

Cognitive Systems

Foundations of Information Processing
in Natural and Artificial Systems

Lecture 9

Mental Representations



Mental Representations

- Fundamental Aspects of Cognitive Representation
- Analogical Representations
- Mental Models
- Preferences

9.0

2

Fundamental Aspects of Cognitive Representation

- Knowledge Representation Theory
- Goal: To understand the nature of (internal and external) representations of the world
- Concise theory of cognitive representations that can be tested by methods of psychology and behavior research

9.1

3

Knowledge Representation Theory

- Meta-Theory of representations to describe properties of representations
- To help us understand *mental* representations, we will first look at properties of *external* representations

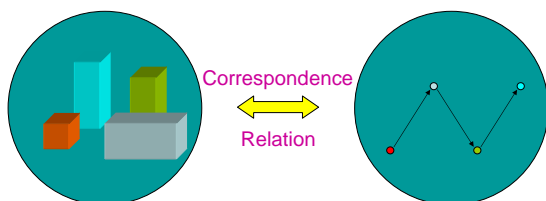
9.1.1

4

Representation Theory

Represented World

Representing World



[Palmer, 1978]

9.1.2

5

Representation System

Five components of a representation system:

- 1) the represented world W_1 ,
- 2) the representing world W_2 ,
- 3) what aspects of the represented world are being modeled?
- 4) what aspects of the representing world are doing the modeling?
- 5) what are the correspondences between the two worlds?

9.1.3

6

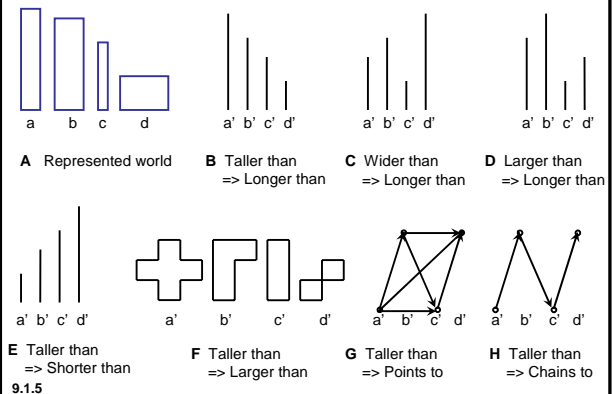
Two Worlds and their Relations

- Represented World: A world *about which* we want to make statements / assertions
- Representing World: A world *in which* we make statements / assertions / inferences
- In cognitive science, it is very important to distinguish the two worlds (e.g. terminologically); it easily can happen that the representing world is identified with the 'true world'.
- A representation always is a representation *of something*.
- Can we make sure that the result of an operation in the representing world represents something in the represented world?

9.1.4

7

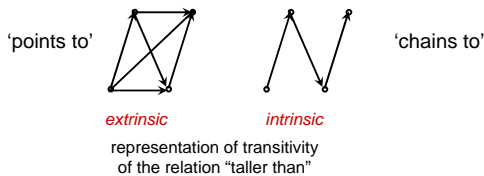
Examples of Spatial Representation



Intrinsic vs. extrinsic representation

A representing world that necessarily maintains a property of the represented world represents this property *intrinsically*, otherwise it represents this property *extrinsically*.

Example:



Analogical Representations

9.2

10

Analogical Representations

- Aaron Sloman: Interactions between philosophy and artificial intelligence: The role of intuition and non-logical reasoning in intelligence (1971)
- Philosophical issues can be enriched considerably through artificial intelligence

9.2.1

11

Intuitive Reasoning

- Non-logic-based reasoning = illogical reasoning ???
- Non-linguistic representations
- Analogical representations, e.g. maps or scaled models

9.2.2

12

“Analogical” and “Analog”

- Analog-ical vs. Frege-an
(*structure-preserving – not structure-preserving*)
- Analog vs. Digital
(*continuous – discrete*)

9.2.3

13

How are Animals Able to Cope with their Spatio-Temporal Environment?

- They require a suitable conceptual and perceptual apparatus
- External and internal representations (in the world / for thinking / in the computer)
- Are diagrams essential for a proof or are they merely psychological padding?

9.2.4

14

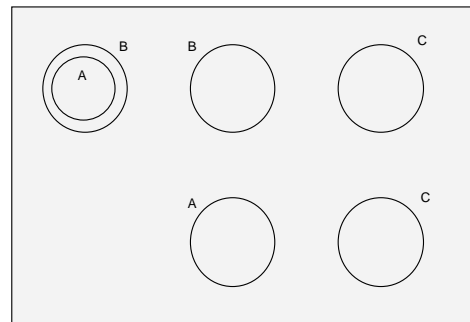
What are Formal Languages?

- Predicate logic?
- Programming languages?
- The “Language” of maps?
- ... of sketches?
- *Logically valid inferences are a special case of something more general*

9.2.5

15

What means *Valid Inference*?



9.2.6

16

Analogical vs. Fregean Forms of Representation

- How can we decide which type of representation system to use in a given situation?
- Specific problem-dependent vs. general problem-independent strategies
- Images, maps, scaled models are largely *analogical*, predicate calculus (invented by Gottlob Frege), programming languages, natural languages are largely (but not exclusively) *Fregean*

9.2.7

17

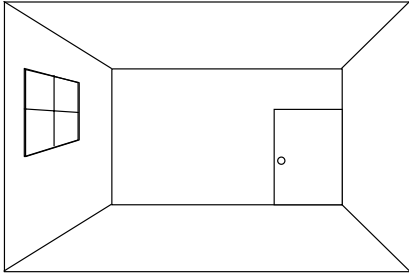
Difference between Analogical and Fregean Representations

- In an *analogical* system properties of and relations between parts of the representing configuration represent properties of and relations between parts of a complex represented configuration
- The structure of the representation reflects the structure of the represented world

9.2.8

18

Example



9.2.9

19

Correspondence Relation may be Complex

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

9.2.10

20

Fregean Representations

- Only one kind of relation between parts of a relation: relation between function symbol and argument symbol

- **Example:**

The brother of the wife of Tom

Two function symbols: The brother of ()
 wife of ()

Two argument symbols: Wife of Tom
 Tom

brother (wife (Tom))

9.2.11

21

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.)

9.2.12

22

Natural Languages and Programming Languages

- Partially analogical: linear sequence of program segments corresponds largely to temporal process sequence
- 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

9.2.13

23

Restrictions for Analogical Representations

- E.g. uniform analogical system for the representation of political, mechanical, musical, and chemical structures and processes
- Trade-off: Generality vs. Efficiency

9.2.14

24

Sloman's Afterthoughts

- Terminological Explanation:

Fregean vs. symbolic (too general),
verbal (too special)

9.2.15

25

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.

9.2.16

26

Misrepresentations (2)

- "Analogical representations are 2-dimensional, Fregean representations are not."

Counter-example:

- 1-d analogical representations (e.g. list)
- 2-dimensional and Fregean mathematical notation (Integral or summation symbols, normal representation of fractions)

9.2.17

27

Misrepresentations (3)

- "Analogical representations are isomorphic with what they represent."

Counter-example:

- 2-d pictures which are not isomorphic with the 3-d scenes they represent analogically

9.2.18

28

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.)

9.2.18

29

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*

9.2.19

30

Misrepresentations (6)

- “Analogical representations are complete” (while Fregean representations may be incomplete: *Tom stood between Dick and Harry*)
- Counter-example:
- A map or sketch map showing only some of the towns

9.2.20

31

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.

9.2.21

32

Misrepresentations (8)

- “Although digital computers can use Fregean representations, only analog computers can handle analogical representations
- See (1) and (2) above.

9.2.22

33

Mental Models

- Human beings translate external events into internal models and reason by manipulating these symbolic representations.

Kenneth Craik 1943

- By a model we thus mean any physical or chemical system which has a similar relation-structure to that of the processes it imitates.

9.3

34

Understanding Discourse

- The spoon is to the left of the knife
- The plate is to the right of the knife
- The fork is in front of the spoon
- The cup is in front of the knife

spoon knife plate
fork cup

- Interpretation by inspection

9.3.1

35

Indeterminate Descriptions

- The spoon is to the left of the knife
- The plate is to the right of the spoon
- The fork is in front of the spoon
- The cup is in front of the knife

spoon knife plate spoon plate knife
fork cup fork cup

- In case of indeterminate models, persons tend to rely more on the linguistic description than on the model

9.3.2

36

Preferred Mental Models

- Certain mental models are generated more easily than others
- Example:
 - the reception immediately precedes the dinner
 - the dinner takes place during the final rehearsal

The following relations are possible:

- the reception overlaps the rehearsal
- the reception takes place during the rehearsal
- the reception starts at the same time as the rehearsal

9.4

37

Discussion

- People frequently are happy when they found one (of several possible) solutions
- People are not good at pursuing several hypotheses simultaneously

9.4.1

38

Next week

- Mental images
 - mental rotation
 - mental scanning
 - attention

9.5

39