Symbol Grounding in AI: A Historical Overview and Recent Neural-Symbolic Approaches

SIAUS

Escuela Técnica Superior de
Ingeniería Informática

UNIVERSIDAD D SEVILLA
1505

Early days of AI

Cibernética (Norbert Wiener…)

> “Cybernetics: Or Control and Communication in the Animal and the Machine” 1948

Walter Pitts and Warren S. McCulloch

> “A Logical Calculus of the Ideas Immanent in Nervous Activity” 1943
>
> “How we know universals; the perception of auditory and visual forms” 1947

UNIVERSALS - PERCEPTION - CONNECTIONIST PARADIGM

Expert Systems

Focus on intelligent behaviour exhibited by humans

Intelligent behaviour is understood conceptual / semantic

- Logic
- Reasoning, inference (Induction: ID3 …)

Language as the syntax of intelligence

- Rudolf Carnap. “The Logical Syntax of Language” 1938
- Problems … forcing propositional logics into language: Fauconnier

LOGICS - REASONING - SYMBOLIC PARADIGM

Symbols

A symbol is (normally) an encoding of some aspect of the world

They are usually consistent and simple (easy to replicate)

Symbols refer to real or imaginary things that exist in our minds or in the world

Language is expressed through symbols (auditory or graphic)

When we use symbols from language to encode some aspect of the world,
then it becomes a **semantic encoding**

Grounding symbols

The relationship between symbols and the realities (or fictions) they encode is … not simple?

Bailaora gitana

Grounding symbols

The relationship between symbols and the realities (or fictions) they encode is … not simple?

Bailaora gitana

Lady in red ?

Señora con carácter ?

SYMBOLIC MODELS - HUMAN BIAS

Grounding symbols

Language and conceptual human cognition are very rich and flexible

Example: an ***expensive*** apartment

In a symbolic model, what is the reality being encoded by the term ***expensive***?

More than EUR 200k? More than EUR 400k? …?

Fuzzy models accommodate a bit of flexibility but ultimately are also driven by human bias

The Chinese Room argument

John R. Searle (1932 -)
“Minds, brains, and programs” 1980

He points out that “if the Turing test were conducted in Chinese, then he himself, Searle (who does not understand Chinese), could execute the same program that the computer was executing without knowing what any of the words he was processing meant. So if there is no meaning going on inside him when he is implementing the program, there is no meaning going on inside the computer...”

- Very interesting in light of the recent LLMs
- Unfortunately we do not have recent comments from Searle on LLMs

LLMs and the Chinese Room argument

Some authors claim that Some philosophers propose the "Virtual Mind" response, suggesting that while the individual components of a system (e.g., the person in the Chinese Room) may not understand the language, the system as a whole could generate a virtual mind that does.

This perspective implies that the collective operation of complex models like LLMs might give rise to an emergent understanding, even if individual parts lack comprehension.

More: https://plato.stanford.edu/entries/chinese-room/

The Symbol Grounding Problem

Formulated by Stevan Harnad
“The Symbol Grounding Problem” 1990

1. “How can the semantic interpretation of a formal symbol system be made intrinsic to the system, rather than just parasitic on the meanings in our heads?”

2. “How can the meanings of the meaningless symbol tokens, manipulated solely on the basis of their (arbitrary) shapes, be grounded in anything but other meaningless symbols?”

No formal definition of the problem? Is that a problem? : P

The Symbol Grounding Problem (SGP)

Reformulated by Taddeo and Floridi
“Solving the symbol grounding problem: A critical review of fifteen years of research” 2005

They introduce the Zero Semantical Commitment Condition or ‘Z condition’

1. “No semantic resources (some virtus semantica) should be presupposed as already pre-installed in the artificial agent”

2. “No semantic resources should be uploaded from the ‘outside’ by some deus ex machina already semantically-proficient”

SGP

In short, how to bridge or move,

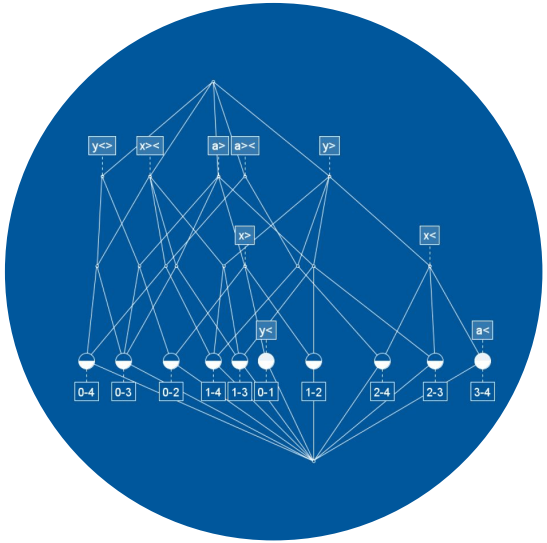
From perception / **sensory data**,

To semantic / **symbolic structures**

Without human **intervention**

SGP

Without human intervention



sensory data

semantic structures

The Symbol Grounding Problem

No solution for many years despite strong efforts

Arguably, still no solution to-date

SHIFT TO MACHINE LEARNING - PERCEPTION - INDUCTION

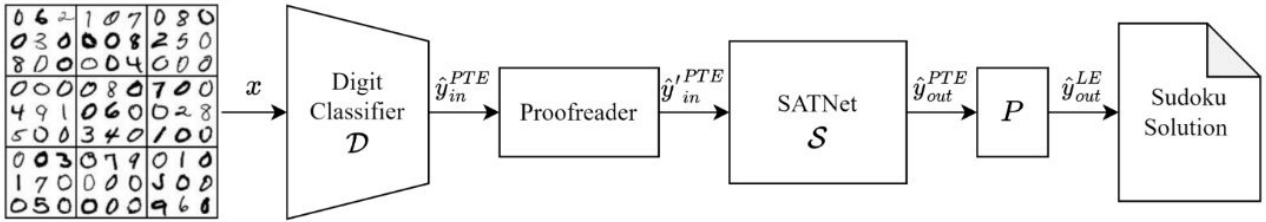
Neural-Symbolic approaches

Po Wei Wang, Priya L. Donti, Bryan Wilder, and Zico Kolter.
“Satnet: Bridging deep learning and logical reasoning using a differentiable satisfiability solver” 2019

- Represents or transforms a problem as a MAXSAT problem
- Allows to tackle logic-based problems with deep learning

Neural-Symbolic approaches

Sever Topan, David Rolnick, and Xujie Si.
“Techniques for symbol grounding with satnet” 2021



Our proposed framework consists of the following steps:

1. Clustering
2. Self-Grounded Training
3. Proofreading

Neural-Symbolic approaches

Wang-Zhou Dai, Qiuling Xu, Yang Yu, and Zhi-Hua Zhou.
“Bridging machine learning and logical reasoning by abductive learning” 2019