Analogical Representations

Aaron Sloman (1971)

- Interactions between philosophy and artificial intelligence: The role of intuition and non-logical reasoning in intelligence
  - Philosophical issues can be enriched considerably through artificial intelligence
  - Influential work triggering many discussions about representation types

Analogical Representations (Aaron Sloman, 1971): Intuitive Reasoning

- Non-logic-based reasoning = illogical reasoning ???
- Non-linguistic representations
- Analogical representations, e.g. diagrams or scaled models
- Are diagrams essential for a proof or are they merely psychological padding?

What are Formal Languages?

- Let $\Sigma$ be an Alphabet.
- A (formal) language is a(ny) subset of $\Sigma^*$
- Formal Languages have precisely defined
  - Syntax (surface structure)
  - Semantics (meaning)
- i.e., precisely defined syntactic and semantic rules

What are Formal Languages?

- Logical valid inference:
  - $p_1, p_2, p_3 \Rightarrow c$
  - $\Rightarrow (T, T, T; F)$ is impossible
  - According to syntactic and semantic rules
- Generalized valid inference:
  - $r_1, r_2, r_3 \Rightarrow r_N$
  - $\Rightarrow (r$s represent different things) is impossible
  - According to syntactic and semantic rules
Analogical Representations (Aaron Sloman, 1971): Valid inferences

- Analogical vs. Fregean
  - Analog-ical vs. Frege-an (structure-preserving – not structure-preserving)
  - Analog vs. Digital (continuous – discrete)
  - Images, maps, scaled models are largely analogical, predicate calculus (invented by Gottlob Frege), programming languages, natural languages are largely (but not exclusively) Fregean

Correspondence relations may be complex

- Context-dependent interpretation may be required:
- “above” in the representation may mean “above”, “farther”, “closer”, “farther and higher”, etc., in the real world, depending on local context

Fregean Representations (in contrast)

- Only one kind of relation between parts of a relation: relation between “function-signs” and “argument-signs”
- Example:
  The brother of the wife of Tom
  Two function-signs: “the brother of ( )”
  Two argument-signs: “Tom”
  → the brother of (the wife of (Tom))
### Analogical Representations (Aaron Sloman, 1971):
#### Fregean Representations
- No correspondence between representing and represented configuration required
- Possibly correspondence with structures of procedures, by which the object is identified (structure of a route through a complex data structure)
- Predicate calculus is exclusively Fregean (compositionality of connectives like \( \not \), and, etc.)

### Analogical Representations (Aaron Sloman, 1971):
#### Natural Languages and Programming Languages
- Partially analogical
  - linear sequence of program segments corresponds largely to temporal process sequence
  - similar with (most) narratives
- Advantage of Fregean system: structure of the medium does not constrain the multitude of structures that can be represented or described
- Very general formation, representation, and inference rules can be applied to Fregean languages for very different domains

### Analogical Representations (Aaron Sloman, 1971):
#### Restrictions for Analogical Representations
- Difficult or impossible to design a single two-dimensional analogical system for the representation of political, mechanical, musical, and chemical structures and processes
- Trade-off: Generality vs. Efficiency
  - Fregean systems are general
  - Analogical representations are more efficient

### Sloman’s “Afterthoughts” (1975)
- Terminological Explanation:
  - Fregean vs. symbolic (too general), verbal (too special)
- Common misrepresentations (8)

### Misrepresentations (1)
- “Analogical representations are continuous, Fregean representations discrete.”
- Counter-example:
  A list whose elements are ordered according to the order of what they represent.

### Misrepresentations (2)
- “Analogical representations are 2-dimensional, Fregean representations are 1-dimensional.”
- Counter-example:
  - 1D analogical representations (e.g. list)
  - 2D Fregean mathematical notation (integral or summation symbols, normal representation of fractions)
Misrepresentations (3)

• “Analogical representations are isomorphic with what they represent.”

Counter-example:
• 2D pictures need not be isomorphic with the 3D scenes they represent analogically.

Misrepresentations (4)

• “Fregean representations are symbolic, analogical representations non-symbolic.”

Counter-example:
• “Symbolic” includes both maps and sentences of a language
  – the notion symbolic often is used in a sloppy way

Misrepresentations (5)

• “Sentences in a natural language are all Fregean.”

Counter-example:
• Some English sentences function in a partially analogical way:
  – She shot him and kissed him
  – vs.
  – She kissed him and shot him
  – Tom, Dick and Harry stood in that order

Misrepresentations (6)

• “Analogical representations are complete”
  – while Fregean representations may be incomplete: Tom stood between Dick and Harry
    – no information about other people

• Counter-example:
• A map or sketch map showing only some of the towns

Misrepresentations (7)

• “Fregean representations have a grammar, analogical representations do not.”

• It is easy to define a grammar for lists and trees frequently used as analogical representations in computing.

Misrepresentations (8)

• “Although digital computers can use Fregean representations, only analog computers can handle analogical representations”

• Should be clear by now.
**Good for**

- Constraining / organizing the search space
- Efficient solution of frequent problems (dealing with space)
- Symbol grounding (embodiment in 1971!)
- Behaving intelligently

**Issues**

- Requires highly specialized procedures to make efficient use of (cf. Palmer)
- Reduced generality
- Reflect intelligence / intelligently
- Distinction difficulties (apart from extreme cases)

**Open Questions**

- Which type of representation system to use for a given problem?
- Realization (in computers)?