COMPUTATIONAL INTELLIGENCE AND KNOWLEDGE ENGINEERING

From Data through Information to Knowledge, Intelligence, and Cognition

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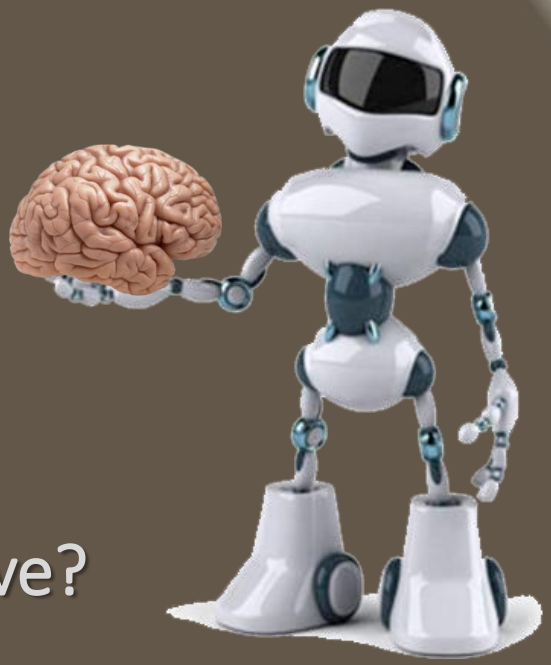
Fundamental Questions

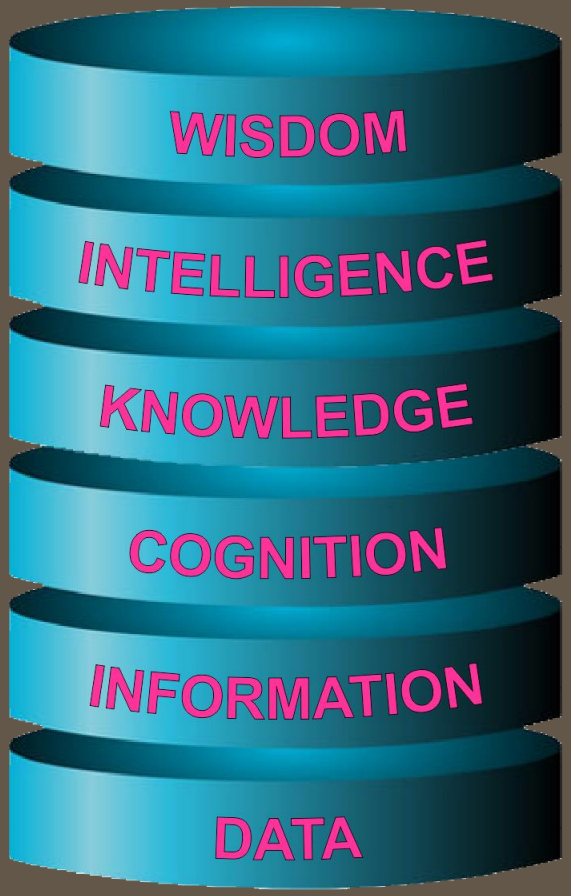
- What do you mean by intelligence?
- What should artificial intelligence be doing to be worthy of this name?
- What does computational intelligence comprise and what problems should it solve?
- What would you like to learn and master during this course?



Scope

- ✓ Fundamental and most commonly used methods, models, and networks
- ✓ Structure creation and development
- ✓ Learning types and parameters
- ✓ Deep architectures and networks
- ✓ Knowledge-based approaches
- ✓ Associative and cognitive systems
- ✓ Inferences and reasoning

From Data to Cognition, Knowledge, and Intelligence!



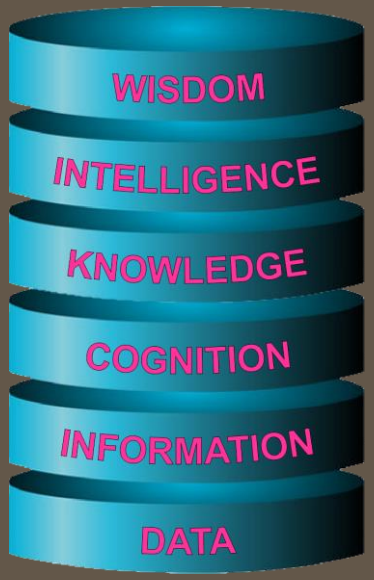
How to create and develop intelligent knowledge-based computer systems?

Data

Data is a collections of numbers, signs, symbols, signals, stimuli, physical or empirical measures, and raw entities that describe various objects or actions, e.g.: 36.6ºC, T, $, φ, 25cm, !

Unrelated data is not useful, because data take on the meaning when related. Data might be raw, inconsistent, unorganized…

It usually describes facts and carries information.



Data Tables

In computer science, we mostly use tables to store, organize and manage data,

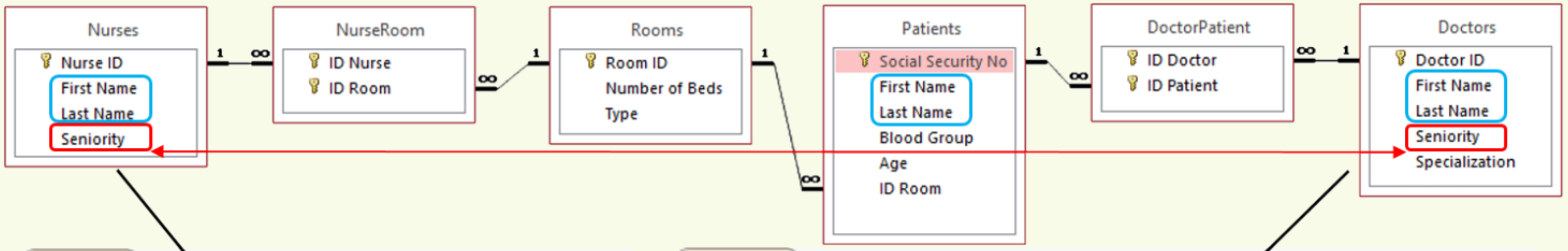
	ATTRIBUTES				
SAMPLE OBJECTS	SEPAL LENGTH	SEPAL WIDTH	PETAL LENGTH	PETAL WIDTH	CLASS LABEL
O1	5.4	3.0	4.5	1.5	Versicolor
O2	6.3	3.3	4.7	1.6	Versicolor
O3	6.0	2.7	5.1	1.6	Versicolor
O4	6.7	3.0	5.0	1.7	Versicolor
O5	6.0	2.2	5.0	1.5	Virginica
O6	5.9	3.2	4.8	1.8	Versicolor
O7	6.0	3.0	4.8	1.8	Virginica
O8	5.7	2.5	5.0	2.0	Virginica
O9	6.5	3.2	5.1	2.0	Virginica

but common relations like identity, similarity, neighborhood, minima, maxima, number of duplicates must be found. The more data we have, the bigger time losses are!

Such relations are not enough!

Relational Databases

Relational databases relate stored data only horizontally, not vertically, so we still have to search for duplicates, neighbor or similar values and objects.



Nurses

Nurse ID	First Name	Last Name	Seniority
N1	Amy	Moon	12
N2	Rose	Jolie	18
N3	Kate	Ford	24
N4	Lisa	Brown	9
N5	Sara	Pitt	4
N6	Kate	Lopez	12

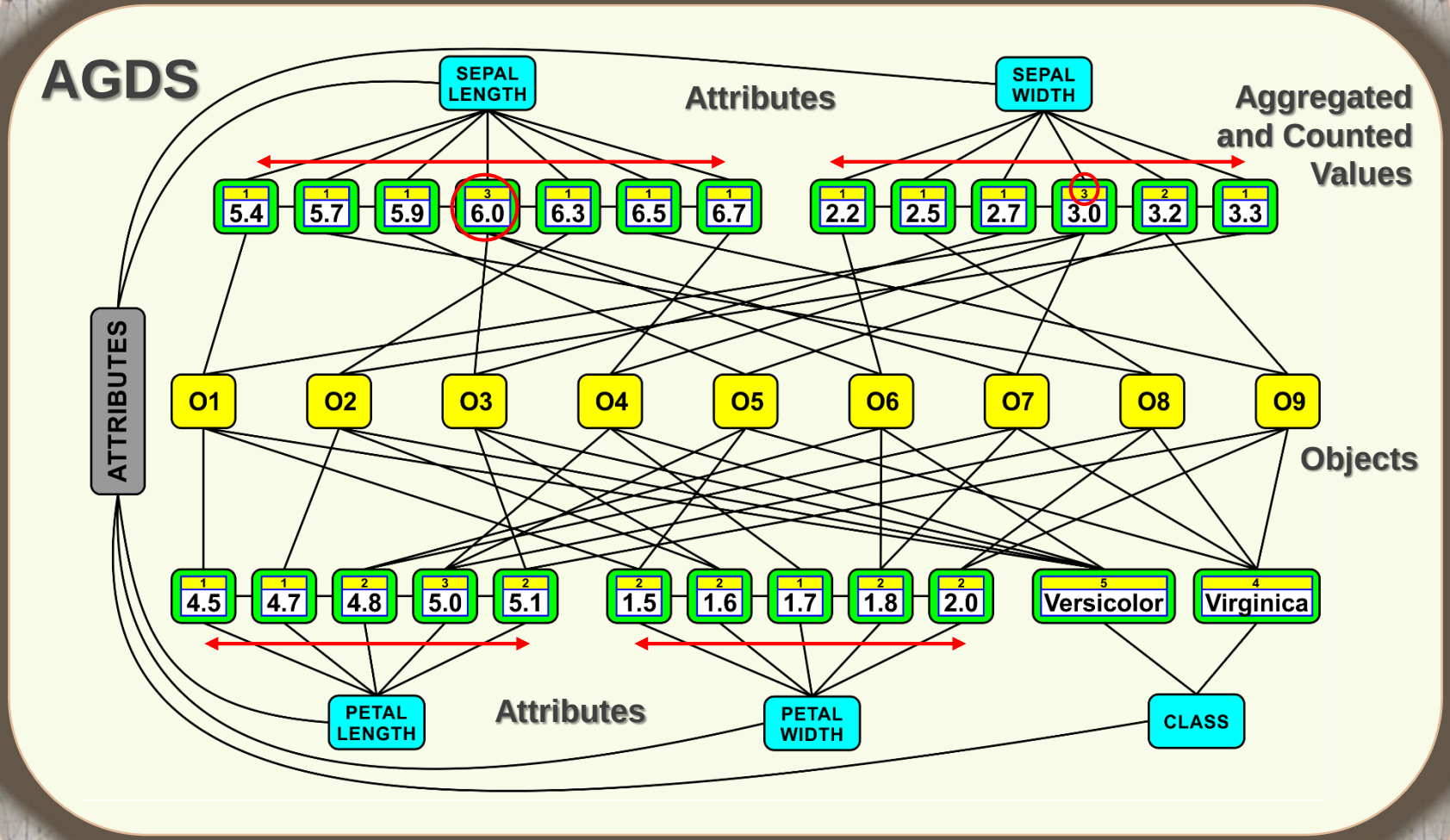
Doctors

Doctor ID	First Name	Last Name	Seniority	Specialization
D1	Tom	Hanks	18	orthopedics
D2	Jack	Brown	15	surgery
D3	Lisa	Ford	23	pediatrician
D4	Tom	Trump	35	pediatrician
D5	Kate	Smith	7	surgery
D6	Amy	Hanks	12	surgery

Data is not perfectly related even horizontally, and many duplicates of the same categories occur in various tables which are not related anyhow. In result, we need to lose a lot of computational time to search out necessary data relations to compute results or make conclusions.

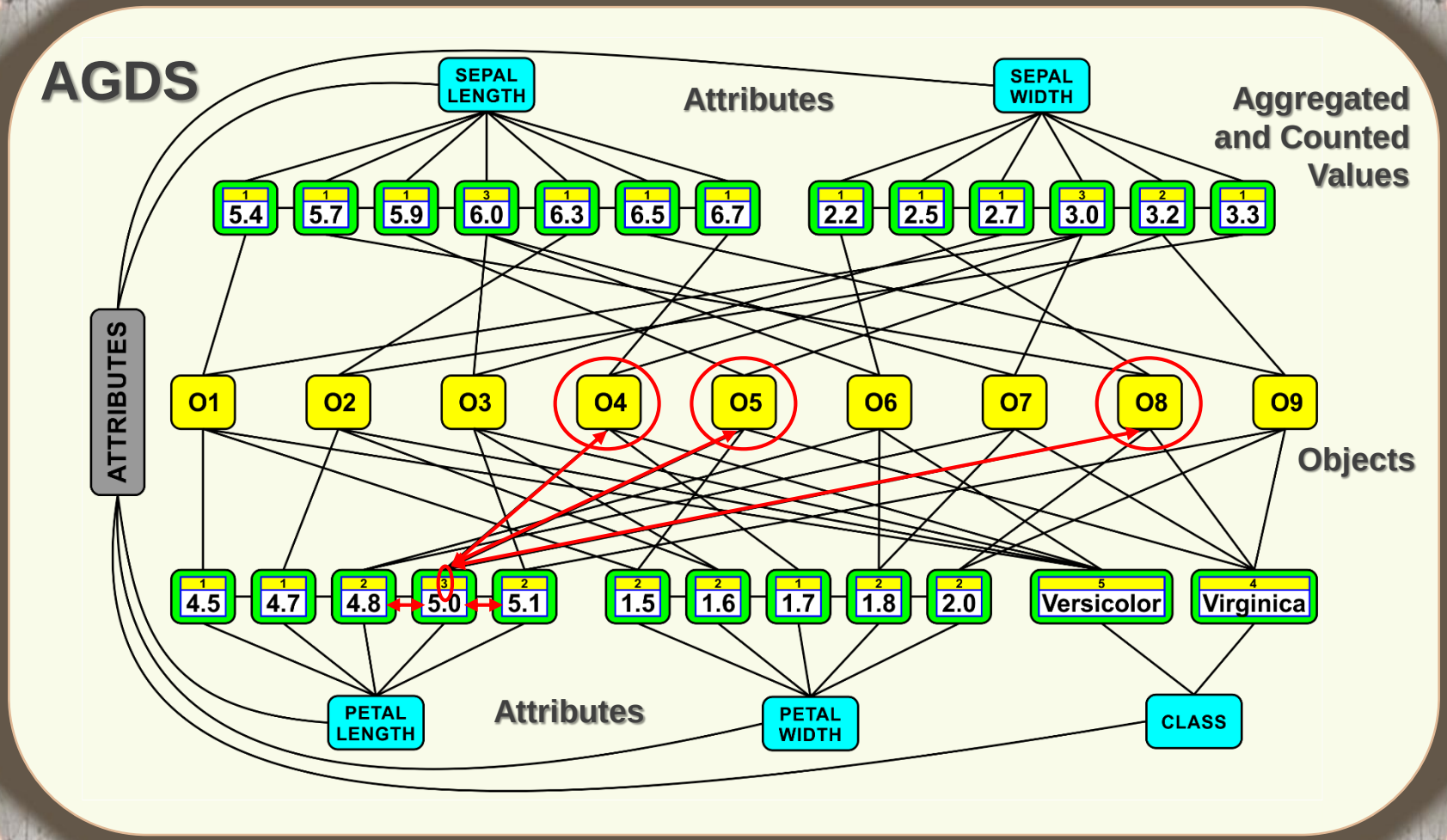
Is it wise to lose the majority of the computational time for searching for data relations?!

AGDS
Associative Graph Data Structure



Connections can represent various relations between AGDS elements like similarity, proximity, neighborhood, definition etc.

AGDS
Associative Graph Data Structure



Connections can represent various relations between AGDS elements like similarity, proximity, neighborhood, definition etc.

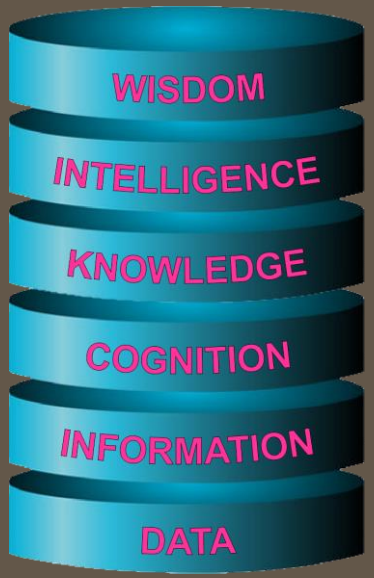
Information

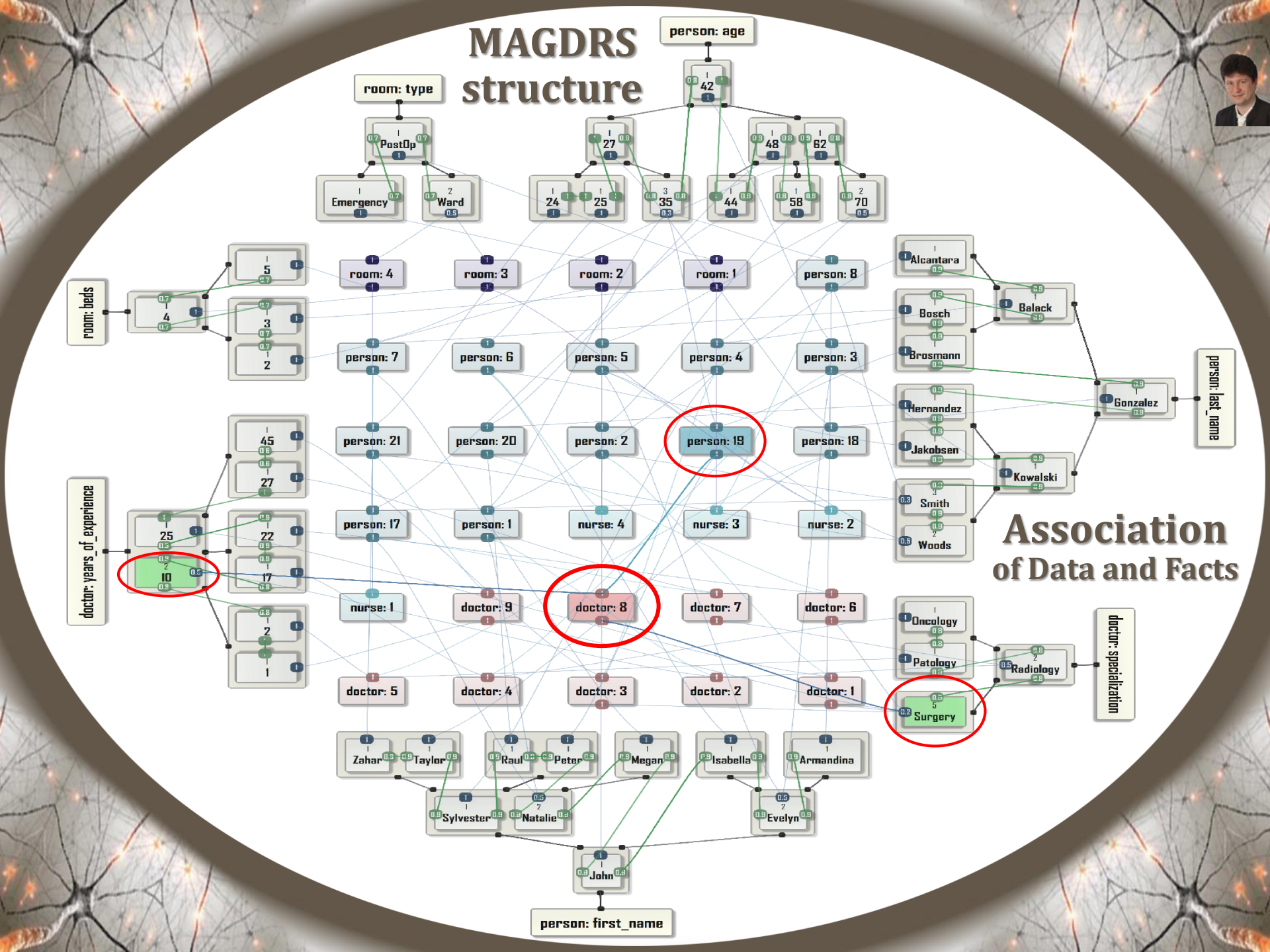
Fact is a collection of related data that is arranged and ordered consistently.

Information is a collection of related data (facts) perceived by a receiver for whom the data has a certain meaning in the context of the already gained knowledge, and the state of the receiver is influenced by these data or the knowledge is updated, e.g. *the normal temperature of a human body is 36.6 ºC*.

Information creates new or modifies existing links between known objects and new data.

The **information receiver** must be able to associate data (pieces of information) to understand the transmitted information.



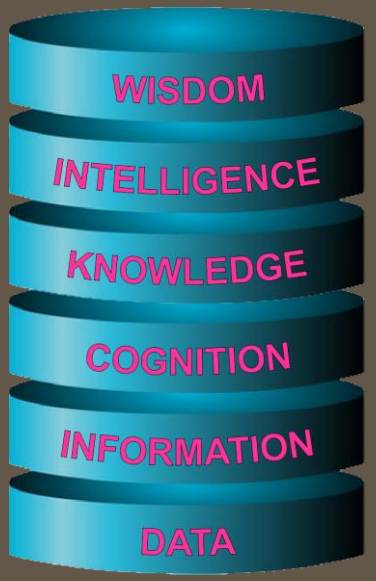

MAGDRS
structure
person: age
room: type
room: beds
doctor: years_of_experience
person: last_name
person: first_name
doctor: specialization
Association
of Data and Facts
PostOp
Emergency
Ward
room: 4
room: 3
room: 2
room: 1
person: 8
person: 7
person: 6
person: 5
person: 4
person: 3
person: 21
person: 20
person: 2
person: 19
person: 18
person: 17
person: 1
nurse: 4
nurse: 3
nurse: 2
nurse: 1
doctor: 9
doctor: 8
doctor: 7
doctor: 6
doctor: 5
doctor: 4
doctor: 3
doctor: 2
doctor: 1
Alcantara
Balack
Bosch
Brosmann
Gonzalez
Hernandez
Jakobsen
Kowalski
Smith
Woods
Oncology
Patology
Radiology
Surgery
Zahar
Taylor
Raul
Peter
Megan
Isabella
Armandina
Sylvester
Natalie
Evelyn
John

Cognition

Cognition is the mental action leading to the acquisition of knowledge from data and understanding them through thought, experience, and the senses.

It encompasses many aspects of intellectual functions and processes such as attention, the formation of knowledge, memory, judgment and evaluation, reasoning, problem solving and decision making, comprehension, processing, and using (production) of language.

Cognitive processes use existing knowledge and generate new knowledge for the processed data.

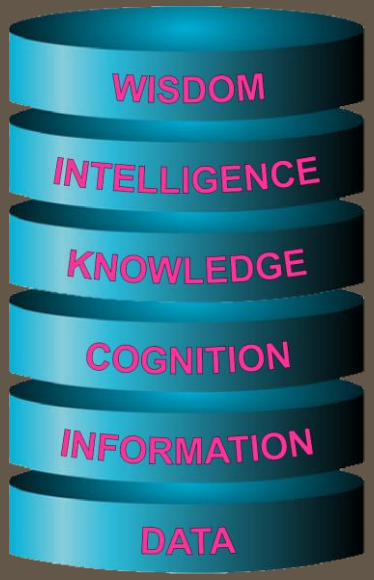


Knowledge

Knowledge is an abstract result of contextual, associative consolidation and representation of patterns, facts, and rules and their generalization, creating new methods, rules, and algorithms of data processing and inference.

In computer science, It can be perceived as a collection of information with its associated context that is in the form of relationships between various pieces of information collected over time.

Knowledge is closely related to intelligence because it allows for the inference and development of individual intelligence as well as the exaltation of your being and nature.



MONKEY

is an example of a set of facts describing this monkey:

”I have a monkey. My monkey is very small.
It is very lovely. It likes to sit on my head.
It can jump very quickly. It is also very clever.
It learns quickly. My monkey is lovely.
I have also a small dog.”

What knowledge we have gained about this monkey on the basis of the above description? Now let's try to answer the following question: What is this monkey like?

KNOWLEDGE GRAPH

Construction of the Associative Neural Graph for the following set of sequential patterns:

1x S1 I HAVE A MONKEY

1x S2 MY MONKEY IS VERY SMALL

1x S3 IT IS VERY LOVELY

1x S4 IT LIKES TO SIT ON MY HEAD

1x S5 IT CAN JUMP VERY QUICKLY

1x S6 IT IS ALSO VERY CLEVER

1x S7 IT LEARNS QUICKLY

1x S8 MY MONKEY IS LOVELY

1x S9 I HAVE ALSO A SMALL DOG

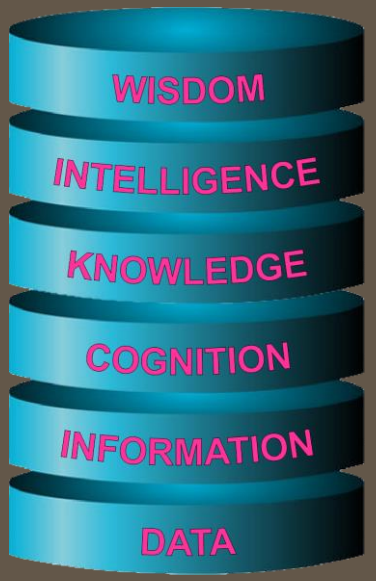

Open Data
Parameters
Learn
Learn Monkey
Learn Slower
2
Learn Faster
Balance Graph
View -
100
View +
Ask
Ask Monkey
Ask Faster
5
Ask Slower
Weights
Background
Exit
Ask times:
1
INPUT:
(Enter a new sentence)
SIMTIME:
0
OUTPUT:
(Results will be brought back by the ANAKG after asking)
Google: Adrian Horzyk (http://home.agh.edu.pl/~horzyk/index-eng.php) to cooperate in developing associative knowledge-based artificial intelligence solutions: horzyk@agh.edu.pl

Intelligence

Intelligence is the mental ability to perceive information and use it to form knowledge to apply it to adapt to the environment, to solve a problem or efficiently achieved goals.

Intelligence is the mental capability of reasoning, planning, solving problems, thinking abstractly, comprehending complex ideas, learn quickly, and use resources efficiently.

It encompasses processes such as learning, recognizing, classification, understanding, logic, planning, creativity, problem-solving, and self-awareness.



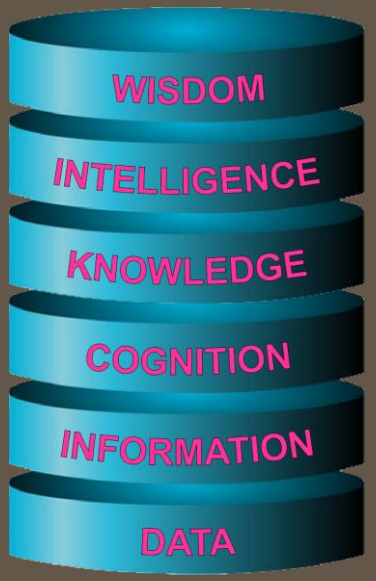
Wisdom

Wisdom is the ability to select the best, wise, efficient, and most profitable way to reach the desired outcome based on knowledge, needs, intelligence, and ethical priorities.

Wisdom allows for good judgment and a high quality of being.

Wisdom is usually a result of earlier attempts to reach a successful outcome on the basis of experience, knowledge, and intelligence.

Therefore, **wisdom** is treated as a manifestation of high intelligence and wide knowledge.



Artificial Intelligence

Artificial Intelligence should be able to:

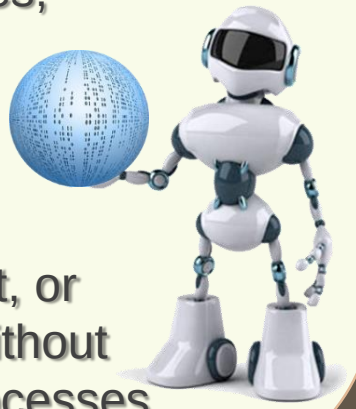
- reproduce and imitate human intelligence;
- recognize and react to human needs and values;
- understand human psychology, personality, needs, and aspirations;
- adapt, learn, remember, and recall objects, facts, rules, and routines;
- recognize similar objects, facts, rules, and routines and generalize them;
- classify objects, associate them in different contexts and recall contextually;

- communicate with people logically and sensitively taking into account their needs and priorities;
- cooperate with people taking into account their weaknesses;
- replace people in frequent or arduous tasks;
- meet the needs of people as well as intelligent machines and define the needs to cooperate to satisfy them.

Computational Intelligence

Computational Intelligence:

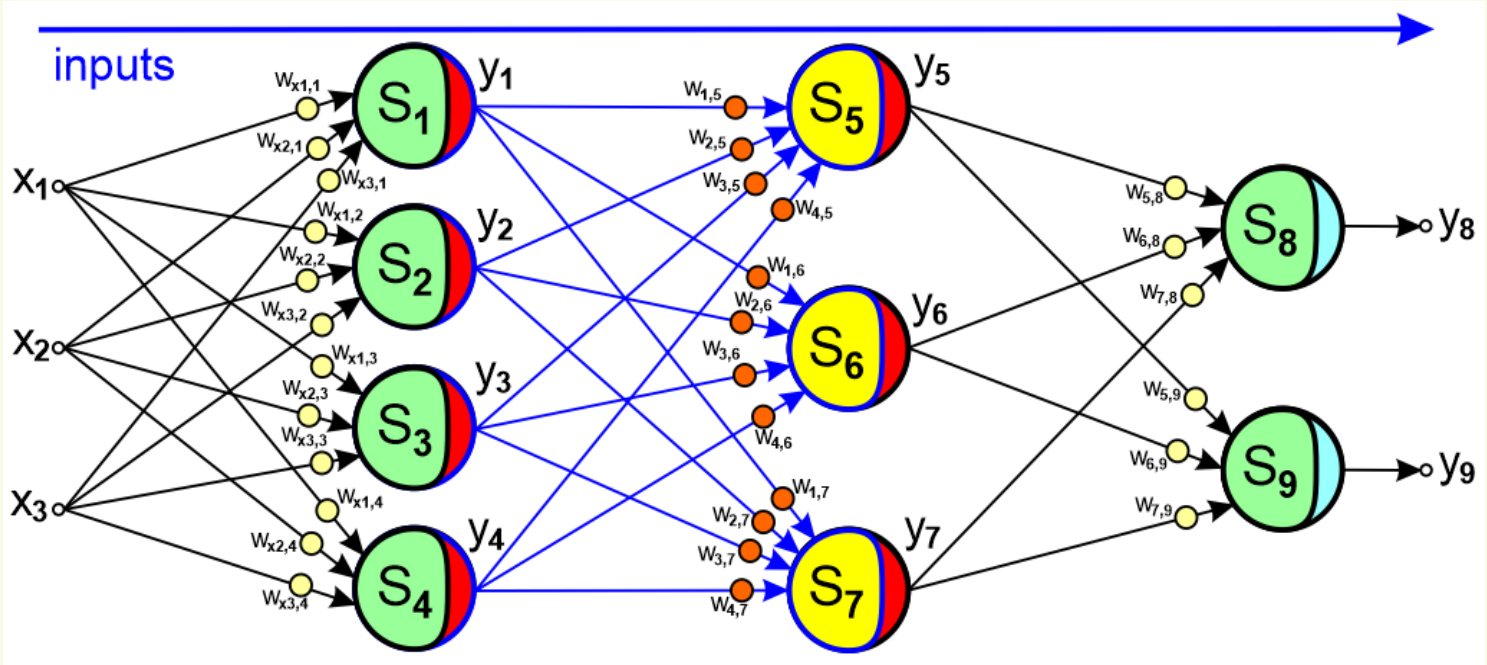
- is a set of nature-inspired methodologies and approaches to address complex real-world problems to which mathematical modeling is useless or not efficient enough;
- usually refers to the ability of a computer to learn specific tasks from data or experimental observations, is focused on solving engineering tasks using adaptive mathematical models based on a human way of thinking or other biological processes;
- encompasses artificial neural networks, fuzzy logic, evolutionary computations, genetic algorithms, and various probabilistic methods;
- is used to recognize, classify, group (cluster), predict, or approximate efficiently in order to make decisions without human assistance or help people in the decision processes.



Neural Networks

Artificial Neural Networks and Artificial Neurons:

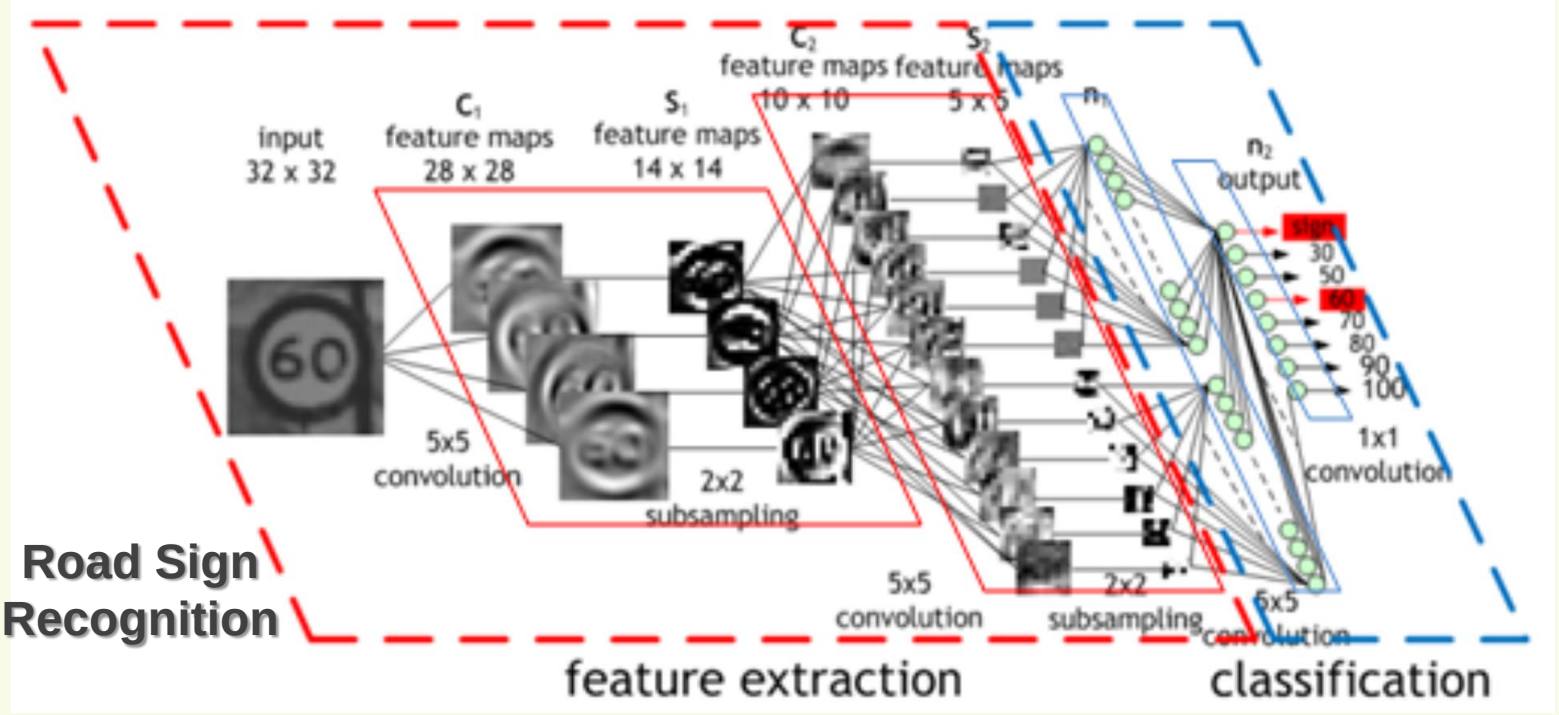
- model real neural networks and neurons;
- can be used in classification, clustering, and regression tasks.



Deep Learning

Deep Neural Networks Architectures and Networks (CNN):

- can overcome some difficulties in the training of classic neural networks.



Source: https://developer.nvidia.com/discover/convolutional-neural-network

Deep Learning

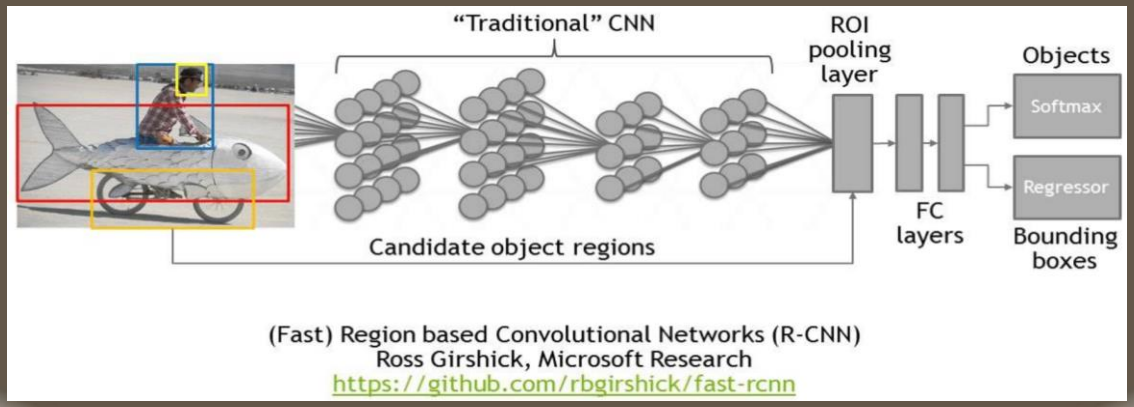
Deep learning simple features to represent a hierarchy of more complex features which are finally used to represent objects, classes and solve the problem.

Today, we have many different deep learning systems which will be described and discussed during these lectures and implemented during laboratory and project classes.

Deep learning networks always have a hierarchical structure constructed from various layers, modules, or subnetworks. They are not always and not necessarily neural networks.

Deep learning systems are a part of:

• Learning systems • Representative learning systems • Hierarchical systems



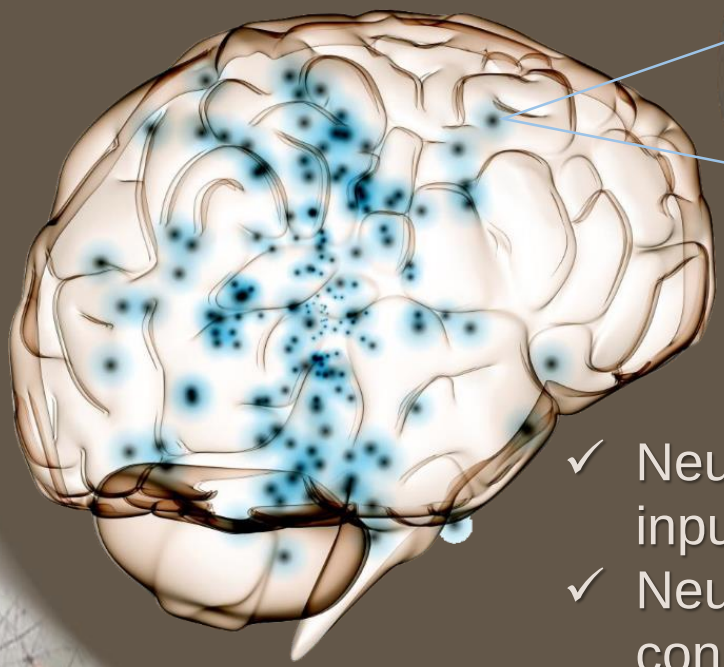
Brains and Neurons

How do they really work?

How we can use brain-like structures
to make computations
more efficient and intelligent?

Data Relationships

We can find a solution in the brain structures where data are stored together with their relations.



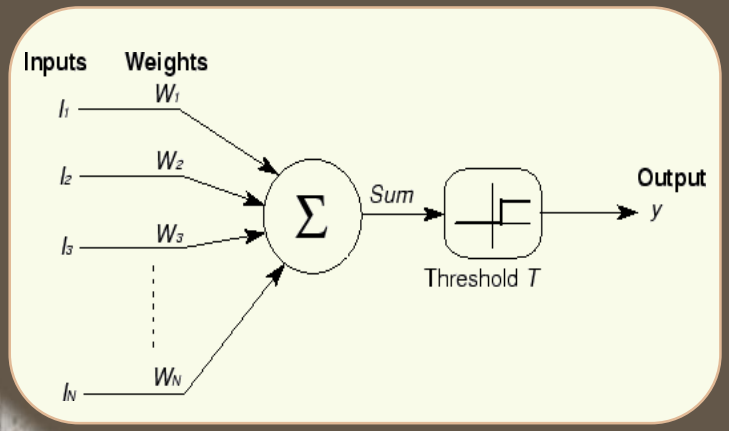
- ✓ Neurons can represent any subset of input data combinations which activate them.
- ✓ Neuronal plasticity processes automatically connect neurons and reinforce connections which represent related data and objects.

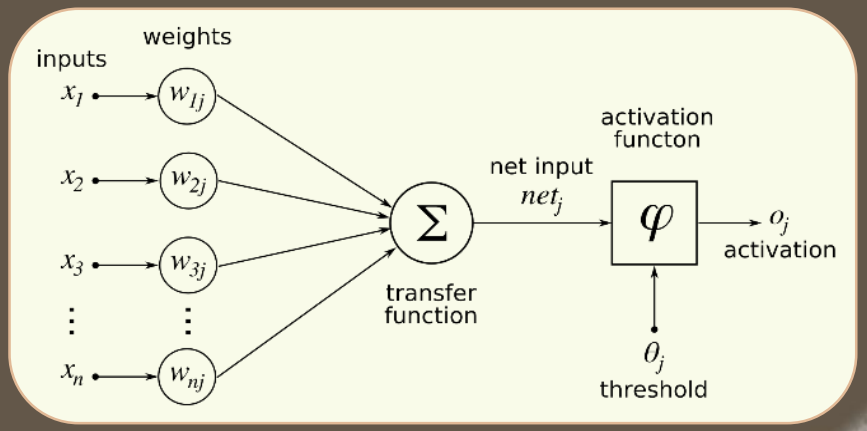
Let us use the biologically optimized solution!

Neuron Models and Generations

1. **The McCulloch-Pitts model of neurons** implements only the most fundamental mechanism of weighted input stimuli integration and threshold activation function leaving aside issues of time, plasticity and other factors.

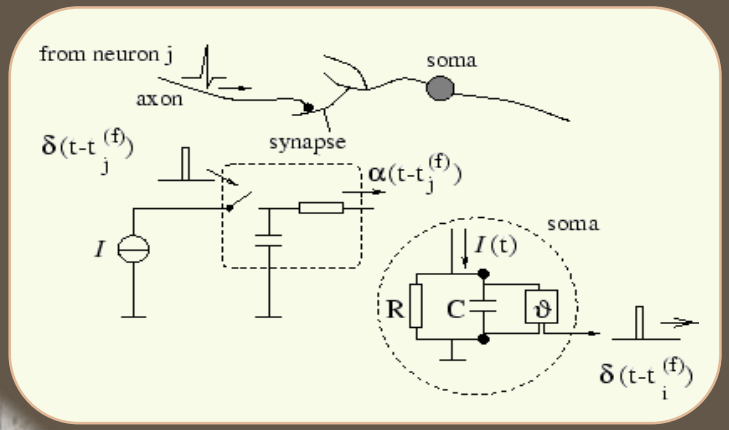
2. **The models of neurons using non-linear continuous activation functions** enable us building multilayer neural networks (e.g. MLP) and adapt such networks to more complex (non-linear) computational tasks.

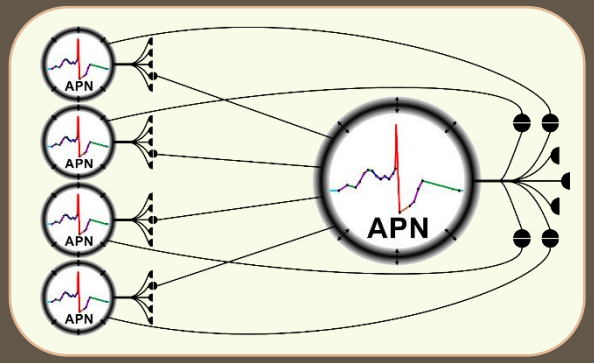




Neuron Models and Generations

3. **The spiking models of neurons** enriched this model with the implementation of the approach of time which is very important during stimuli integration and subsequent processes modeling.





4. **The associative pulsing models (APN) of neurons** produce a series of pulses (spikes) in time which frequency determines the association level. Moreover, they enrich the model with the automatic plastic mechanism which let neurons to conditionally connect and configure associative neural structures representing data, objects and their sequences.

Evaluation and Final Grading

All tasks during laboratory and project classes should end by the creation and development of a personal CI system (applications) which:

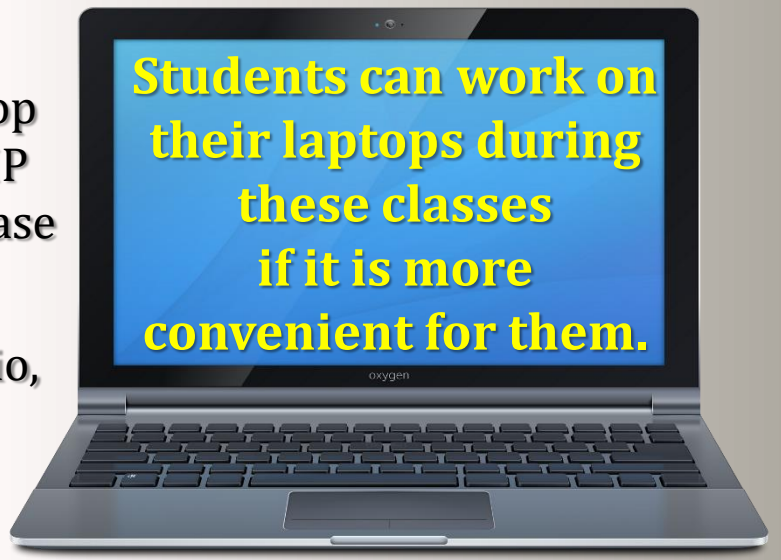
- ✓ **comprises all realized laboratory tasks and a final project;**
- ✓ **have a unified common interface for reading input data from text, spreadsheet, xml, and/or database files containing training data;**
- ✓ **have a unified graphical output interface for presentation of output data, achieved results, structures of neural networks or other models as well as possibly animated intermediate training and evaluation stages to clarify the way of how the structure and parameters are created and modified in the given adaptation process;**
- ✓ **have clearly implemented algorithms and data structures realized with state-of-the-art, good programming practices, rules, and a selected object programming model (MVC, MVVM, etc.).**

Students initiatives will be appreciated and the best projects can be broadened to Master's theses and/or scientific papers with the help of the lecturer.

Final Projects

All application must be implemented in one of the top programming languages: C#, C++, Java, Python, or PHP and if necessary supplemented by the use of a database or programming libraries (e.g. TensorFlow, Keras).

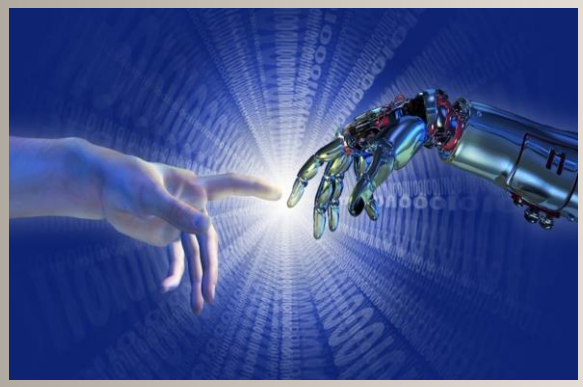
In the laboratory room there are only MS Visual Studio, Java, and Python available, so if you wish to perform your classes in the other programming language, you are responsible for the possibility to work in it.



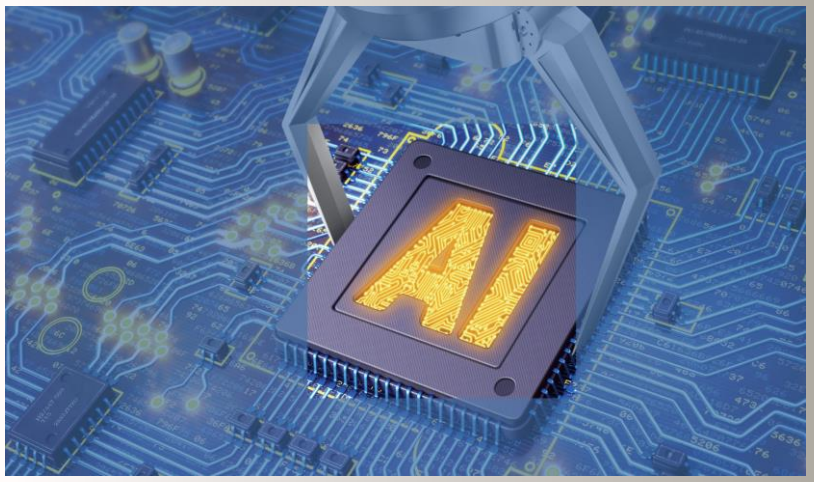
All final projects should be presented (about 10 min.) to all participants during the last project classes in the semester! **Prepare your final presentation** of the used methods, data structures, achieved results etc. **Draw valuable conclusions and summaries for us. Inspire us, give us advice and suggestions! Describe the abilities** of your CI system and show us how it works for some sample data. **Interpret** and possibly **compare** achieved results.

All final complete projects (including the developed CI system with a source code of all modules, a compiled application, training data, databases, presentations etc.) should be send to the lecturer at the end of the semester because the lecturer is obligated to store them during at least one year as a proof of the grades given to students. **Hence, only the sent complete projects can be finally evaluated and students will be graded!**

Let's start with AI!



- ✓ Questions?
- ✓ Remarks?
- ✓ Suggestions?
- ✓ Wishes?



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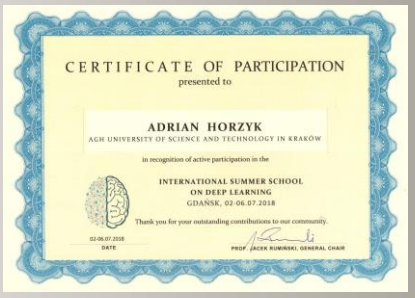

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