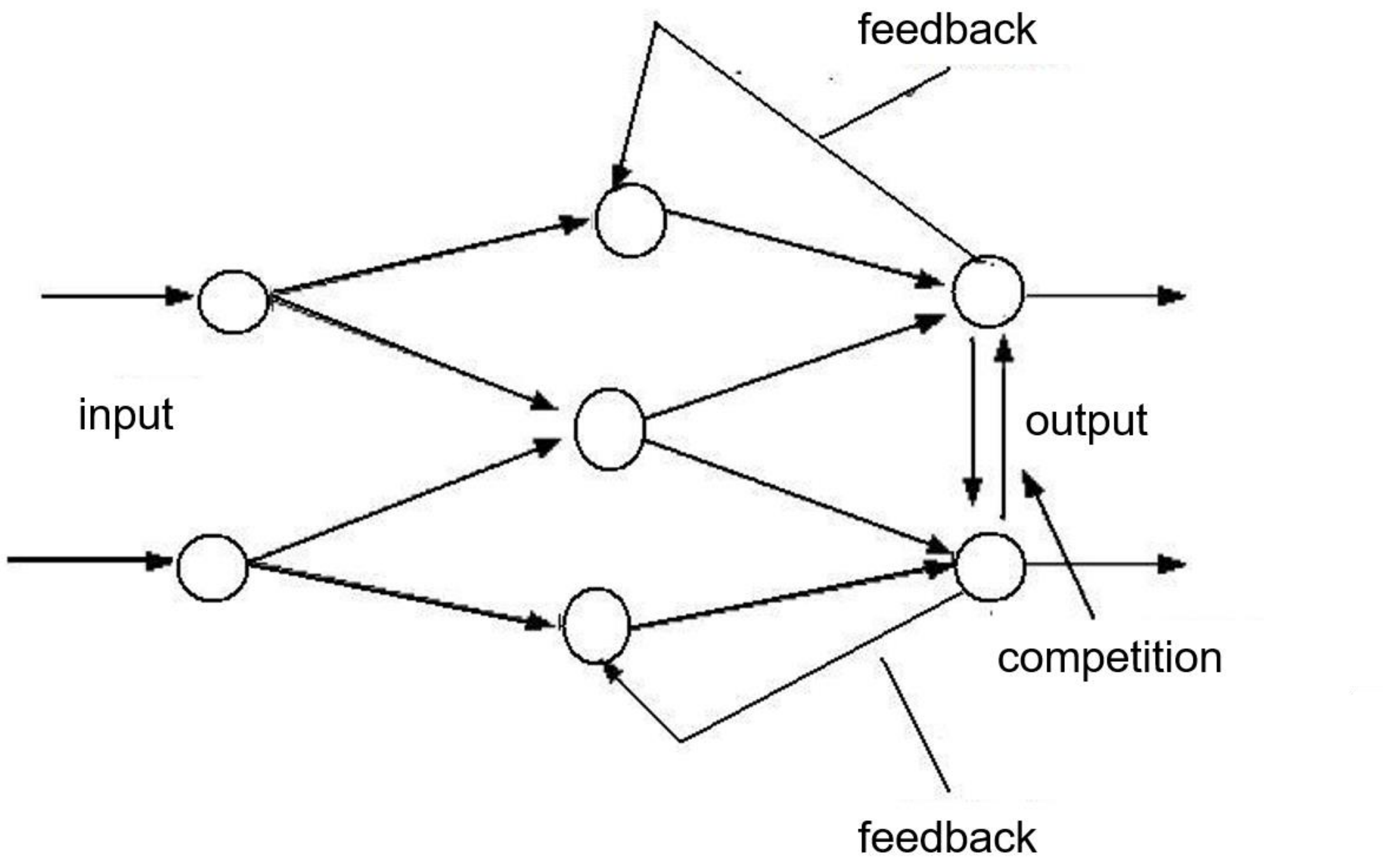
CONTENT 5

Structure of recurrent NN

When NM has some internal recurrence, i.e. signals feed back to some neuron or layer that has already received and processed that signal, the network is of the feedback type. Most of the feedback networks are single layer.



CONTENT 6

NN according to the type of input and output values

The input values of the network, i.e. the signals received by the elements of the input layer, as well as the output values of the network, i.e. the signals that the output layer elements output to the environment can be:

- **binary** - 0 or 1;
- **analog** – real numbers.

In case that the output values of the network must be binary, additional requirements are imposed on the activation function.

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CONTENT 7

Learning stage

One of the most important characteristics of NN is the ability to learn, i.e. adapting the network to better handle a task by considering sample observations.

This is done for better result by minimizing observed errors.

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INTELLIGENT COMPUTER SYSTEMS

Svetlana Stefanova

September, 2022

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LECTURE 11

SHALLOW NEURAL NETWORKS

1. Introduction
2. Hidden layer
3. Mathematical modeling
4. Weights definition

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CONTENT 1

Definition

Under NN we imagine a structure consisting of many layers, including hidden ones. But there is also a type of NN with only a few hidden layers.

Shallow neural networks consist of only 1 hidden layer. Understanding them provides insight into exactly what is happening in a deep neural network.

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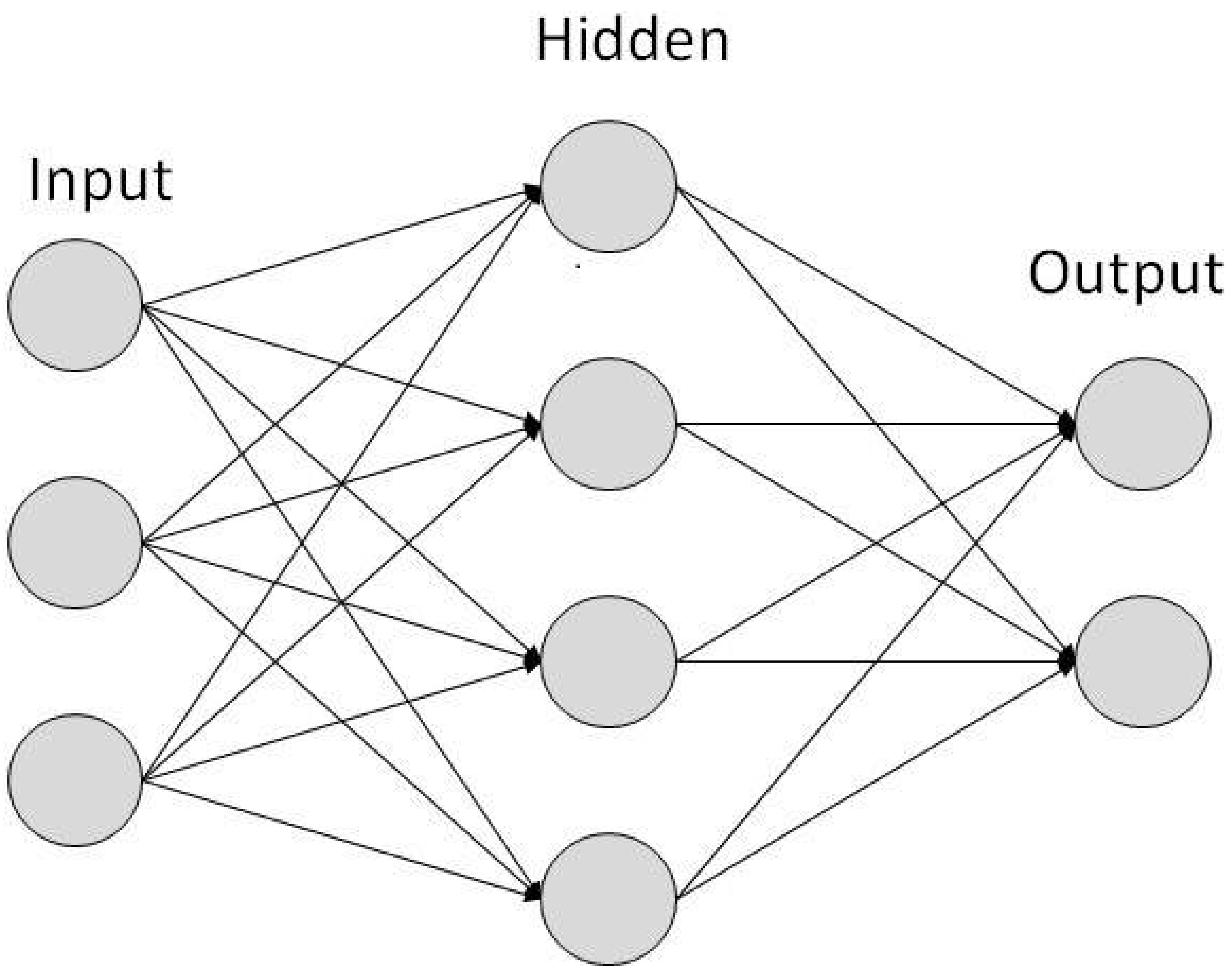
CONTENT 1

Example

Shallow neural network with 1 hidden layer, 1 input layer and 1 output layer.



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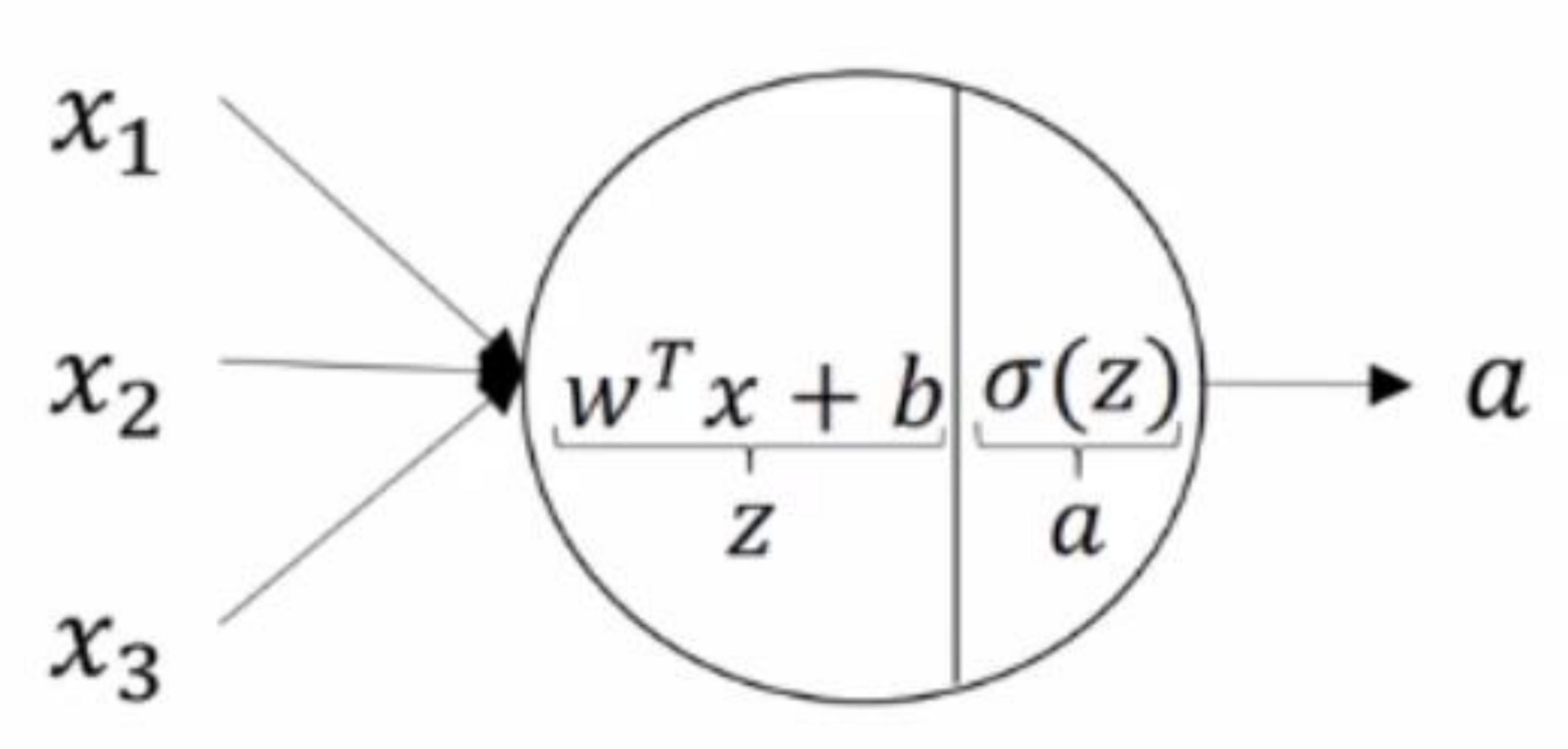
CONTENT 1

Model of a neuron

The neuron is the building block of the NN. Given an input, it provides the output and passes that output as input to the next layer. A neuron can be seen as a combination of 2 parts:

The first part - computes the output **z** by using the inputs and their weights.

The second part - performs the activation of **z** to give the final output **a** of the neuron.



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Hidden layer

The hidden layer consists of different neurons, each of which performs the 2 consecutive calculations.

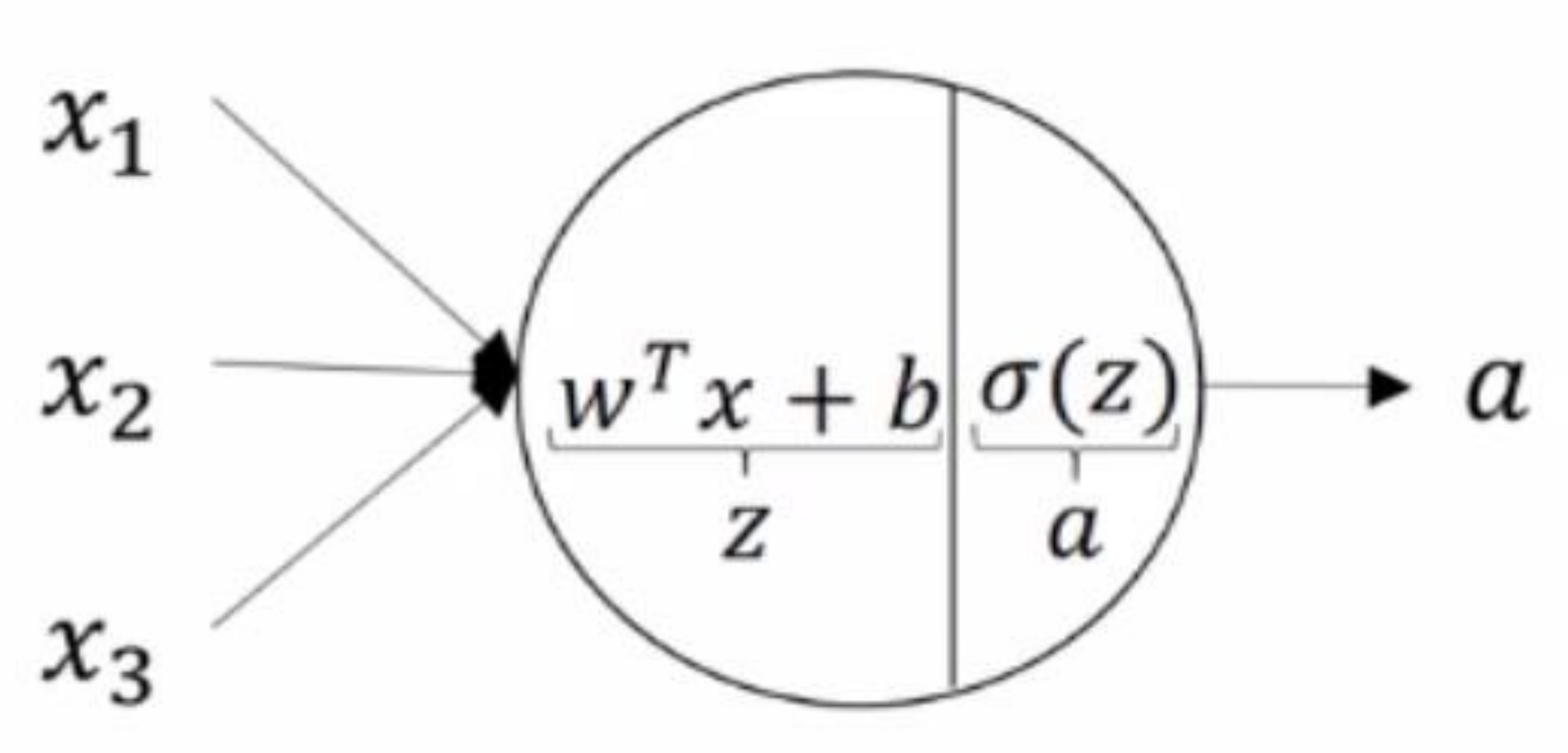
Let's have 4 neurons in the hidden layer of our shallow NN computing the following:

$$z_1^{[1]} = w_1^{[1]T}x + b_1^{[1]}, a_1^{[1]} = \sigma\left(z_1^{[1]}\right)$$

$$z_2^{[1]} = w_2^{[1]T}x + b_2^{[1]}, a_2^{[1]} = \sigma\left(z_2^{[1]}\right)$$

$$z_3^{[1]} = w_3^{[1]T}x + b_3^{[1]}, a_3^{[1]} = \sigma\left(z_3^{[1]}\right)$$

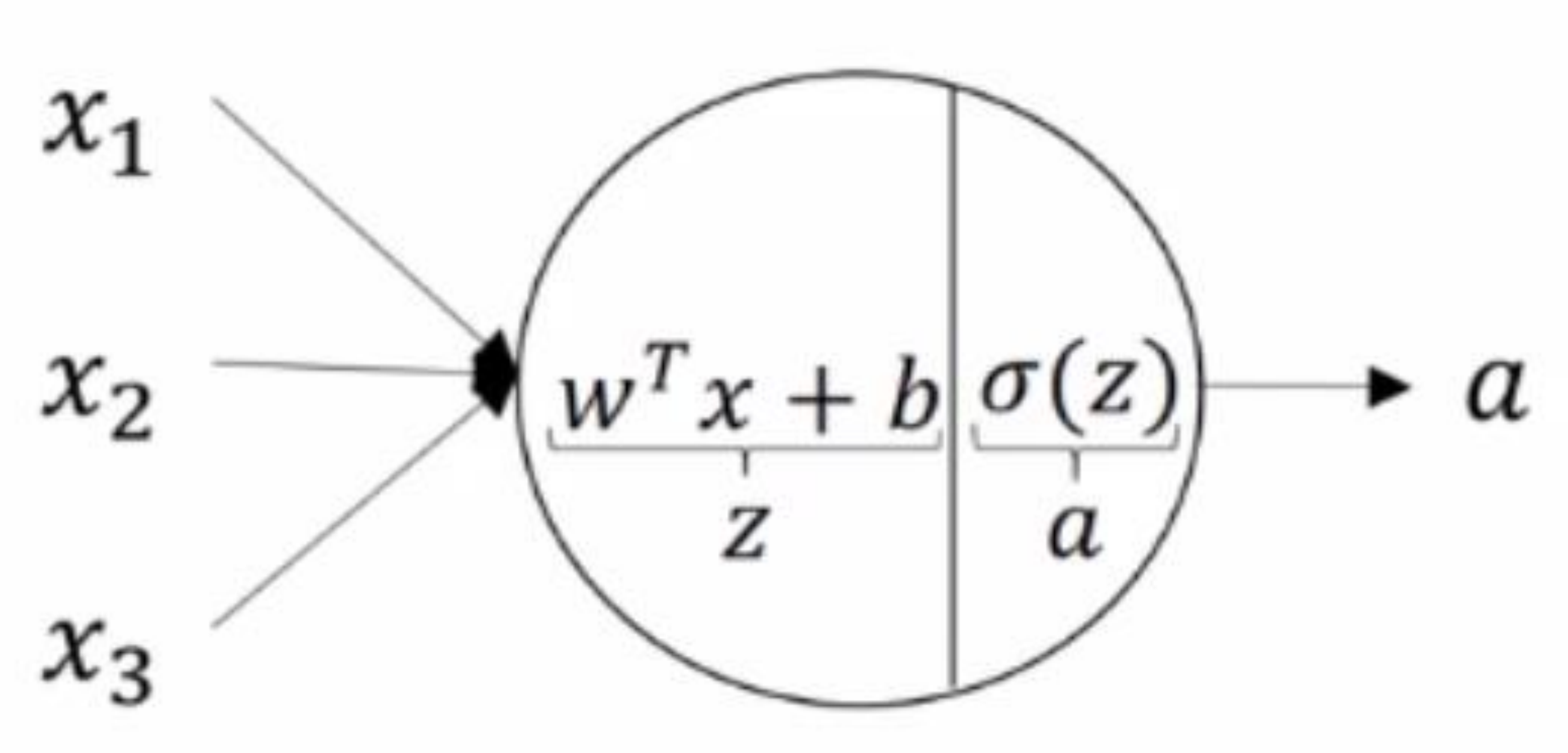
$$z_4^{[1]} = w_4^{[1]T}x + b_4^{[1]}, a_4^{[1]} = \sigma\left(z_4^{[1]}\right)$$



Hidden layer

In the above equations,

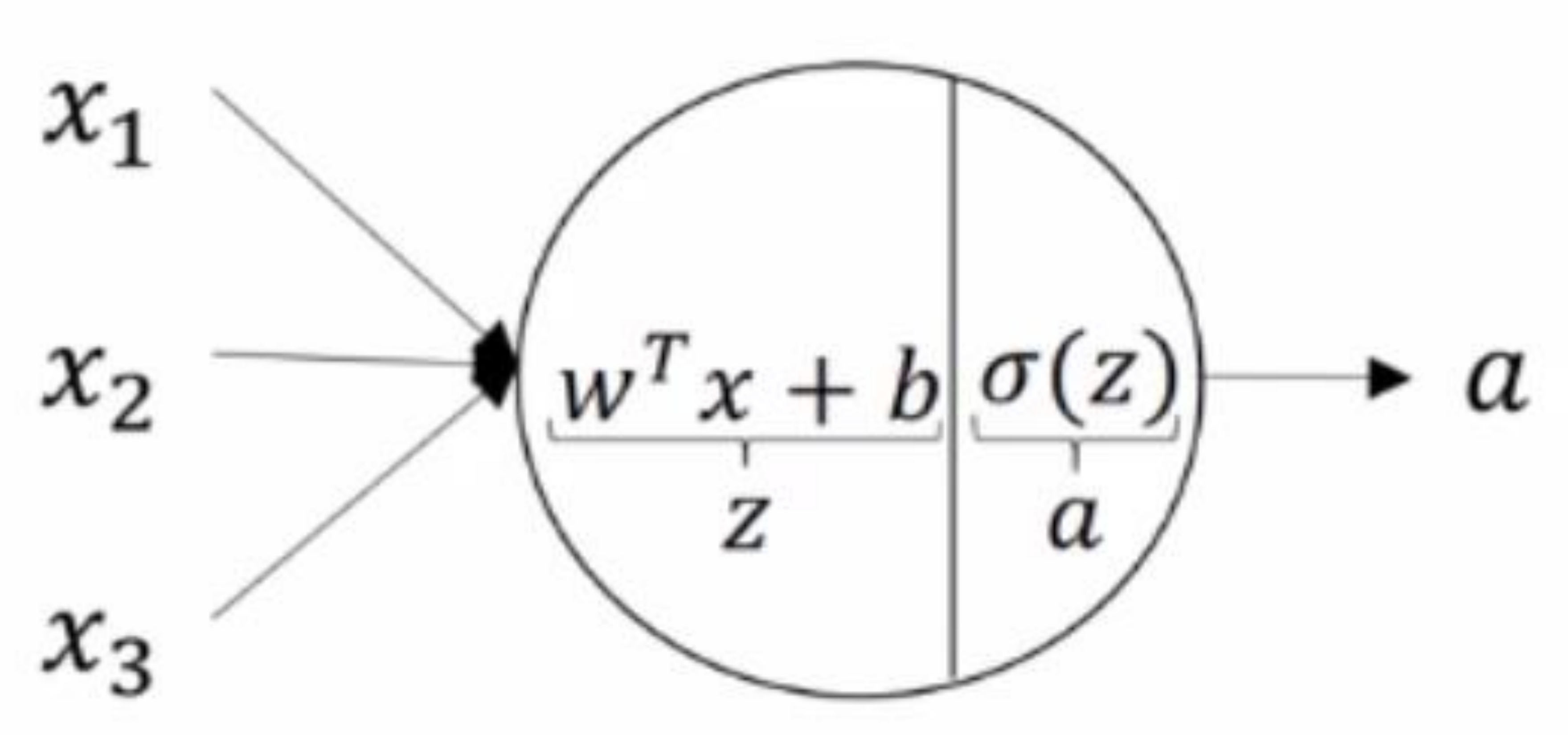
- the above index $^{[i]}$ denotes the layer number, and the index number $_j$ denotes the neuron number in a particular layer.
- ***X*** is the input vector consisting of 3 features.
- $W^{[i]}_j$ is the weight associated with neuron ***j***, present in layer ***i***.
- $b^{[i]}_j$ is the bias associated with neuron ***j***, present in layer ***i***



Hidden layer

- $Z^{[i]}_{j}$ is the intermediate output associated with neuron ***j***, present in layer ***i***.
- $a^{[i]}_{j}$ is the final output associated with neuron ***j***, present in layer ***i***.
- σ is the activation function (e.g. sigmoid). Mathematically it is defined as:

$$\sigma(x) = \frac{1}{1 + e^{-x}}$$



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Hidden layer

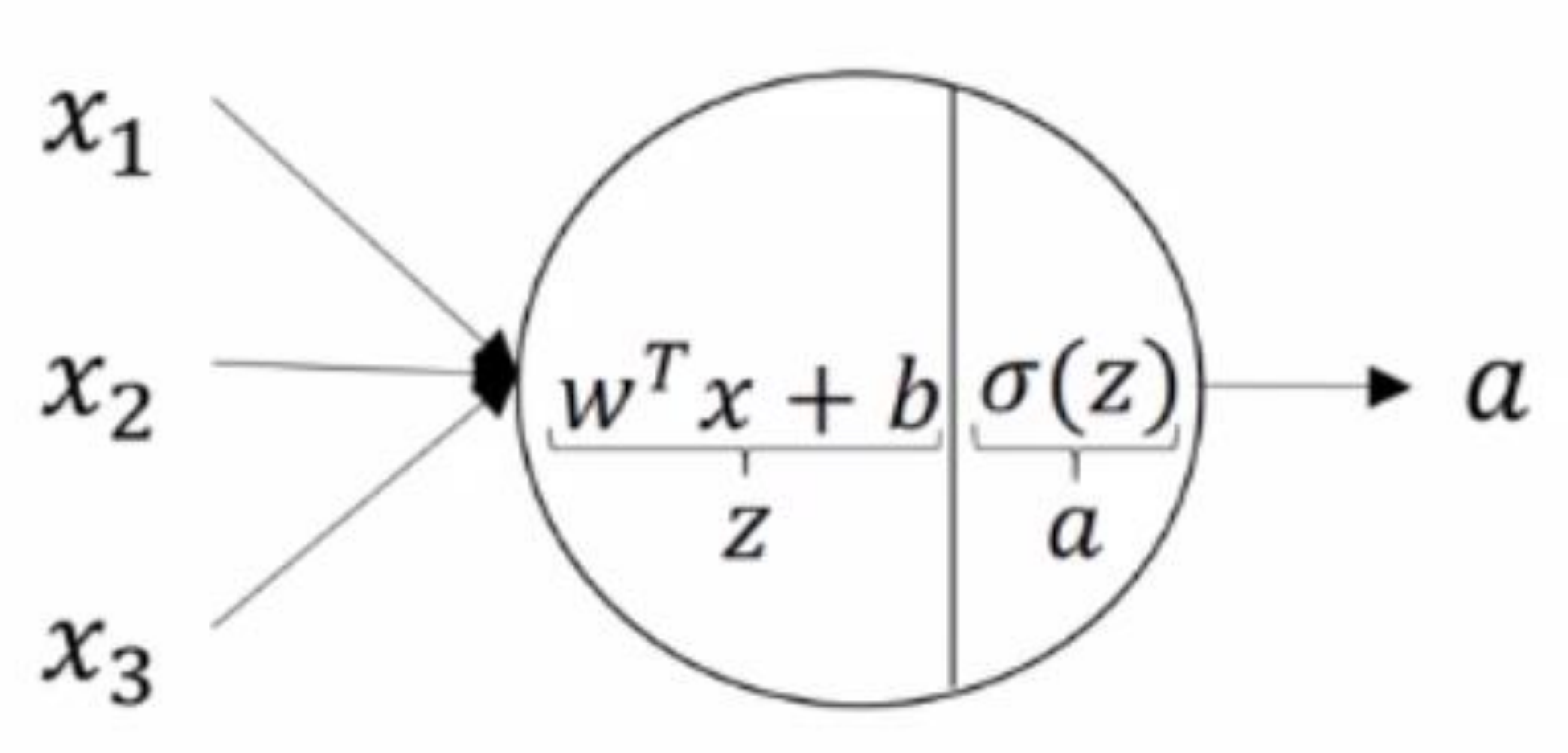
We can vectorize the equations:

The first equation calculates all intermediate outputs ***Z*** in a single matrix multiplication.

The second equation calculates all activations ***A*** in a single matrix multiplication.

$$Z^{[1]} = W^{[1]T} X + b^{[1]}$$

$$A^{[1]} = \sigma\left(Z^{[1]}\right)$$



CONTENT 3

Forward propagation equations

- The 1st equation calculates the intermediate output $Z^{[1]}$ of the first hidden layer.
- The 2nd equation calculates the final output $A^{[1]}$ of the first hidden layer.
- The 3rd equation calculates the intermediate output $Z^{[2]}$ of the output layer.
- The 4th equation calculates the final output $A^{[2]}$ of the output layer, which is also the final output of the entire neural network.

$$Z^{[1]} = W^{[1]T} X + b^{[1]}$$

$$A^{[1]} = \sigma\left(Z^{[1]}\right)$$

$$Z^{[2]} = W^{[2]T} A^{[1]} + b^{[2]}$$

$$\hat{y} = A^{[2]} = \sigma\left(Z^{[2]}\right)$$

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CONTENT 3

Activation function

NN is mainly a set of mathematical equations and weights. To make it stable so that it performs well in different scenarios, we use activation functions. They introduce non-linear properties into the NN.

Let's try to understand why activation functions are crucial for any NN using the shallow neural network.

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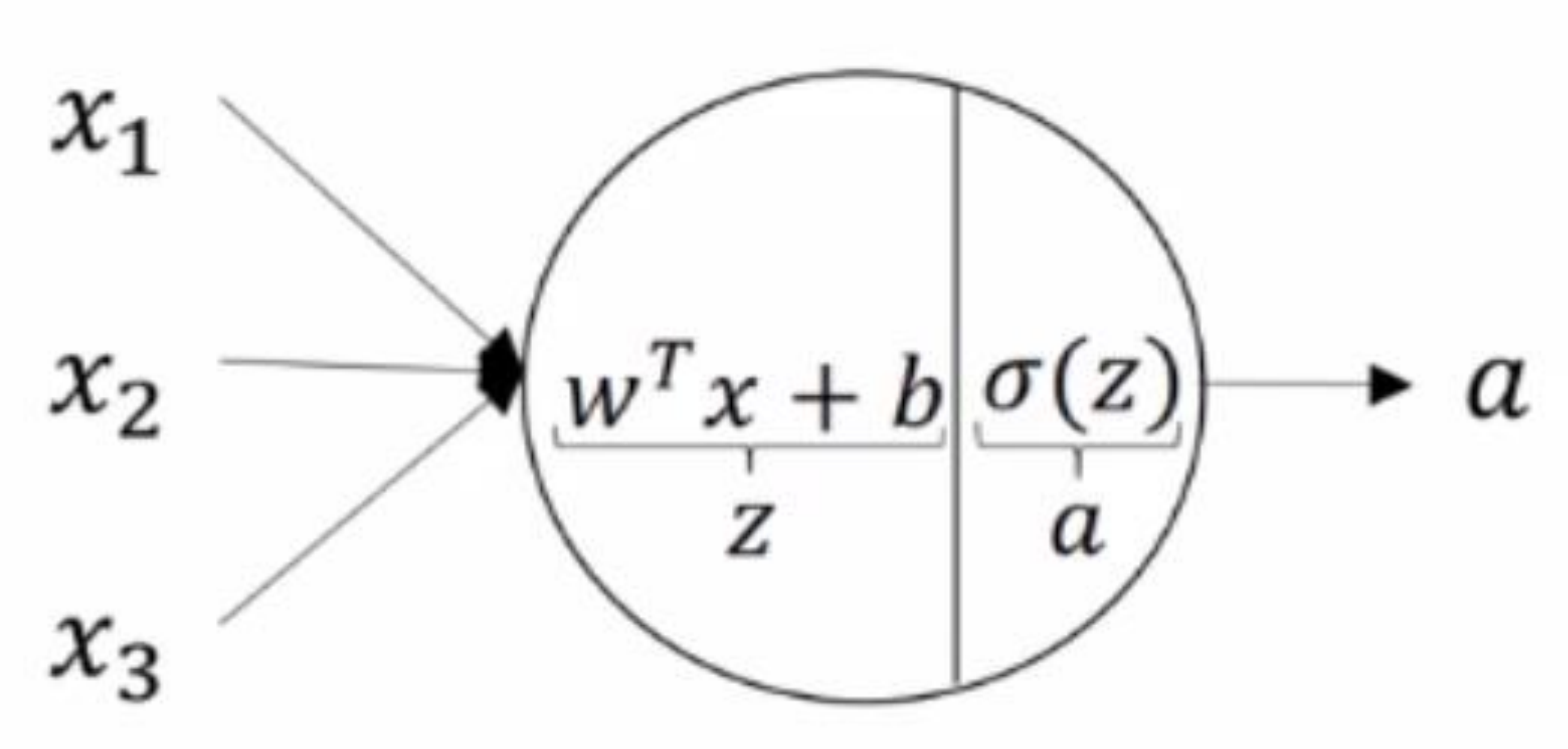
CONTENT 3

Activation function

Without the activation functions, our shallow neural network can be represented:



$$Z^{[1]} = W^{[1]T} X + b^{[1]}$$

$$\hat{y} = Z^{[2]} = W^{[2]T} Z^{[1]} + b^{[2]}$$

CONTENT 3

Activation function

If we substitute the value of $Z^{[1]}$ from equation 1 into equation 2, we get the following:

$$Z^{[1]} = W^{[1]T}X + b^{[1]}$$
$$\hat{y} = Z^{[2]} = W^{[2]T}W^{[1]T}X + W^{[2]T}b^{[1]} + b^{[2]}$$
$$\hat{y} = Z^{[2]} = W_{new}X + b_{new}$$

CONTENT 3

Activation function

As we can see, the output will become a linear combination of a new weight matrix ***W***, with an input ***X*** and new bias ***b***, which means that the neurons present in the hidden layer and their weights remain irrelevant.

Therefore:

- to introduce non-linearity into the network we need to use the activation functions;
- it is not necessary to use one activation function for all layers.

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CONTENT 4

Initialization of weights

The weight matrix ***W*** of NN is initialized **randomly**.

Why it cannot be initialized to 0 or some specific value? – let us figure this out using the shallow neural network.

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CONTENT 4

Initialization of weights

Let

W^1 - the matrix of weights of layer 1 and

W^2 - the matrix of weights of layer 2

are initialized to 0 or some other value.

If the weight matrices are the same - the activation of neurons in the hidden layer will be the same. Also, the derivatives of the activations would be the same. Therefore, the neurons in the hidden layer will modify the weights in a similar way, i.e. it will not matter if there is more than 1 neuron in one hidden layer.

We do not want that - we want each neuron in the hidden layer to be unique, have a different weight, and work as a unique function. So we initialize the weights randomly.

Xavier’s method

The best initialization method is Javier's method. Mathematically, it is defined as:

$$W^{[l]} \sim \mathcal{N}\left(\mu = 0, \sigma^2 = \frac{1}{n^{[l-1]}}\right)$$

$$b^{[l]} = 0$$

It states that the weight matrix ***W*** of a particular layer ***l*** is randomly selected from a normal distribution with value ***μ = 0*** and variance ***σ² = the multiplicative inverse of the number of neurons in layer l − 1***.

The bias ***b*** of all layers is initialized with **0**.

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Gradient descent

We already know that the neural network weights are initialized randomly.

To use the neural network for correct predictions, we need to update these weights.

The method by which we update the weights is known as **gradient descent**.

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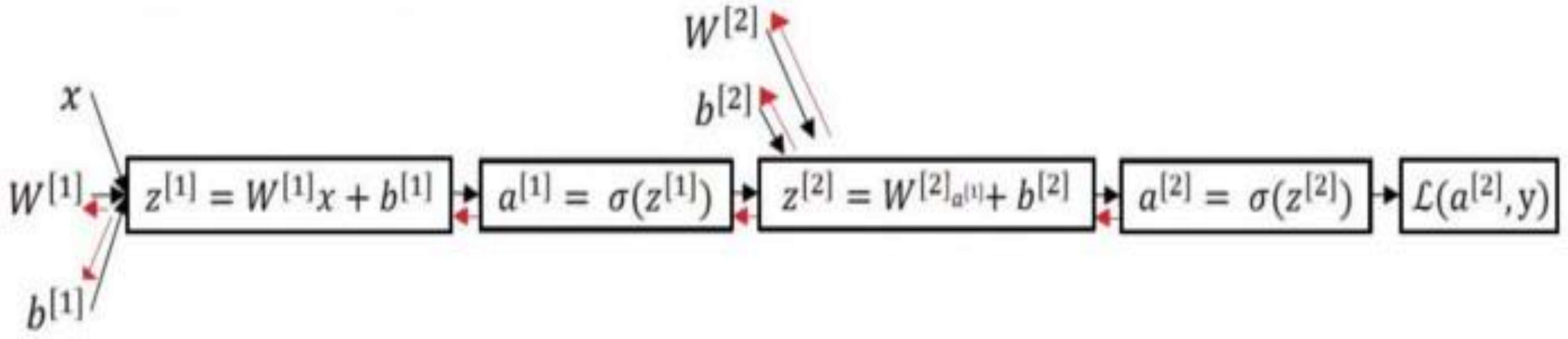
CONTENT 4

Gradient descent

- **Forward propagation** (the **black** lines) - used to calculate the output for a given input ***X***.
- **Backward propagation** (the red lines) - used to update the weight matrices $W^{[1]}$, $W^{[2]}$ and biases $b^{[1]}$, $b^{[2]}$. It is done by calculating derivatives of the inputs at each step.



CONTENT 4

Result error

The error ***L*** is defined mathematically:

$$L\left(\hat{y}, y\right) = -\left[y \log \hat{y} + (1-y) \log\left(1-\hat{y}\right)\right]$$

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CONTENT 4

Backward propagation

Using the error equation ***L*** and a sigmoid activation function of the hidden and output layers, using a chain rule of derivatives, we calculate:

$$dA^{[2]} = \frac{\delta L\left(A^{[2]}, Y\right)}{\delta A^{[2]}} = \frac{-Y}{A^{[2]}} + \frac{1-Y}{1-A^{[2]}}$$

$$dZ^{[2]} = \frac{\delta L\left(A^{[2]}, y\right)}{\delta Z^{[2]}} = \frac{\delta L\left(A^{[2]}, y\right)}{\delta A^{[2]}} * \frac{\delta A^{[2]}}{\delta Z^{[2]}} = A^{[2]} - Y$$

$$dW^{[2]} = \frac{\delta L\left(A^{[2]}, y\right)}{\delta W^{[2]}} = \frac{\delta L\left(A^{[2]}, y\right)}{\delta Z^{[2]}} * \frac{\delta Z^{[2]}}{\delta W^{[2]}} = dZ^{[2]} A^{[1]T}$$

$$db^{[2]} = \frac{\delta L\left(A^{[2]}, y\right)}{\delta b^{[2]}} = \frac{\delta L\left(A^{[2]}, y\right)}{\delta Z^{[2]}} * \frac{\delta Z^{[2]}}{\delta b^{[2]}} = dZ^{[2]}$$

$$dA^{[1]} = \frac{\delta L\left(A^{[2]}, Y\right)}{\delta A^{[1]}} = \frac{\delta L\left(A^{[2]}, Y\right)}{\delta Z^{[2]}} * \frac{\delta Z^{[2]}}{\delta A^{[1]}} = dZ^{[2]} W^{[2]}$$

$$dZ^{[1]} = \frac{\delta L\left(A^{[2]}, y\right)}{\delta Z^{[1]}} = \frac{\delta L\left(A^{[2]}, y\right)}{\delta A^{[1]}} * \frac{\delta A^{[1]}}{\delta Z^{[1]}} = W^{[2]T} dZ^{[2]} * \sigma'\left(Z^{[1]}\right)$$

$$dW^{[1]} = \frac{\delta L\left(A^{[2]}, y\right)}{\delta W^{[1]}} = \frac{\delta L\left(A^{[2]}, y\right)}{\delta Z^{[1]}} * \frac{\delta Z^{[1]}}{\delta W^{[1]}} = dZ^{[1]} X^{T}$$

$$db^{[1]} = \frac{\delta L\left(A^{[2]}, y\right)}{\delta b^{[1]}} = \frac{\delta L\left(A^{[2]}, y\right)}{\delta Z^{[1]}} * \frac{\delta Z^{[1]}}{\delta b^{[1]}} = dZ^{[1]}$$

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INTELLIGENT COMPUTER SYSTEMS

Svetlana Stefanova

September, 2022

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LECTURE 12

DEEP NEURAL NETWORKS

1. Introduction
2. Types of deep neural networks

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CONTENT 1

Definition

Deep NN (Deep-Learning) differ from the more common shallow NN by the number of layers through which the data passes in a multi-level pattern recognition process.

With more than 3 layers (including input and output) networks qualify as "**deep**". A term that means more than 1 hidden layer.

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CONTENT 1

Feature hierarchy

In deep learning networks, each layer of nodes is trained on a separate set of features based on the output of the previous layer.

The further one progresses in the NN, the more complex the features that the nodes can recognize are, as they merge and combine features from the previous layer.

This is known as a **feature hierarchy** (a hierarchy of increasing complexity and abstraction). This makes deep networks capable of handling large arrays with billions of parameters that pass through non-linear functions.

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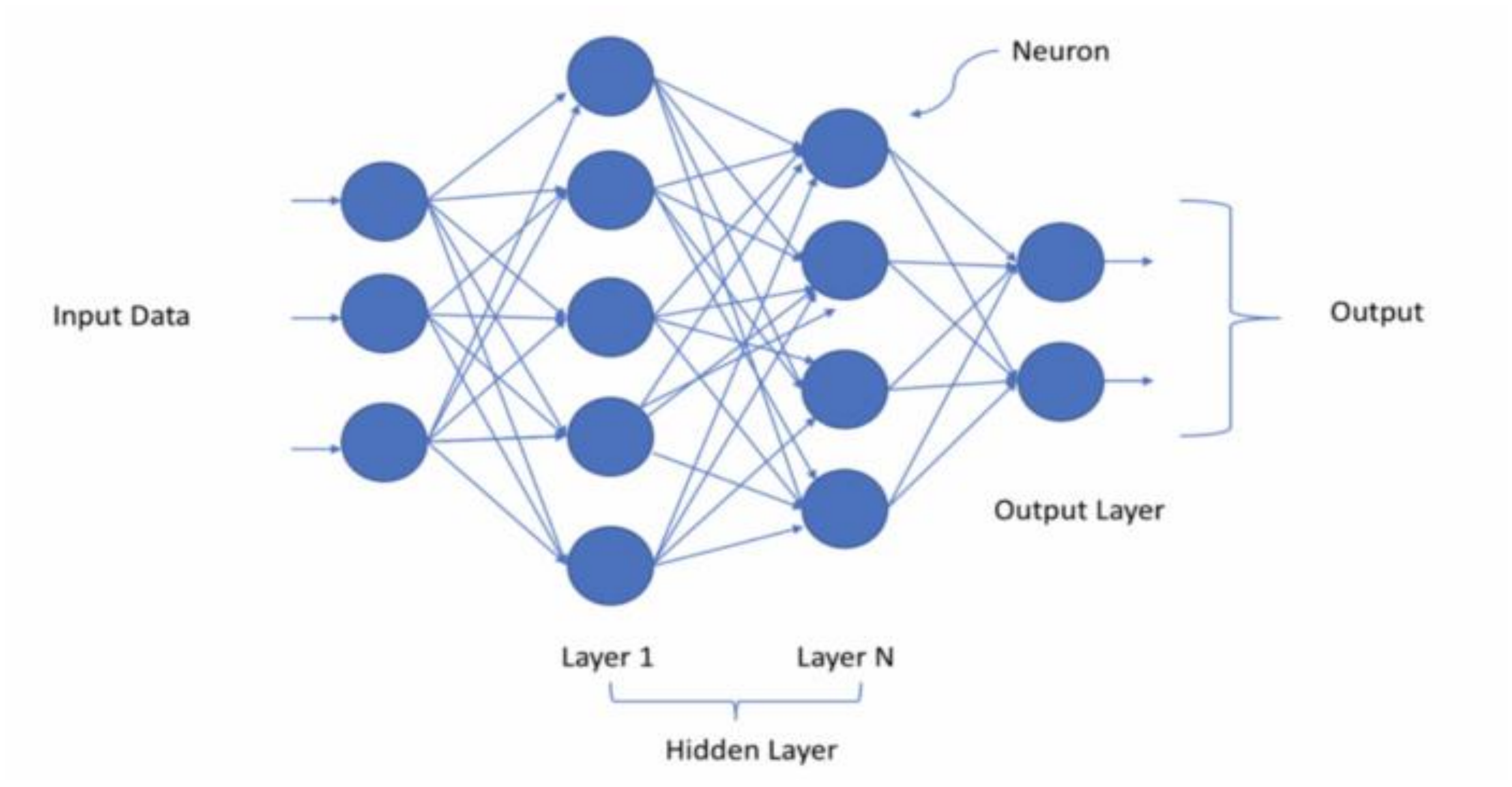
CONTENT 1

Deep NN architecture



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CONTENT 1

Deep NN function

Although deep learning algorithms are self-learning, they depend on the structure of the NN.

- During the multilevel training process, the algorithms use:
- unknown elements in the input distribution for feature extraction;
- object grouping;
- discovering useful data patterns.

Although no network is considered perfect, some algorithms are better suited for specific tasks. In order to choose the right ones, at least the main ones should be well known.

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Types of deep NN

- Convolutional **Neural Networks** (CNNs);
- Recurrent **Neural Networks** (RNNs);
- Long Short-Term **Memory** Networks (LSTMs);
- Generative Adversarial Networks (GANs);
- Multilayer Perceptrons (MLPs);
- Radial Basis Function Networks (RBFNs);
- Self Organizing Maps (SOMs);
- Deep Belief Networks (DBNs).

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Convolutional Neural Networks, CNN

They consist of multiple layers and are mainly used for **image processing and object detection**.

In 1988 Yann LeCun developed the first CNN called **LeNet** for character recognition such as zip codes and numbers.

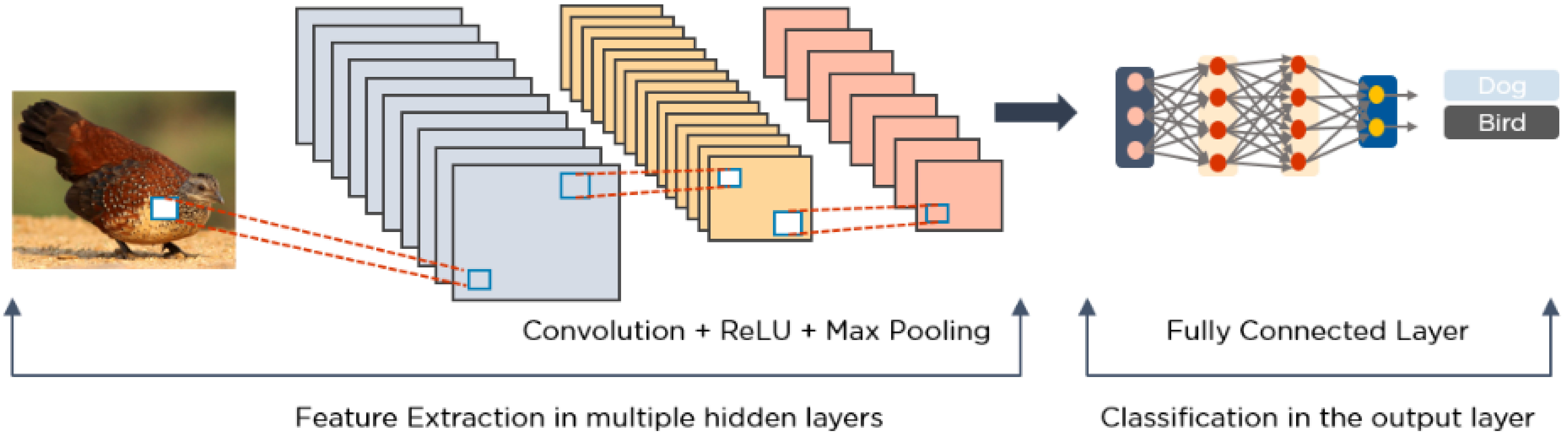
CNN are used for:

- identification of satellite images;
- medical image processing;
- anomaly detection;
- time series forecasting (a sequence of data measured usually at successive points in time) - for the prediction of future values based on previous observed values.

CNN layers

- **Convolutional layer** - there are several filters for performing the convolution operation (in mathematics, convolution is a bias function);
- **Rectified Linear Unit** (ReLU) - a layer for performing operations on elements in order to correct the feature map.
- **Pooling Layer** - reduces the dimensions of the feature map and transforms the resulting 2D arrays of the pooled feature map into a long, continuous, linear vector by flattening it.
- **Fully connected layer** – the linear vector is fed as input which classifies and identifies the images.

Example of an image, processed through CNN



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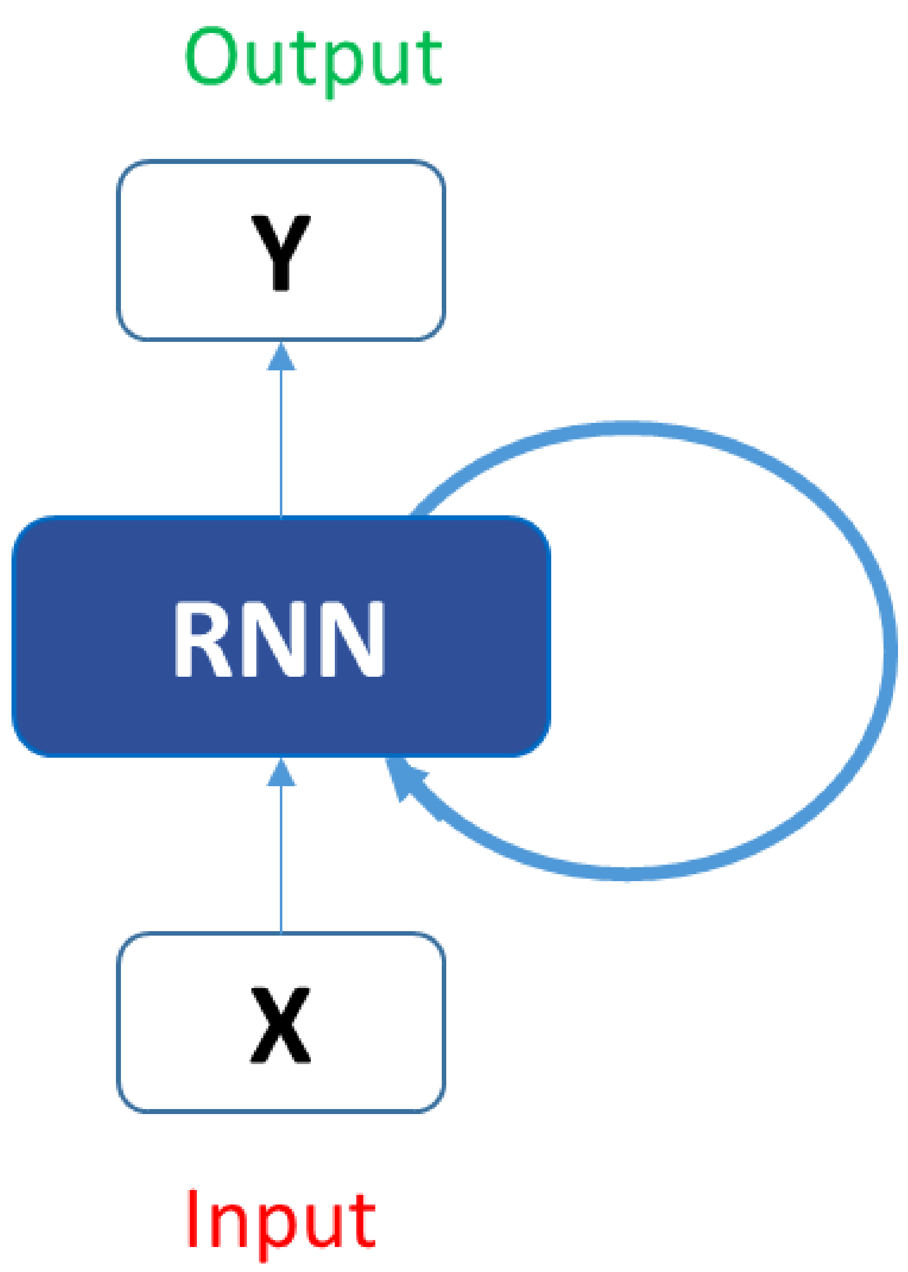
Recurrent NN, RNN

RNNs have connections that form directed loops that allow outputs to be fed as inputs to the current phase. The output becomes the input for the current phase and can remember previous inputs due to its internal memory.

Application:

- image captioning;
- time series analysis;
- natural language processing;
- handwriting recognition;
- machine translation.



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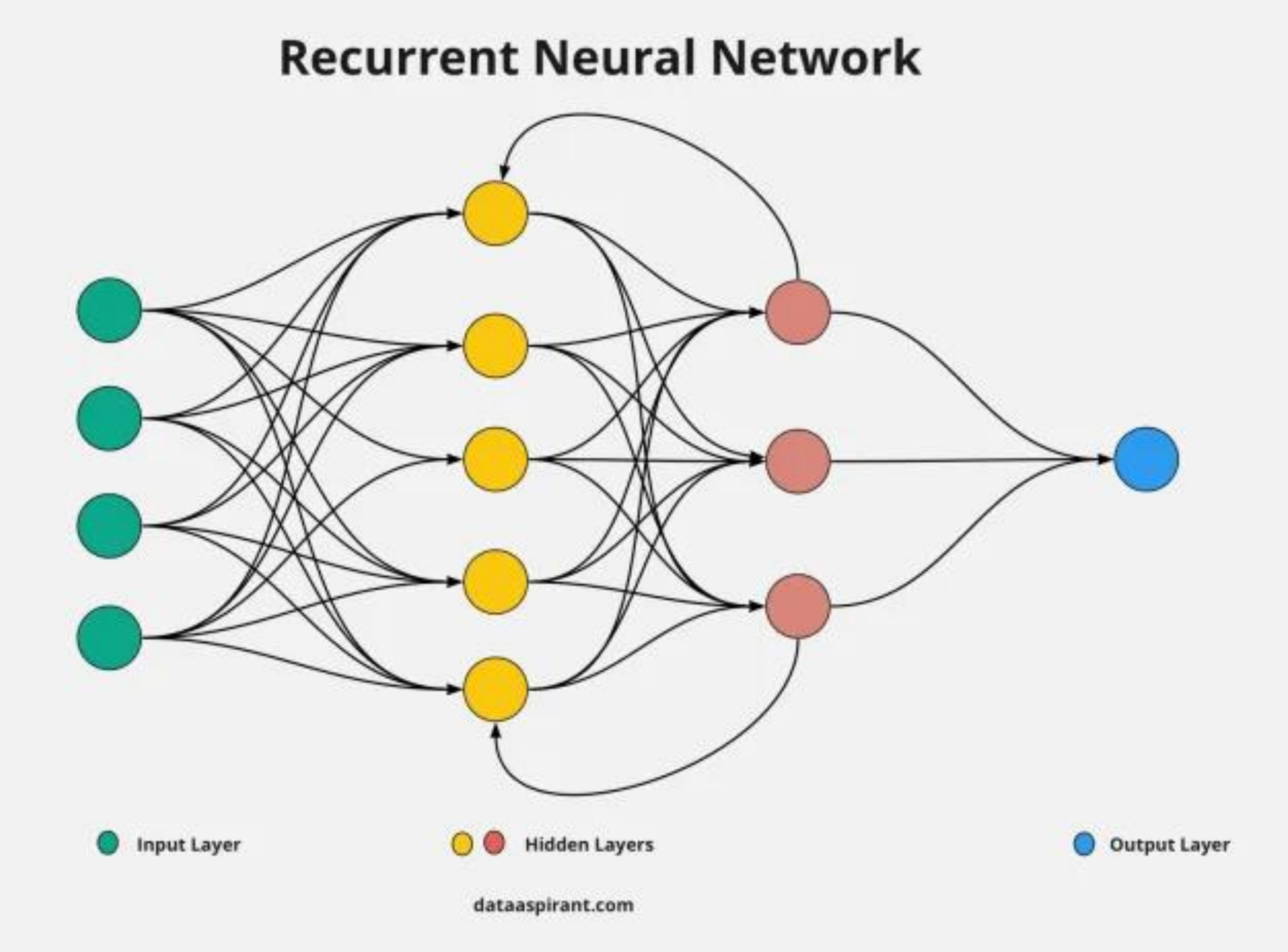
Recurrent NN, RNN



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RNN limitations

RNN remembers things only for a short period of time i.e. if we need the information after a short time, it can be reproducible, but after many words are entered, this information is lost somewhere.

This problem can be solved by applying a slightly modified version of RNNs – long short-term memory networks.

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Long short-term memory networks, LSTM

A type of recurrent NN that can learn and remember long-term dependencies based on past information over long periods (retains information over time).

LSTM has a chain-like structure of 4 interacting layers.

Application:

- in time series forecasting;
- for speech recognition;
- for music composition;
- for pharmaceutical development.

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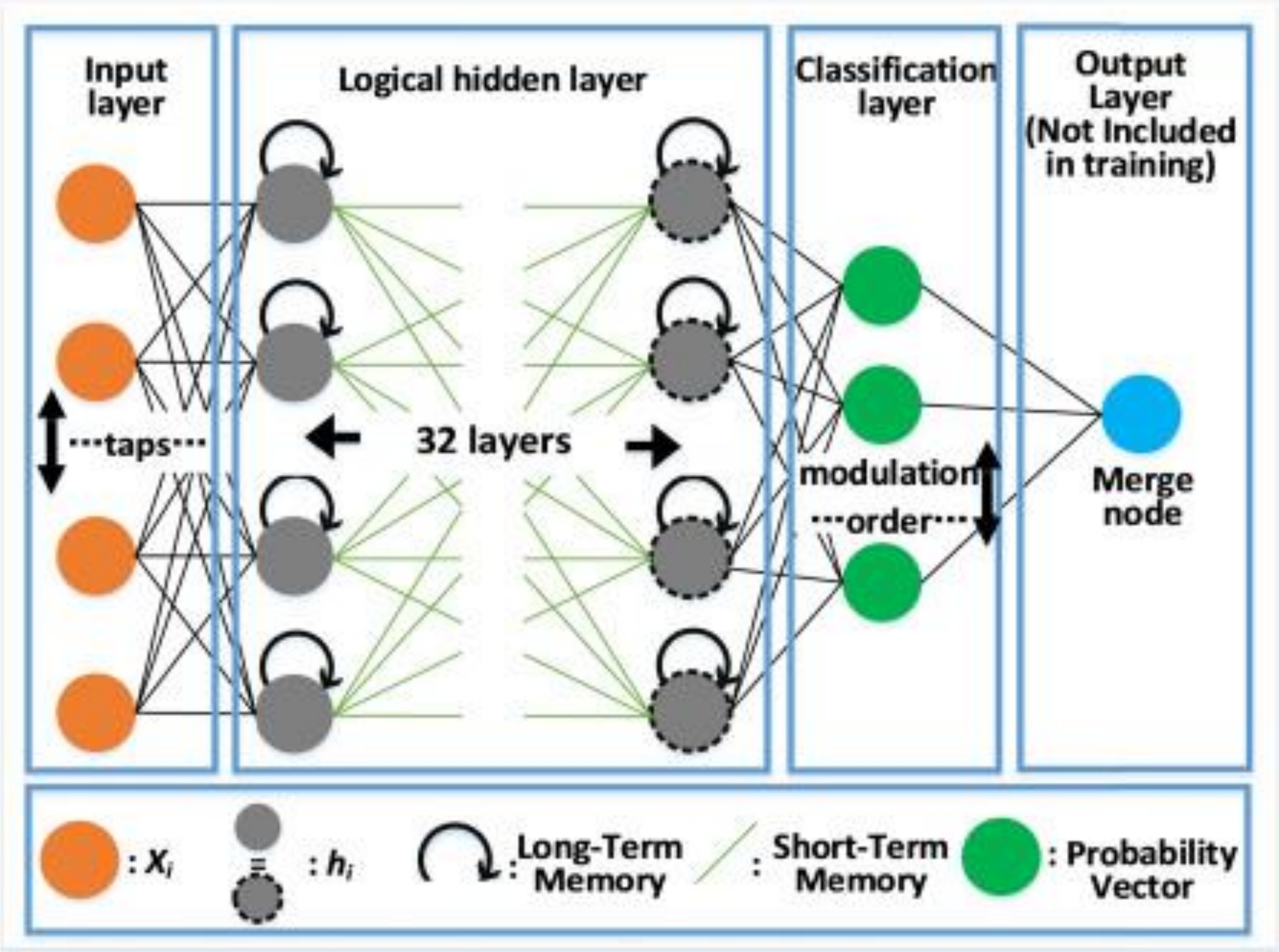
Long short-term memory networks, LSTM



Generative adversarial networks, GAN

GANs are generative deep learning algorithms that create new instances of data that resemble the training data.

GAN has two components:

- a generator that learns to generate fake data;
- a discriminator that learns from this false information.

Application:

- to improve astronomical imaging and simulate gravitational lensing to study dark matter.
- to upscale low-resolution 2D textures in old video games by having programmers recreate them at higher resolutions through image training.
- to generate realistic images and cartoon characters by creating photographs of human faces and rendering 3D objects.

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Multilayer perceptron, MLP

MLPs belong to the NN class of feedforward multi-layer perceptrons that have activation functions. They have no backlinks.

It is a feedforward network whose goal is to approximate some function f *.

Example: a classifier function y = f * (x) converts an input x to a category y. The feedforward network defines y = f (x; θ) and learns the value of the parameters θ, that lead to the best approximation of the function.

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Multilayer perceptron, MLP

Application:

- for speech recognition;
- for image recognition;
- for machine translation.

When feedforward NNs are extended to include feedback loops, they are called **recurrent neural networks**.

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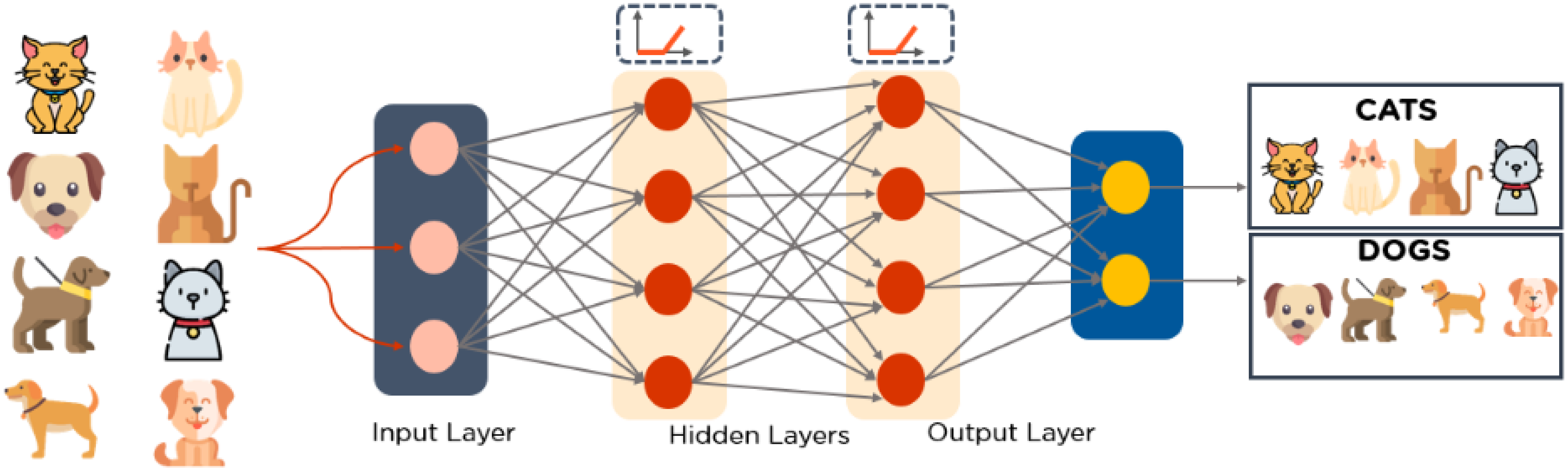
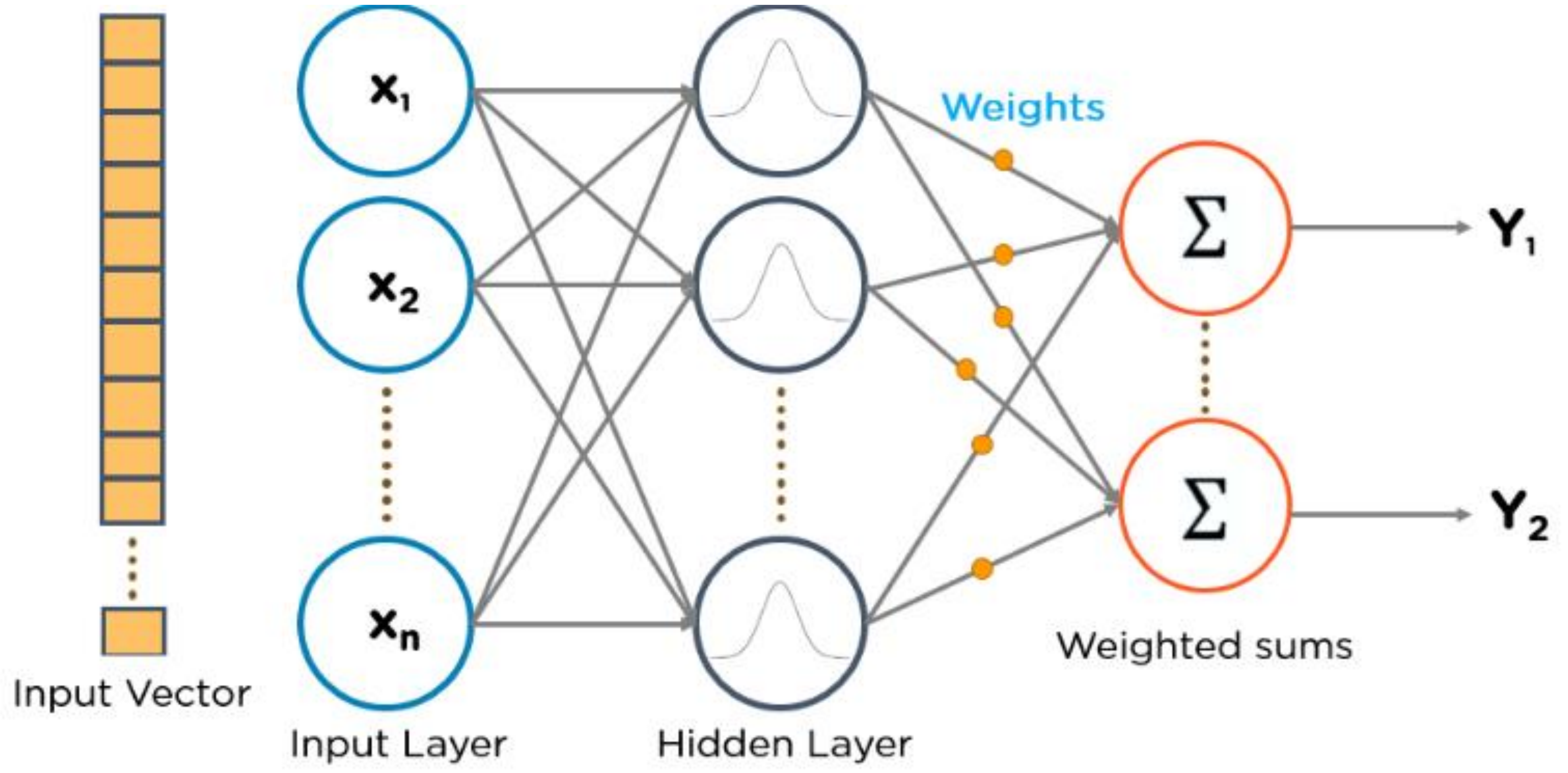
An example of MLP for classifying cat and dog images



Feedforward network architecture



Universal approximation theorem

Hornik and Cybenko, 1989.

A feedforward network with a linear output layer and at least 1 hidden layer, with any activation function (e.g. sigmoid) can approximate any measurable Borel function (French mathematician: For any function f $\in$ C[a,b] and for any non-negative number n there exists an nth-degree polynomial for best uniform approximation of f) from one finite measurable space to another with any desired non-zero amount of errors, given that the network is provided with enough hidden units.

I.e. there is a network, large enough to achieve the desired degree of accuracy, but the theorem does not say how large that network would be.

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LECTURE 13

NEURAL NETWORK TRAINING

1. Introduction
2. Artificial intelligence learning
3. Learning algorithms
4. Training with a trainer
5. Training without a trainer

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CONTENT 1

Learning

The question of learning is in the field of neuroscience and psychology.

Learning is the opposite of instinct:

- **instinct** is genetically determined behavior;
- **learning** is behavior that is changed by experience.

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CONTENT 1

Why are some things learned and others instinctive?

- In 1896 James Mark Baldwin, an unknown American theorist, writes a philosophical survey article on the subject.
- In the late 1980s, a group of computer scientists decided that his reasoning had a lot to do with their task of making computers learn.

CONTENT 1

Plasticity

By learning something, we place ourselves in a selective environment, which contributes to the emergence of a new instinct in the future. Learning gradually gives way to instinct.

Brain plasticity - the ability to adjust the nervous system to its environment.

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CONTENT 1

Learning through experience

Experiential learning is a fundamental ability of the human brain.

Learning in a biological system - takes place by correcting the synaptic connections between neurons or forming new connections.

During this process, the brain shows continuous improvement.

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CONTENT 1

Cumulative learning

Evolution - in a sense, the human genome can be looked at as a cumulative learning spanning for four billion years.

Learning and AI

AI researchers put learning on a pedestal and their goal became a general purpose learning machine.

Attention is directed towards the synapses between neurons. Learning seems to be a change in their properties.

NN and the brain - similarities

- Knowledge enters NN from the environment and is used in the learning process;
- To accumulate knowledge, connections between neurons - synaptic weights - are applied.

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NN training

One of the most important characteristics of NN is the ability to learn.

Training - adapting the network to better handle a task, given sample observations. It is done for better result by minimizing observed errors. Technically, it is a process of processing the input/output data while repeatedly using the training algorithm and adjusting the weights of the synapses until similarity is achieved.

NNs can also change their own topology - this is due to the fact that neurons in the human brain are constantly dying and new synaptic connections are constantly being created.

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CONTENT 3

Learning algorithms

The rule by which connection weights are changed is called the **network's learning rule or algorithm**.

Most often, it starts with random values of the required weights, and then they iteratively change so that at the next step the new output of the network is better than the old one.

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CONTENT 3

Completed training

- Training is completed when additional observations do not reduce the percentage of the errors.
- Even after training, the error rate is usually not 0.
- If, after training, the error rate is too high, the network must be redesigned.

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CONTENT 3

NN according to the training method

- **trained with a trainer** - the difference between the obtained and the expected output of the network is monitored (the teacher sets the expected output) and iterative adjustments are made to the weights of the connections according to the selected training rule.
- **trained without a trainer** – there is missing data on the correct output of the network. The weights of the connections are adjusted so that the data representation in the network is the best according to the specified representation quality criterion.

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CONTENT 4

NNs trained with a trainer

The task of training with a trainer consists of choosing a specific function *a* that optimally approximates the expected response *y.*

The selection is based on the set of *n* independent, uniformly distributed training examples.

Let *C(y,a(x,w))* be a **measure of the losses** or dissimilarities between the desired output *y* corresponding to an input vector *x* and the response *a* generated by the learning machine.

CONTENT 4

NNs trained with a trainer - problems

Making small changes to the weights *w* and biases *b* often does not lead to a change in the elements of the training data.

This makes it difficult to understand how to change the weights and biases to improve performance.

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CONTENT 4

More famous learning rules

- perceptron learning rule (fixed-increment learning algorithm);
- error backpropagation learning algorithm;
- competitive learning rule;
- etc.

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CONTENT 4

Smooth loss function

If we use a **smooth loss function** (such as the quadratic loss function), it turns out to be easy to figure out how to make small changes to the weights and biases so as to achieve an improvement in loss.

We first focus on quadratic loss minimization and then investigate the classification accuracy.

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CONTENT 4

Smooth loss function - quadratic type

- ***w*** - all weights in the network;
- ***b*** – all biases;
- ***n*** - the total number of learning inputs;
- ***a*** - the vector of outputs from the network when ***x*** is input, and the sum is of all learning inputs ***x***. The output ***a*** depends on ***x***, ***w*** and ***b***.
- ***C*** – quadratic loss function, also known as the ***mean squared error*** or ***MSE***.

$$C(w, b) \equiv \frac{1}{2n} \sum_x \|y(x) - a\|^2.$$

CONTENT 4

Gradient learning

Designing and training an NN is not much different from training any other gradient descent machine learning model.

The biggest difference between linear models and NNs is that the nonlinearity of NNs makes the most interesting loss functions non-convex. his means that NNs are typically trained not by solving linear equations, but by using iterative gradient-based optimizers that drive the loss function to a very low value.

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CONTENT 4

Learning through generalization

Generalization - the ability to obtain a reasoned result based on data that was not encountered in the learning process.

This property allows NNs to solve complex tasks, which at the given moment are considered difficult to solve.

In reality, the autonomous work of the NN cannot provide ready-made solutions. It is necessary to integrate them into complex systems. The complex task is divided into relatively simple sequences, some of which can be solved by NN.

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CONTENT 5

NNs trained without a trainer (learning without a trainer)

The name itself emphasizes the absence of a manager controlling the process of setting the weighting coefficients. There are also no marked examples on which the training is conducted.

- We can distinguish two methods:

➢ reinforcement learning - the formation of reflected input signals into output signals is performed in the process of interaction with the external environment, with the aim of minimizing the scalar performance index.

➢ learning based on self-organization (self-organized) - takes place without the intervention of an external trainer or corrector controlling the training process. There is only a task-independent quality measure of performance that the NN needs to learn, and the free parameters of the network are optimized in regard to this measure.

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