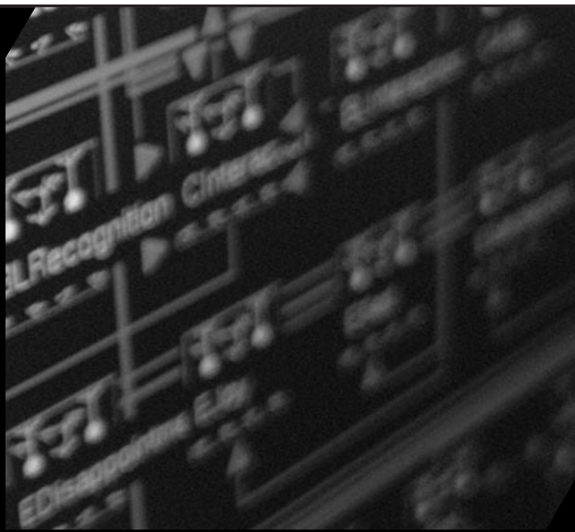
2c



>Ada knowledge: Processing data

The human brain is a complex neural network. We have the dynamics of the brain to thank for our faculties of perception, movement and emotion as well as our thinking and our consciousness.

This chapter contains:

- Information on information processing in the human brain and with Ada
- Illustrations
- Recommendations for instruction
- Worksheet

A: Factual information

Processing data according to the principles of neural networks

With Ada, the data obtained through the artificial sensory organs is not processed by means of conventional software, but according to a principle like that found in the human nervous system.

Technical devices emulating individual sensory organs, such as cameras or microphones, are nothing new and have benefited from continual enhancements in performance over the years. The achievement of the "Ada" project consists of linking the components together in an intelligent way. Ada is thus more than just the sum of her individual parts. The data that Ada collects through her artificial sensory organs is not processed by means of conventional software, but in a way similar to the human nervous system. While Ada is made up of normal computers with ordinary operating systems, their organisation and linking and the way the information is processed is new: Ada was programmed as a hybrid network modelled after the way biological nervous systems function, performing neural and digital computations in a computer system.

Ada is the first large-scale neuromorphic system of its kind. Many of the technologies employed have never been integrated in a common system. The software on which Ada is based not only simplifies the developing of neural networks, but also the integration of external devices, like cameras, loudspeakers, microphones etc. In addition, it is possible to study the neural networks in real time, that is, being able to simultaneously record and evaluate data and display the results with no time lag.

Neural network

In the neural network, there is no paramount authority issuing simultaneous commands to all the different functional units. Rather, the functional units adjacent to one another communicate much more extensively with each another than with those further apart. Communication thus by and large occurs locally. By contrast, the conventional computer features hierarchical organisation: A superordinate authority can simultaneously contact all points.

In the neural network, communication operates from functional unit to functional unit, as from nerve cell to nerve cell in the nervous system. One can think of dominos, with the signal transmitted from one domino tile to the next as they successively topple over.

Technology that can learn

Neural networks are information processing systems that are able to learn. Based on preceding examples, they can learn to choose the best possible solution for a particular situation and continue to refine it accordingly. Like a brain, a technical neural network is a complex system of autonomous parts, so-called neurons or units, whose local interactions yield global patterns of activity ("answers"). The dynamics of the brain is not centrally directed by programs as with computers, but is capable of organising itself. Like brains, technical neural networks are flexible and able to learn, tolerating deviations from the norm and making use of parallel signal processing.

The neural networks developed for Ada are based on models that reflect the way real brains function. There are countless models explaining how the nerve cells in specific regions of the brain communicate with one another. All such models make assumptions as to how a specific brain region exchanges information with other regions of the brain. Yet today we are still far from fully understanding how the various regions of the brain all work together. Even less is known about how to link together the various available models so the whole can function as a unit. Ada represents a first step in this direction.

Does the brain function like a computer?

To distinguish the specific characteristics of neural networks, it is helpful to compare the operational mode of conventional computers with that of the human brain. As previously mentioned, the predominant visual conception of the brain is that of a computer.

The processes in the brain and in a computer, however, are marked by several important distinctions:

- The computer is only able to deal with a limited number of information units at any given time, while the brain can process more than a billion information units simultaneously (highly parallel data processing).

- The brain mostly processes data in an analogue fashion, whereas the conventional computer can only process digital data; all the information thus has to be converted into a code of 0 or 1.

- The brain is then also much better equipped to recognise a picture than a computer when individual parts of the image are missing or erroneous.

- With a conventional computer, data processing and data storage are spatially divided so that the data always has to be shifted back and forth in the operating procedure. In the brain, however, information processing and storage are very closely linked; the site where data processing occurs can also be where data is stored.

Ada's neural network

>Ada knowledge: Processing data

Learning
A central ability in humans is learning, for it facilitates an adjustment of behaviour to the respective environmental conditions. From birth up until death, humans learn about themselves and their surroundings. Learning means a perpetual acquisition of knowledge, which can bring about a change in attitudes and modes of behaviour. Learning can occur consciously or subconsciously.

Learning proceeds in two phases: When subjected to stimuli, a living being takes in information and stores this in its memory (learning mode). In appropriate situations, the stored information is called up and – conditioned through experience – effects a changed behaviour (recall mode).

Yet learning is not just a purely rational process. Emotions also play an important role.

How Ada learns
Like humans, Ada learns from experience: She can store an incident and later build upon it. Ada can furthermore link various pieces of information and draw conclusions from this. Upon observing two individuals standing close together for a long period of time, she concludes that they are a pair. Ada likewise learns how to synchronise her various components, such as the floor plates, the movable eyes and the light fingers. This process can be compared to a child who has to learn how to grasp an object. From the behaviour patterns of individual visitors, Ada also learns something about their character, such as their inclination to play or their behaviour in groups. These "experiences" determine Ada's subsequent mode of behaviour and regulate her scale of values for the longer term.

Memory
The ability to store information so that it can be called up later is called memory. The recording of the information is the impressing, while the act of recalling is termed remembering. Without memory, there would be no learning. The material foundation of memory is the totality of all nerve cells and the brain.

The memory does not work like an electronic storage device that permanently holds the recorded information. The details of how the information storage occurs by and large remain unclear.

In humans, three types of memory can be identified. The ultra short-term memory keeps information up to approximately 20 seconds. The short-term memory stores information for a maximum of one to two hours, though its storage capacity is limited. In long-term memory, information is retained for up to a lifetime.

In the sense of information storage, Ada is able to remember the visitors with whom she has played and whose gestures, movements and sounds she has observed.

Dreams

Dreams are fantasy experiences that spontaneously arise during sleep. All humans and higher developed animals have dreams. In dreams, emotions are predominant, notions of time and space are unclear and non-real images are frequently featured. Experiences of the day, the so-called day residue, may likewise be a part of dreams.

The purpose of dreaming

There are various opinions regarding the purpose of dreaming in humans. Some researchers expound the theory that dreams help us process information received over the course of the day. According to this view, this occurs through the taking up of day residue and through the linking of this day residue with older, similar experiences of the dreamer. Memory researchers, on the other hand, are of the opinion that dreams serve to delete unnecessary information that has been collected over the day. Physiologists believe that dreams are an attendant phenomenon of neural discharge sequences of the brain stem and reject any sort of independent function.

When Ada is asleep, the sounds and the light are calm and soft. The sudden occurrence of abrupt and accentuated light effects and sounds indicates that Ada is dreaming. Ada's dreams consist of images of visitors she found interesting for some reason.

Definition of terms

•Neural network

A neural network consists of idealised neurons, the so-called "units." The units are linked together in a parallel configuration through a network and receive signals (inputs) from other units, which are added up and, from this, calculate an output with simple mathematical functions. The signals are determined by the product of the weight and strength of the link between the units.

Artificial neural networks are, motivated by the biological model (the nervous systems/brains of animals), a computational model for information processing.

•neuromorphic

Modelled after the structure of nerve cells.

•hybrid

Produced through crossing or mixing, mixed.

B: Recommendations for instruction

Sheets with border can be copied and distributed to students.

Explanations of **Worksheet 2c.8**

The worksheet deals with data processing in conventional computers and compares these with information processing in humans.

Text translation programs (see Exercise **1***) present an opportunity to take a look at the topic. This exercise involves problems of perception and usability of such text translation programs, reflecting the core difficulties with artificial intelligence.*

Information processing can also be examined through various informatics problems. One such example is game programs. For instance, a game tree (for more on such trees in informatics, see Goldschlager 1990) can be constructed and played through for the simple Nim game (Exercise **3***). In this game, there are five matchsticks on the table and the two players may remove one or two of them at a time. The one who has to take the last matchstick loses.*

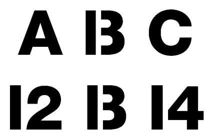
A game tree is a depiction of the consequences of all potential combinations of a game. Each node represents a potential action, while the "leaves" show the potential game results. This depiction is the basis on which a conventional computer makes the decisions for its actions. Only for very simple games like the Nim game is it possible to depict a complete game tree.

Answers

1. *Simple translation programs are able to analyse the grammar (syntax) of a sentence quite well. Where they get tripped up, however, is in their inability to understand the meaning (semantics). The sentence "Aschenputtel besuchte den Ball" is grammatically indistinguishable from the sentence "Aschenputtel warf den Ball," yet they have completely different meanings. The same is true of the "Autobahn" sentences.*

The problem lies in resolving ambiguities, which constitutes a significant problem for computers. By knowing the meaning of "werfen" and "besuchen," a person can immediately tell the meaning of "Ball" in this context. Recognising the meaning of a word requires a faculty of imagination that is absent in computers.

2. Picture a

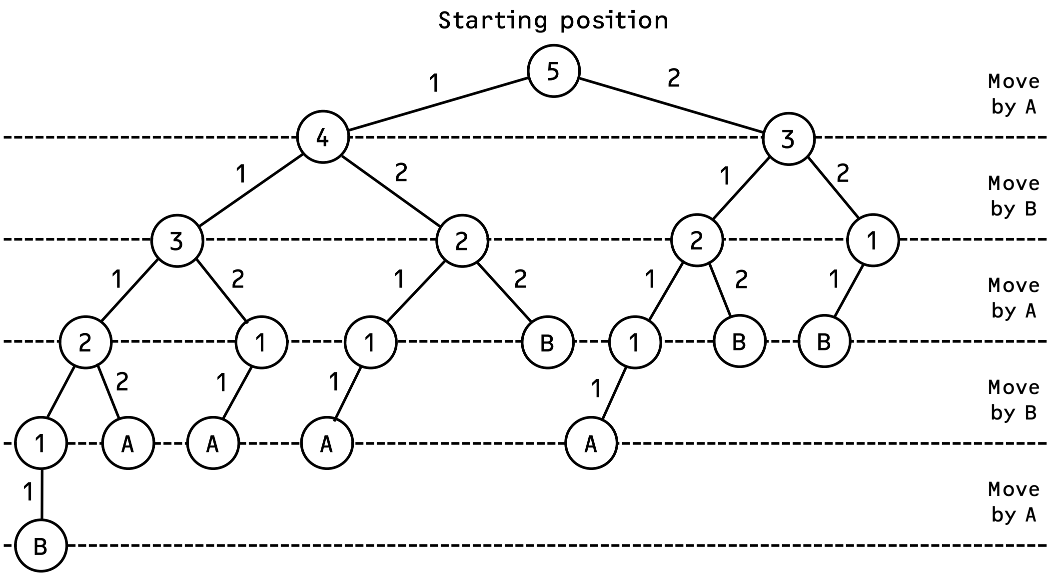


Our perceptions are not always consistent: In one case, we interpret the middle character as the number 13 and in another instance as the letter B, depending on the context.

Picture b

When looking at this image, people who spend very little time indoors tend to perceive a group of people sitting outside (with a woman bearing a vessel on her head). By contrast, people who spend most of their time in indoor spaces see a group of people sitting inside under a window.

Our experiences and the context in which something is situated thus influence our perception.



Game tree for the Nim game: The numbers on the branches indicate the number of removed matchsticks, while the numbers shown in the nodes express the number of remaining matches. The letters in the final node designate the winner. (From •Goldschlager 1990, p. 298*)*

Links

Neural networks

www.mantik.de/de/netze.html
www.gc.ssr.upm.es/inves/neural/ann3/anntutor.htm
www.genesis-sim.org

Tutorial on programming a neural network

www.imagination-engines.com/anntut.htm

Babelfish translation program

http://de.altavista.com/pos/babelfish/trns/

Bibliographic information

•Mainzer, Klaus: **Gehirn, Computer, Komplexität.** Berlin, Heidelberg 1997.
•Goldschlager, Les/Lister, Andrew: **Informatik. Eine moderne Einführung.** München 1990.

>**Ada knowledge: Processing data** (Worksheet)

1. Compare the sentences below with the French translations generated by the Internet translation program Babelfish. What difficulties does the translation program encounter?

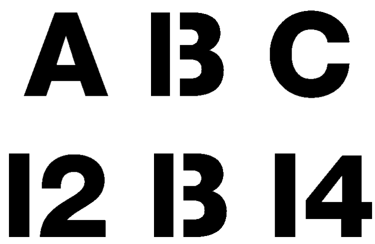
Aschenputtel besuchte den Ball
Le Aschenputtel a visité la boule

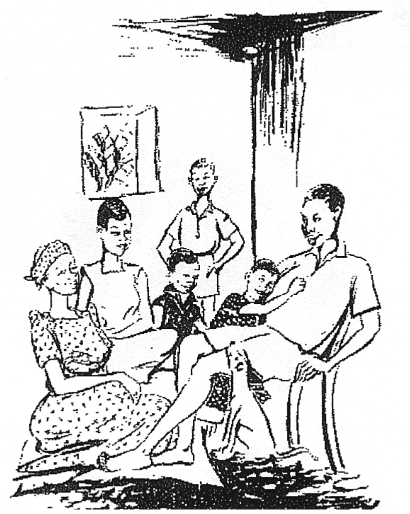
Aschenputtel warf den Ball
Le Aschenputtel a jeté la boule

Die Autobahn wurde durch einen Baumeister gebaut
L'autoroute a été construite par un architecte

Die Autobahn wurde durch ein Waldgebiet gebaut
L'autoroute a été construite par un secteur de forêt

2. Two interesting examples of varying perception. What factors make people see the images differently?





3. Sketch a game tree for the Nim game.