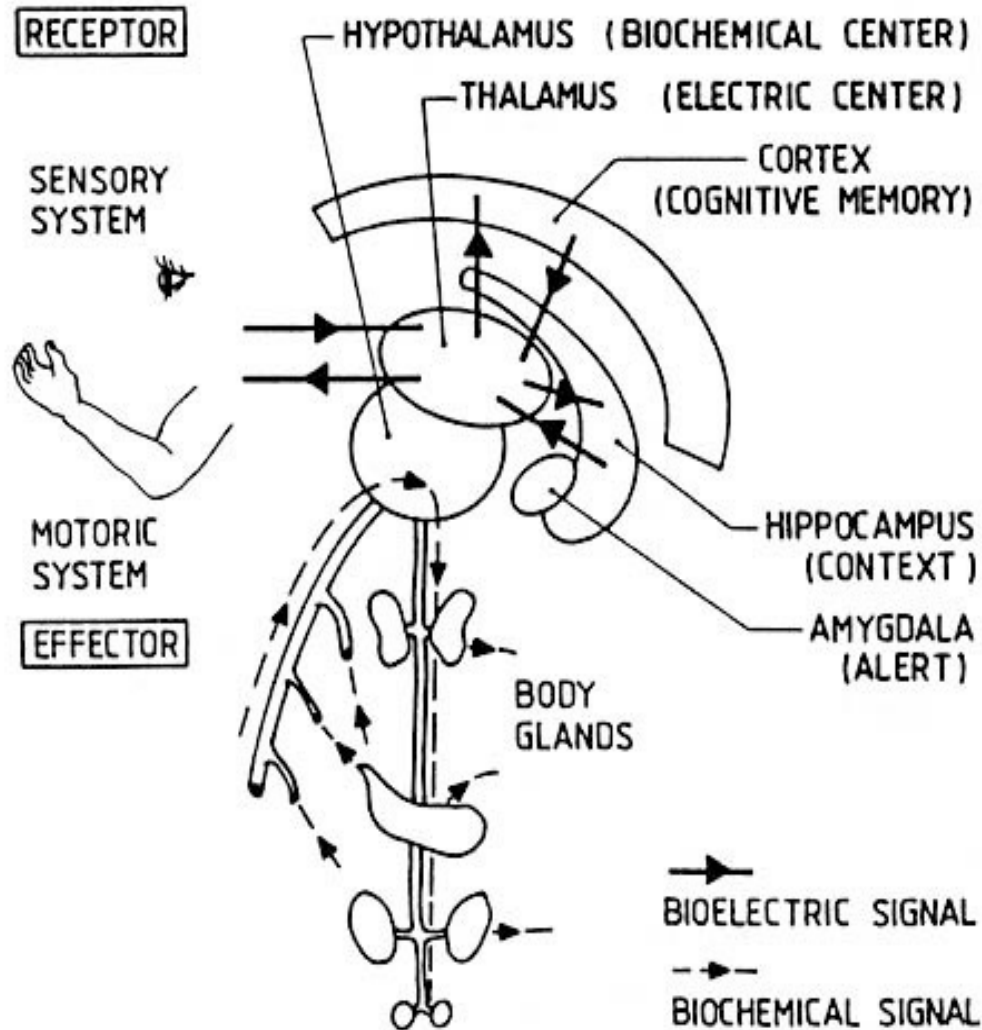# Analytical methods in complex systems

2010

Lecture 9: Cognition, artificial intelligence and neural networks

Jarl-Thure Eriksson

# Signal flow in the human brain and body

Source: Eriksson

Perception

Perception is the process of becoming aware of incoming sensory signals.

The concept is still not fully understood.

It is not clear whether perception means conscious or subconscious awareness,
- or simply received information, but not recognized.

The importance of pattern recognition

Prototype vector
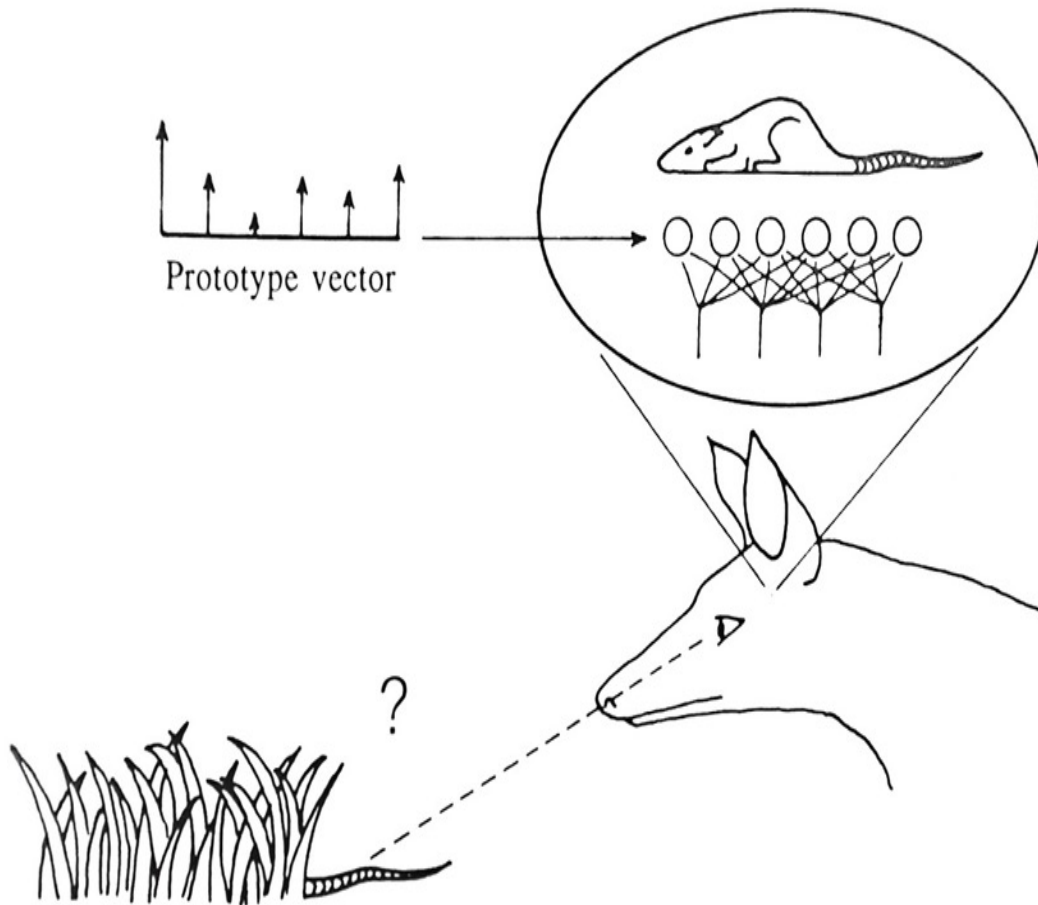
The vision of the real world is based on a limited amount of sensational information.

Usually we need only a scarce glimpse to make correct conclusions.

Some times we are mistaken, especially when the sensation is vague, e.g. in darkness.

Source: Klaus Meinzer, Thinking in Complexity, 1994

Impact of Damage to the Frontal Lobe
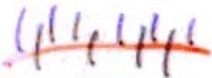
Phineas Gage, 1823-1860
- in 1848 hit by an iron rod from beneath in his left cheek,
- the rod passed his fore-brain and flew tenths of meters away,
- he lived twelve more years physically recovered,
- major changes in mind and social qualities.

Phineas P. Gage
1823-1860
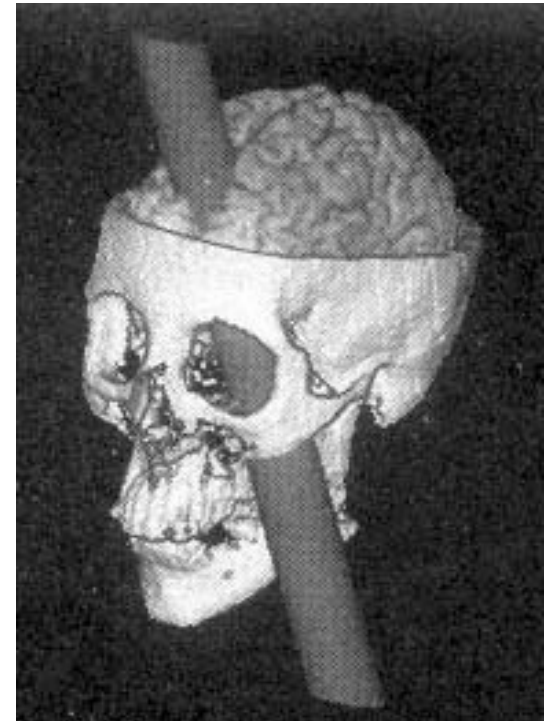
Source: Antonio Damasio, Descarte's Error, 1994

Input rates of sensory information

Sensory inputs

Vision	10^7	bit/s
Sensing (skin)	10^6	bit/s
Hearing	10^5	bit/s
Smelling	10^5	bit/s
Tasting	10^3	bit/s

Source: Eriksson

Information flow and compression in the brain

Multimedia-
communication
10 Mbit/s

Speachcomm
40 bit/s
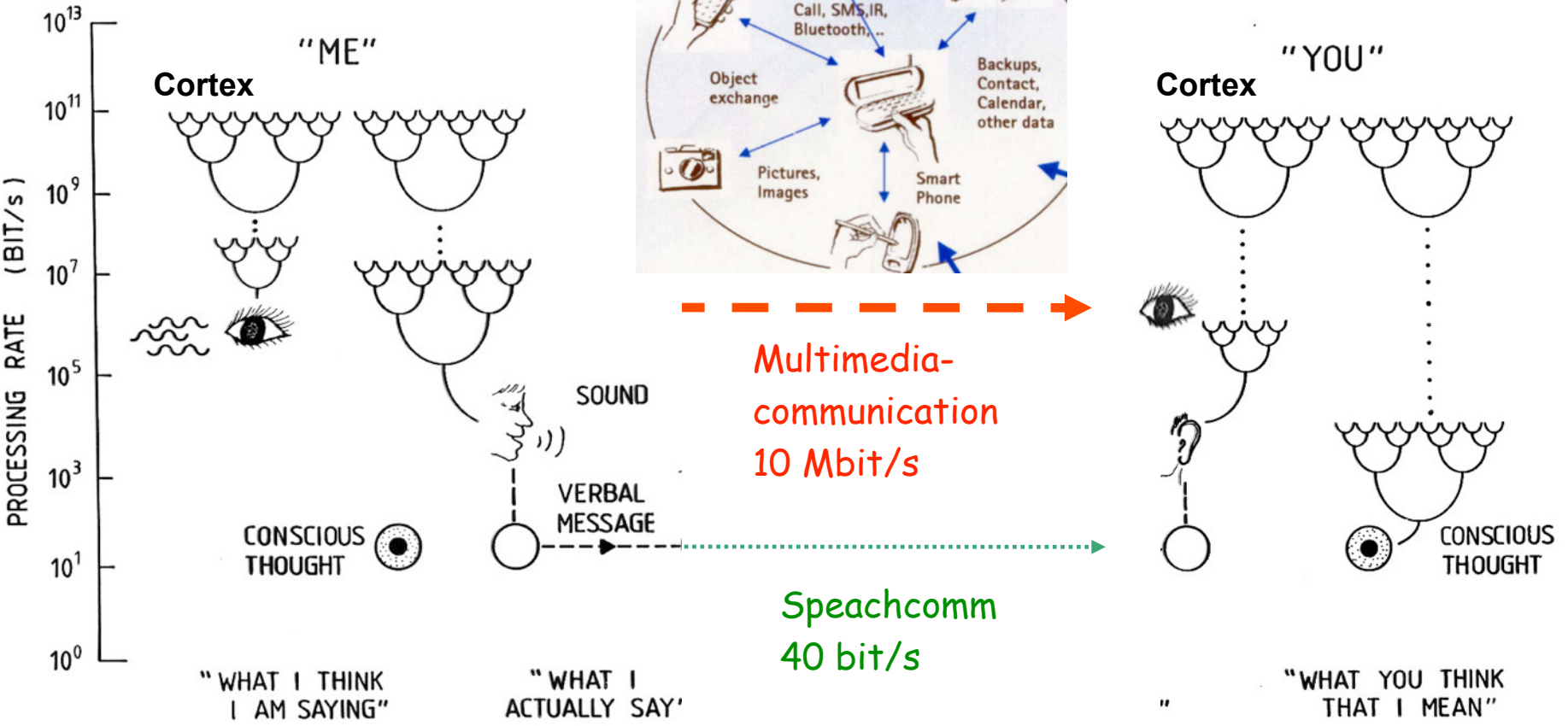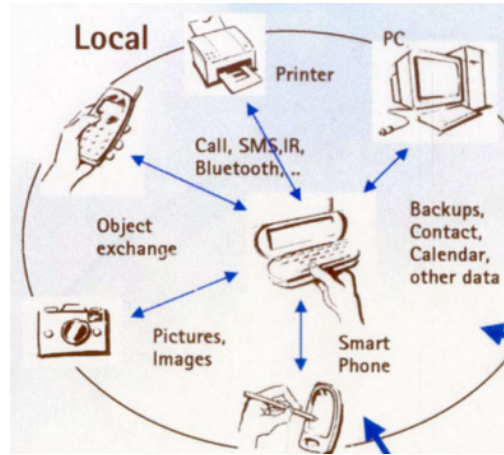
Source: Eriksson, Nokia/YrjöNeuvo

2. Difficulties to define consciousness

Too many features to fit into a holistic description:

i) Attention, awareness

Awareness

Attention focus

Time

Context space
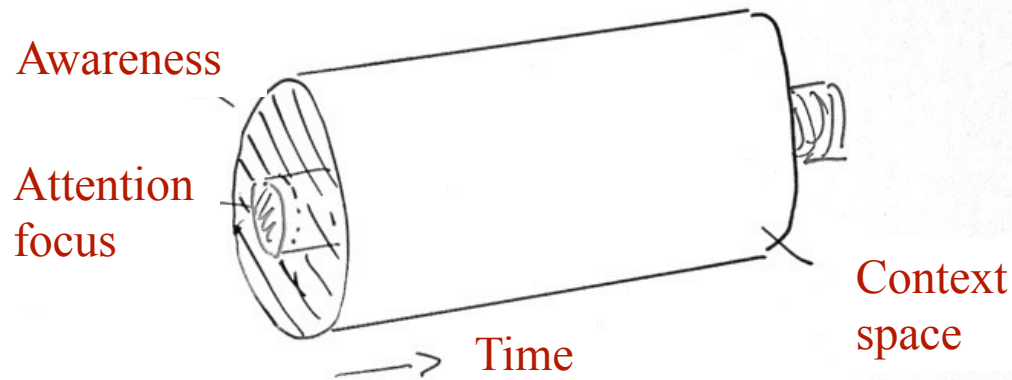
ii) Thinking, reasoning.
iii) An uninterrupted process, however performing different
   stages of awareness: awake, sleeping modes.
iv) Opposite to unconsiousness.
v) Cortical activity (EEG).

Source: Eriksson

Motivation:

the reason we are continuously acting and making plans

Intentionality

"Arrow of action"

Inherited hierarchy of "values" forming the reference frame of recognition and association:

(Maslow) — Self-fulfilment

Long term — Recogniton by fellow human beings

Medium and short term — Love and sex / Security

"Basic instinct": Food, shalter
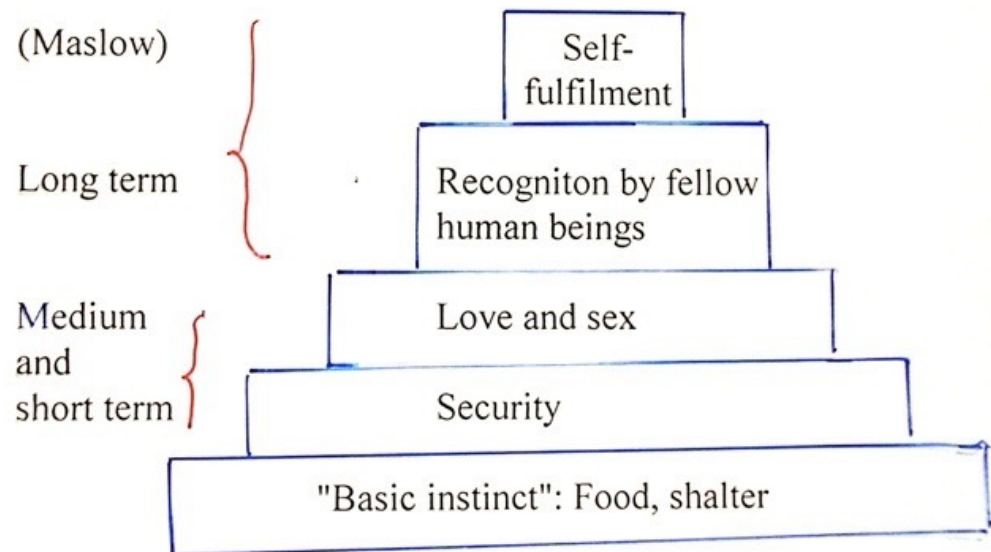
⟹ Gradient of Surprise: Potential to expand your knowledge base

Context controlled activation of relevant cortex centers:
- emotions
- ethical values
- etc.

Source: Eriksson

The making of a character

The world view of every human being is written in
- inherited nerve connections,
- memories of experience and
- the process of compressing information to a conscious thought.

The compression is also controlled by
- intentions,
- context,
- state of emotion and
- state of resolution.

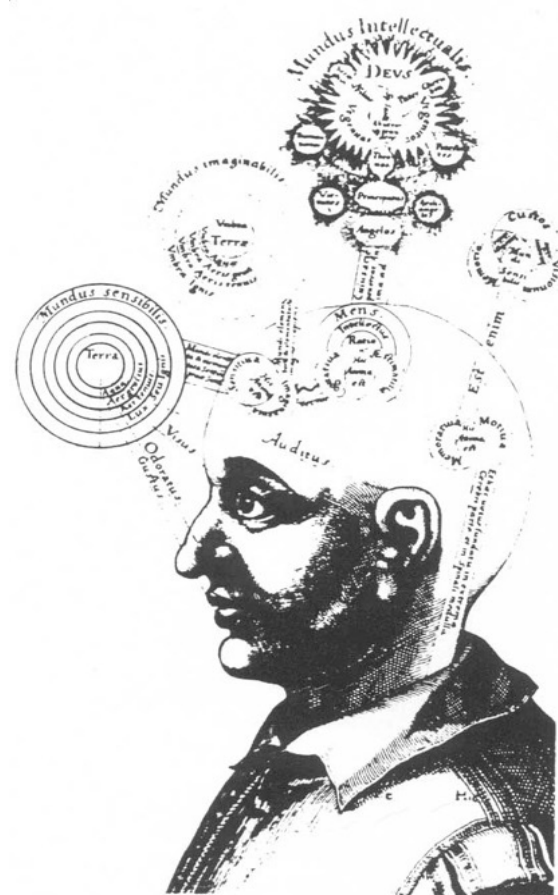**4 Man as a microcosm** of the universe is depicted in this diagram by the English alchemist Robert Fludd (1574–1637), harmoniously integrating cosmic principles. All the great traditions teach of the exalted cosmic status of man, if only implicitly. Hinduism has the idea of Primal Man, whose dispersal created the universe. The Judaeo-Christian tradition speaks of man being made in the "image of God". But these are conceptions of man in a state of perfection. Fallen man is neither microcosm, nor mirror of God, nor Primal Man. The work of spiritual discipline is to recover or reconstitute the latent microcosmic nature of the human self.

Summery of the most essential cognitive functions: Reasoning, timetravel and simulation

Consciousness as a continuous result display of reality simulations

PATTERN RECORN.

1. The brain experiences the outside world by pattern recognition of sensory signals. For this there must be a world model in the memory, adapted through a learning process.

CONTEXT, VIRTUAL SENSORY SIGNALS

2. The recognition process starts a search for a context producing associative signals, that in turn give birth to virtual sensory signals - in order to keep the sensory stimulus alive even with the "eyes closed".

VERBAL INPUT 30 BIT/S

3. The interpretation of verbal communication requires a transformation of a very scarce message to a virtual reality environment comprising 10^{10} times more information.

REASO-NING

4. In an "introvert" thinking process conscious attention checks the result in order to provide steering.

TIME-TRAVEL

5. The virtual reality model allows time travelling, i.e. free flotation in different time directions at unlimited speed.

REFE-RENCE FRAME

6. The simlation is subconsciously controlled by a reference frame, which is stipulated by
    - the context frame,
    - emotions,
    - ethics,
    - inherited boundaries,
    - etc. EDUCATION, EXPERIENCE OF CHILDHOOD

Wikipedia

Aalto 2010, J-T Eriksson

Source: Eriksson

Summary on consciousness

Humans perceive the real world through the representations of neural networks that are formed by cumulating experiences and learning processes. When brain functions are active, the cerebral cortex processes large volumes of information.

Conscious thought is a result of a massive information compression process, which originates from external sensations, such as sight and hearing, or from internal thoughts or associations, and is governed by the context and the emotional state.

The condensation of relevant information, which takes place in the subconscious, generates instructions for reactions as well as new cognitive input for the cortex.

A conscious thought itself should be considered as the control feedback of what the subconscious has already determined.

Source: Wikipedia: J.T Eriksson

What is intelligence?

The **short definition**:
Intelligence is the ability to make "correct" conclusions from a minimum amount of information (received outside information combined with knowledge).

The **longer definition**
includes the consideration of different skills, such as social, musical, verbal/linguistic, analytical/mathematical, etc. skills. Also inner motivation, enthusiasm, is an important human quality.

Moreover, one has to consider the level of education (knowledge base) and experience. In intelligence tests one tries to rule out these factors in order to compare basic "human" intelligence. In artificial intelligence, memory data and learned patterns are in a central position.

Artificial intelligence

Intelligence vs. Automation

Today's robots are just sophisticated **automata**:
- movements are programmed or learnt,

- "decisions" are choices based on a list of possible cases and restrictions.

- the final decision is the result of an algorithmic analysis of the possible outcomes using, say, fuzzy logic,

- "human" speech or gestures are responses to programmed alternatives chosen according to a complex logic agenda, cf. previous comments.

Source: Scientific American

Artificial intelligence

Intelligence vs. Automation

What do we expect from a humanly intelligent being?

- a slave doing all laborious household
  tasks,

- a pet being, a surrogate for a dog or a
  cat – or a child,

- a humanoid friend, social
  companion,

- an assistant arranging travels, movie
  tickets or

- a teacher providing information and
 advice through conversation.

Source:BBC Focus, September 2008

The Turing machine

Alan Turing, 1912 – 1954

- showed early sign of being a genius in mathematics,
- developed the algorithmic approach to computing,
- presented the principle of the modern computer suitable for algorithmic simulations, the **Turing machine,**
- presented the philosophical question of the testability of a machine being a machine or a human mind, the **Turing test**,
- was one of the key developers of a mechanical computer decoding the Nazi's Enigma messages.

The Turing machine
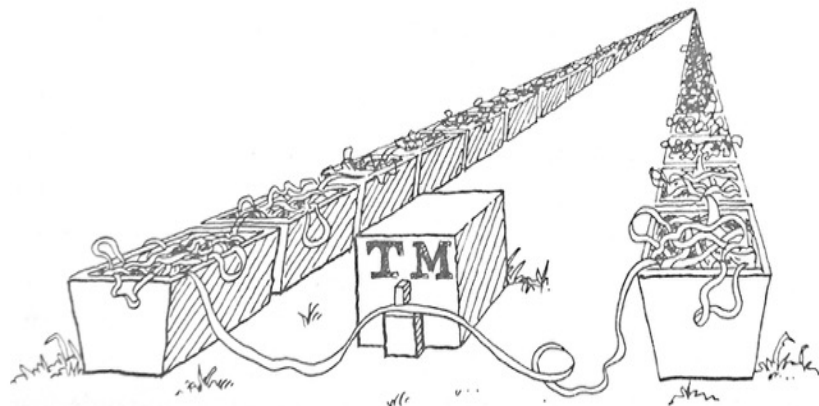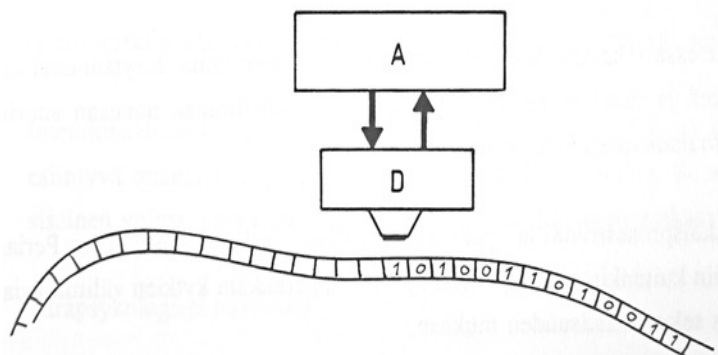
The Turing machine "computer" and "endless" memory:

A is the CPU having a logic operator and a limited working memory.

D is the actor reading the data strip, changing the mark on the data strip and moving the strip stepwise.

The logic operator in A gives the next order to D according to input from D and existing data in the working memory.

Source: Roger Penrose, The Emperor's New Mind

The Turing machine

The Turing machine is used as a thought experiment simulator of computer algorithms. For this purpose it's assumed that there is an endlessly long data strip available and that a simulation is not restricted by time.

The Turing machine metaphor has been used to analyze complex algorithmic problems.

One such problem is the "stop problem", which says that one can never predict if a computation according to a certain algorithm will ever stop. Turing showed that we can never prove that an algorithm has a "stop problem".

The Turing Test

The philosophic question behind the Turing test was that, will it ever be possible to build an intelligent computer, which in every sense matches a human being.

The thought experiment was connected to the Turing machine, which in itself was far too complicated for the layman to understand.

Turing asked, would it be possible that the machine could give answers to any kind of questions from a living person and never unveil being a machine.
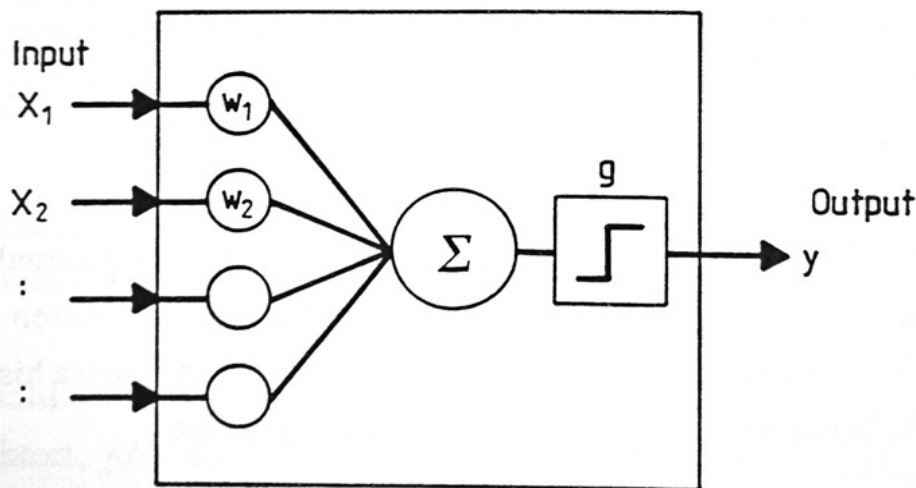
Protesters argued that a machine never could establish emotions, e.g. joy or sorrow. It is not creative and have no divine connection (the religion factor).

Artificial Neural Networks

Dendrit

Axon
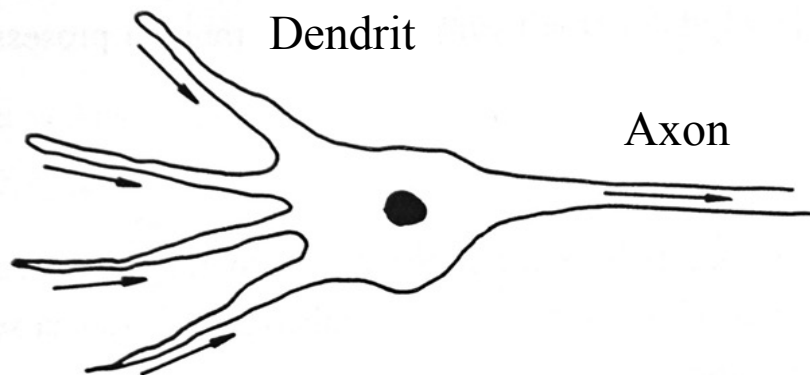
Schematic description of a neuron cell.

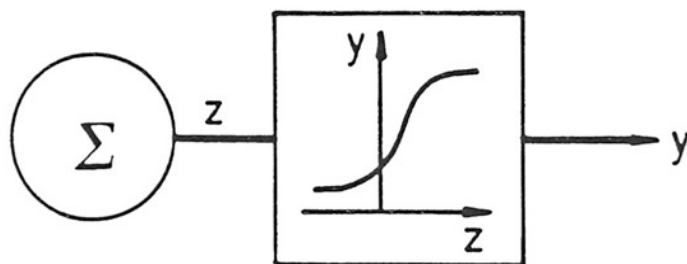The equivalent artificial electronic neuron.

Xi are the inputs from earlier neurons, Wi are the weighting factors, which are to be estimated in the pattern recognition process.

Σ is the summary element and the g-box "acceptor" function, i.e. the incoming signal will get the step-value if exceeding the threshold.


Source: Eriksson

Artificial Neural Networks

The Sigmoid function

$$y = \frac{1}{e^{-z} + 1}$$

The "acceptor" does not need to be a step function, but can also be shaped according to the Sigmoid curve. Such a function will give a smooth impact on the output signal comparable with the fuzzy logic technique.

Source: Eriksson

Pattern Recognition

Artificial neural network-

Multiplication in the human brain

Input task
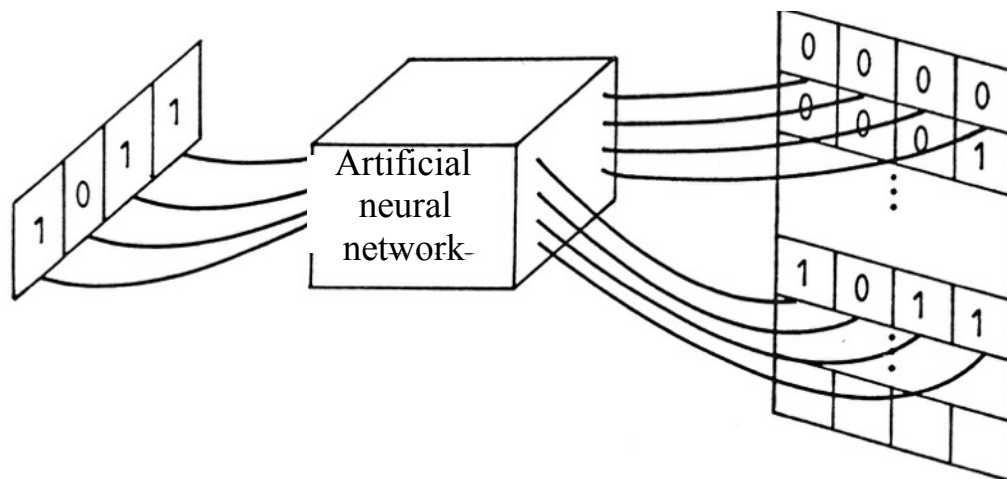
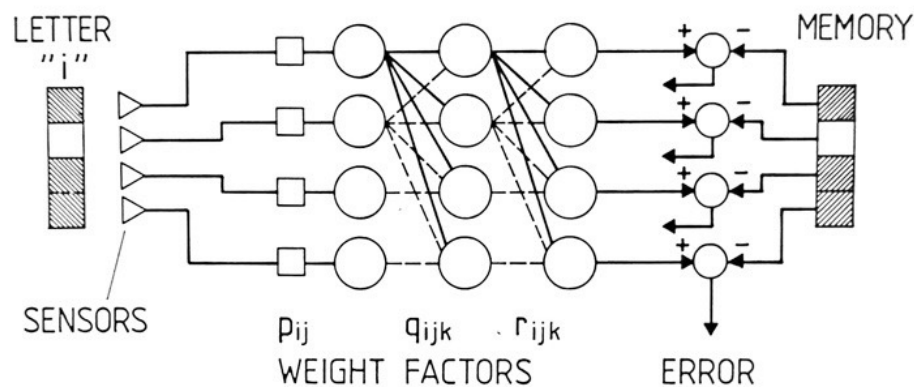The basic principle of pattern recognition.
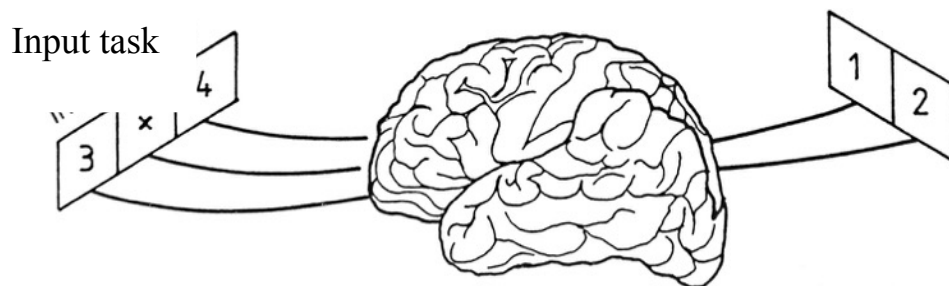
Humans are no calculators, when we solve arithmetic problems in our head, we identify an operation with the memory of the result: three times four is the same as twelve.

We can do this in many sophisticated ways with training.

Source: Eriksson

Pattern Recognition

LETTER "i"

MEMORY

SENSORS

p_{ij} q_{ijk} r_{ijk}

WEIGHT FACTORS   ERROR

RECOGNITION PROBLEM:

TO CHOOSE FACTORS p_{ij}, q_{ijk} AND r_{ijk} IN SUCH A WAY THAT THE ERRORS ARE MINIMIZED.

NEW INFORMATION:
MEMORY ADDRESS AND PATTERN OF WEIGHT FACTORS

Source: Eriksson

The main objective of an artificial neural network is to recognize an incoming signal (message) with an information strip in the own memory.

The standard network consists of three neuron layers: input layer, intermediate layer and output layer.

Using different mathematical approaches the weight factors can be optimized in such a way that the error is minimized.

As a result the network identifies the input and uses the own memory result for further operations (part of sentence, etc.). Actually the result is coded in the pattern of the weight factors.

Pattern Recognition

Examples where neural network pattern recognition is a useful tool:

1. Text and speech recognition.
2. Robotics, artificial vision.
3. Medical diagnostics, tomographic imaging of diseased organs.
4. Medical diagnostics, expert systems based on large symptom data bases.
5. Process control, continuos "pattern recognition" of the state of the process.

Source: Eriksson

Weather Forecasts using Neural Networks

The state of the weather at a certain time
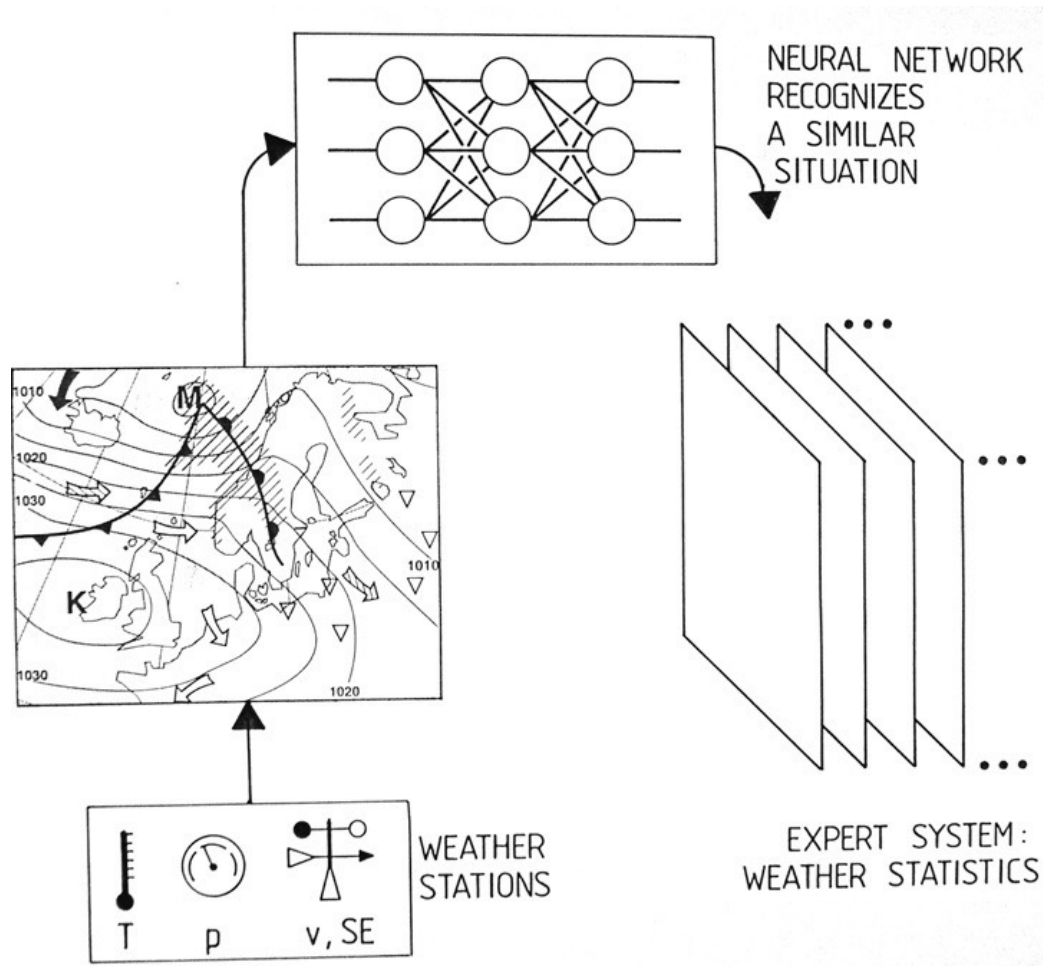
The forecast is made on the basis of historic records, "memory".

Source: Eriksson
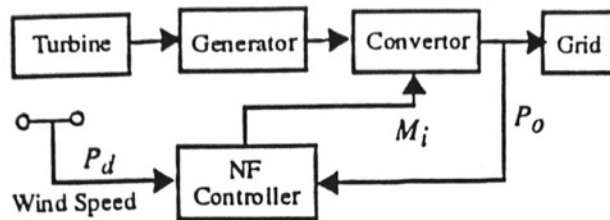
Controlling the wind generator power take off

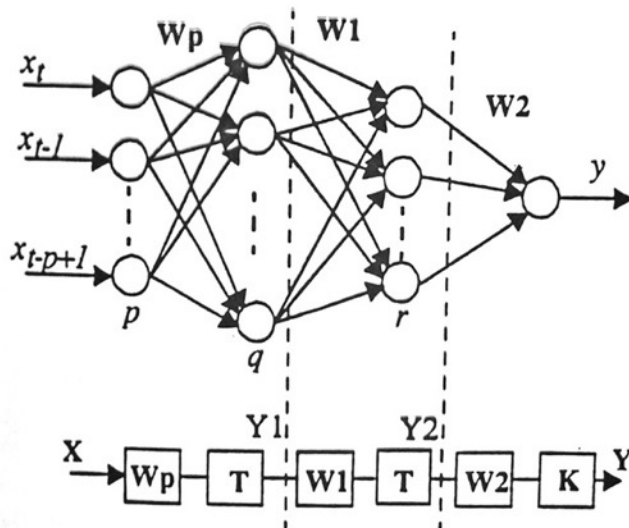Figure 1: WECS with neuro-fuzzy controller.

This case study is based on a thesis project aiming at developing techniques to use artificial neural networks in the prediction of wind turbine direction and generator maximum output.

The information came from a wind meter station some 500 m from the wind mill.

The mill had to be turned in advance to the wind eye and the power electronics of the generator had to be controlled in a way, which would take maximum advantage of wind torque at high speed winds.

Figure 1. Multilayer neural network

Source: Li Lin, Eriksson