

Symbolism vs. Connectionism

There is another major division in the field of Artificial Intelligence:

- **Symbolic AI** represents information through symbols and their relationships. Specific Algorithms are used to process these symbols to solve problems or deduce new knowledge.
- **Connectionist AI** represents information in a distributed, less explicit form within a network. Biological processes underlying learning, task performance, and problem solving are imitated.

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Symbolic AI

One of the paradigms in symbolic AI is propositional calculus.

In propositional calculus, features of the world are represented by **propositions**.

Relationships between features (constraints) are represented by **connectives**.

Example:

LECTURE_BORING \wedge TIME_LATE \supset SLEEP

This expression in propositional calculus represents the fact that for some agent in our world, if the features LECTURE_BORING and TIME_LATE are both true, the feature SLEEP is also true.

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The Language

Atoms:

The atoms T and F and all strings that begin with a capital letter, for instance, P, Q, LECTURE_BORING, and so on.

Connectives:

- \vee "or"
- \wedge "and"
- \supset "implies" or "if-then"
- \neg "not"

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Rules of Inference

We use **rules of inference** to generate new expressions from existing ones.

One important rule is called **modus ponens** or the **law of detachment**. It is based on the tautology $(P \wedge (P \supset Q)) \supset Q$. We write it in the following way:

P	The two hypotheses P and $P \supset Q$ are written in a column, and the conclusion below a bar, where \therefore means "therefore".
$P \supset Q$	
$\therefore Q$	

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Rules of Inference

$\frac{P}{\therefore P \vee Q}$ <p>Addition</p>	$\frac{\neg Q \quad P \supset Q}{\therefore \neg P}$ <p>Modus tollens</p>
$\frac{P \wedge Q}{\therefore P}$ <p>Simplification</p>	$\frac{P \supset Q \quad Q \supset R}{\therefore P \supset R}$ <p>Hypothetical syllogism</p>
$\frac{P \quad Q}{\therefore P \wedge Q}$ <p>Conjunction</p>	$\frac{P \vee Q \quad \neg P}{\therefore Q}$ <p>Disjunctive syllogism</p>

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Rules of Inference

Example:

"Gary is intelligent, or he is a good actor.
If Gary is intelligent, then he can count from 1 to 10.

Gary can only count from 1 to 2.
Therefore, Gary is a good actor."

Propositions:

I: "Gary is intelligent."

A: "Gary is a good actor."

C: "Gary can count from 1 to 10."

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Rules of Inference

I: "Gary is intelligent."
A: "Gary is a good actor."
C: "Gary can count from 1 to 10."

Step 1: $\neg C$	Hypothesis
Step 2: $I \supset C$	Hypothesis
Step 3: $\neg I$	Modus Tollens Steps 1 & 2
Step 4: $A \vee I$	Hypothesis
Step 5: A	Disjunctive Syllogism Steps 3 & 4

Conclusion: **A** ("Gary is a good actor.")

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Computers vs. Neural Networks

"Standard" Computers	Neural Networks
one CPU	highly parallel processing
fast processing units	slow processing units
reliable units	unreliable units
static infrastructure	dynamic infrastructure

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Why Artificial Neural Networks?

There are two basic reasons why we are interested in building artificial neural networks (ANNs):

- **Technical viewpoint:** Some problems such as character recognition or the prediction of future states of a system require massively parallel and adaptive processing.
- **Biological viewpoint:** ANNs can be used to replicate and simulate components of the human (or animal) brain, thereby giving us insight into natural information processing.

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Why Artificial Neural Networks?

Why do we need another paradigm than symbolic AI for building "intelligent" machines?

- Symbolic AI is well-suited for representing **explicit** knowledge that can be appropriately formalized.
- However, learning in biological systems is mostly **implicit** – it is an adaptation process based on uncertain information and reasoning.
- ANNs are inherently parallel and work extremely **efficiently** if implemented in parallel hardware.

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How do NNs and ANNs work?

- The "building blocks" of neural networks are the **neurons**.
- In technical systems, we also refer to them as **units** or **nodes**.
- Basically, each neuron
 - receives **input** from many other neurons,
 - changes its internal state (**activation**) based on the current input,
 - sends **one output signal** to many other neurons, possibly including its input neurons (recurrent network)

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How do NNs and ANNs work?

- Information is transmitted as a series of electric impulses, so-called **spikes**.
- The **frequency** and **phase** of these spikes encodes the information.
- In biological systems, one neuron can be connected to as many as **10,000** other neurons.
- Usually, a neuron receives its information from other neurons in a confined area, its so-called **receptive field**.

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How do NNs and ANNs work?

- In biological systems, neurons of similar functionality are usually organized in separate **areas** (or **layers**).
- Often, there is a **hierarchy** of interconnected layers with the lowest layer receiving sensory input and neurons in higher layers computing more complex functions.
- For example, neurons in macaque visual cortex have been identified that are activated only when there is a **face** (monkey, human, or drawing) in the macaque's visual field.

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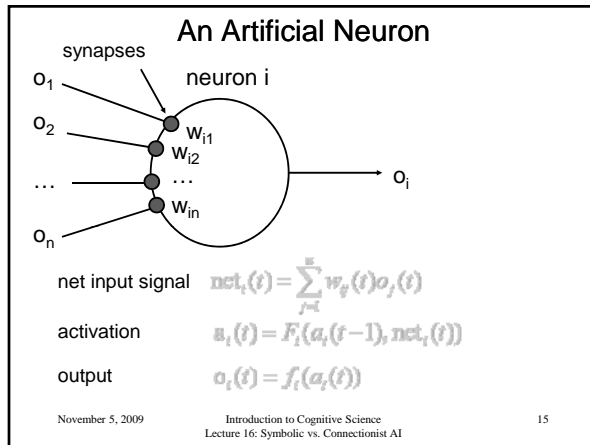
How do NNs and ANNs work?

- NNs are able to **learn** by **adapting their connectivity patterns** so that the organism improves its behavior in terms of reaching certain (evolutionary) goals.
- The strength of a connection, or whether it is excitatory or inhibitory, depends on the state of a receiving neuron's **synapses**.
- The NN achieves **learning** by appropriately adapting the states of its synapses.

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