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

Aalto 2010, J-T 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

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.

Source: Antonio Damasio, Descarte's Error, 1994
Input rates of sensory information

Sensory inputs

<table>
<thead>
<tr>
<th>Sensory Input</th>
<th>Rate (bit/s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vision</td>
<td>$10^7$</td>
</tr>
<tr>
<td>Sensing (skin)</td>
<td>$10^6$</td>
</tr>
<tr>
<td>Hearing</td>
<td>$10^5$</td>
</tr>
<tr>
<td>Smelling</td>
<td>$10^5$</td>
</tr>
<tr>
<td>Tasting</td>
<td>$10^3$</td>
</tr>
</tbody>
</table>

Source: Eriksson
Information flow and compression in the brain

Source: Eriksson, Nokia/YrjöNeuvo

Multimedia-communication
10 Mbit/s

Speechcomm
40 bit/s
Optimal use of information: Attention, awareness and the influence of context

2. Difficulties to define consciousness

Too many features to fit into a holistic description:

i) Attention, awareness

ii) Thinking, reasoning.

iii) An uninterrupted process, however performing different stages of awareness: awake, sleeping modes.

iv) Opposite to unconsciousness.

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)

Long term

Self-fulfilment

Recognition by fellow human beings

Medium and short term

Love and sex

Security

"Basic instinct": Food, shelter

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.
Consciousness as a continuous result display of reality simulations

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.

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".

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.

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

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

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

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.
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.
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

Schematic description of a neuron cell.

The equivalent artificial electronic neuron.

$X_i$ are the inputs from earlier neurons, $W_i$ are the weighting factors, which are to be estimated in the pattern recognition process.

$\sum$ is the summary element and the g-box “acceptor” function, i.e. the incoming signal will get the step-value if exceeding the threshold.
Artificial Neural Networks

The Sigmoid function

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.

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

Source: Eriksson
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

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.

Source: Eriksson
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 databases.
5. Process control, continuous “pattern recognition” of the state of the process.
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

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.

Source: Li Lin, Eriksson

Aalto 2010, J-T Eriksson