

Artificial Intelligence (AI)

## Symbolic and Sub-symbolic AI

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# Is there a definition of AI?

**Pseudo-definitions** found in textbooks usually adopt a totally arbitrary definition-by-extension approach, such as: “*AI regards machines capable of perception, learning, communicating and navigation in complex environments, ..., blabla*”.

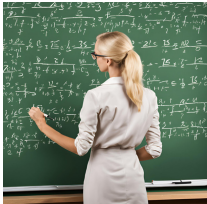
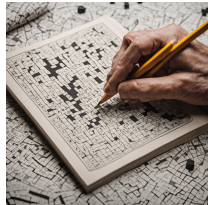
**In fact, there is not a universal, exhaustive, and univocal definition of AI.**

Defining AI seems to be easy: *AI is the science that studies and builds machines that possess intelligence.*

Unfortunately, **there is no universal, exhaustive, and univocal definition of “intelligence”**

This is due to three major reasons:

(1) the term “intelligence” refers to many different and often unrelated things





(3) different schools of specialist disciplines, namely

- ▶ psychology
- ▶ philosophy
- ▶ cognitive sciences
- ▶ anthropology
- ▶ ...

have not yet converged to a shared, univocal, exhaustive notion of “intelligence” .

# Towards a definition of AI: Experimentalism

In 1963, the experimental psychologists pointed out that all we can do scientifically is to focus our attention on **observable behaviors** that can be said to be the effect of '**intellectual activities** and subjected to replicable experiments. Here is their list.

1. **Induction**: developing ("learning") universal models from individual stimuli or instances;
2. **Subsumption**: tracing back a stimulus to the corresponding model ("recognition")
3. **Reasoning**: chain of logical/mathematical deductions starting from known models, even in absence of external stimuli
4. **Problem solving**: creatively combining activities (1), (2), and (3) to find solutions to new, still unsolved problems .

**We define AI as the science that studies and builds machines that realize at least one process (behavior) that belongs to the aforementioned list.**

# Symbolic vs. sub-symbolic AI

AI can be split into two major branches:

- ▶ **Symbolic AI**: it pertains the logical and syntactic manipulation of symbols belonging to a **finite and discrete alphabet**. It is the traditional framework for long-established AI.

*Examples*: search in finite-state spaces, puzzle solving, chess playing, rule-based chatbots.

- ▶ **Sub-symbolic AI**: it models, learn, and recognize continuous-valued multi-dimensional vectors (or, sequences and graphs of such vectors) by means of probabilistic approaches, deep neural networks, kernel methods, etc.

*Examples*: speech recognition and generation, face recognition, MRI or PET-CT scanograms analysis.

*Remark*: some tasks are inherently symbolic but are better accomplished by modern sub-symbolic algorithms. Major instance: **text generation** in a given natural language, currently achieved via LLMs based on deep neural nets (the *transformers*).