Cognitive Systems

Foundations of Information Processing in Natural and Artificial Systems

Lecture 9

Mental Representations

Universität Bremen

Mental Representations

(1) Fundamental Aspects of Cognitive Representation

(2) Analogical Representations

(3) Mental Models

(4) Preferences

Fundamental Aspects of Cognitive Representation

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

Knowledge Representation Theory

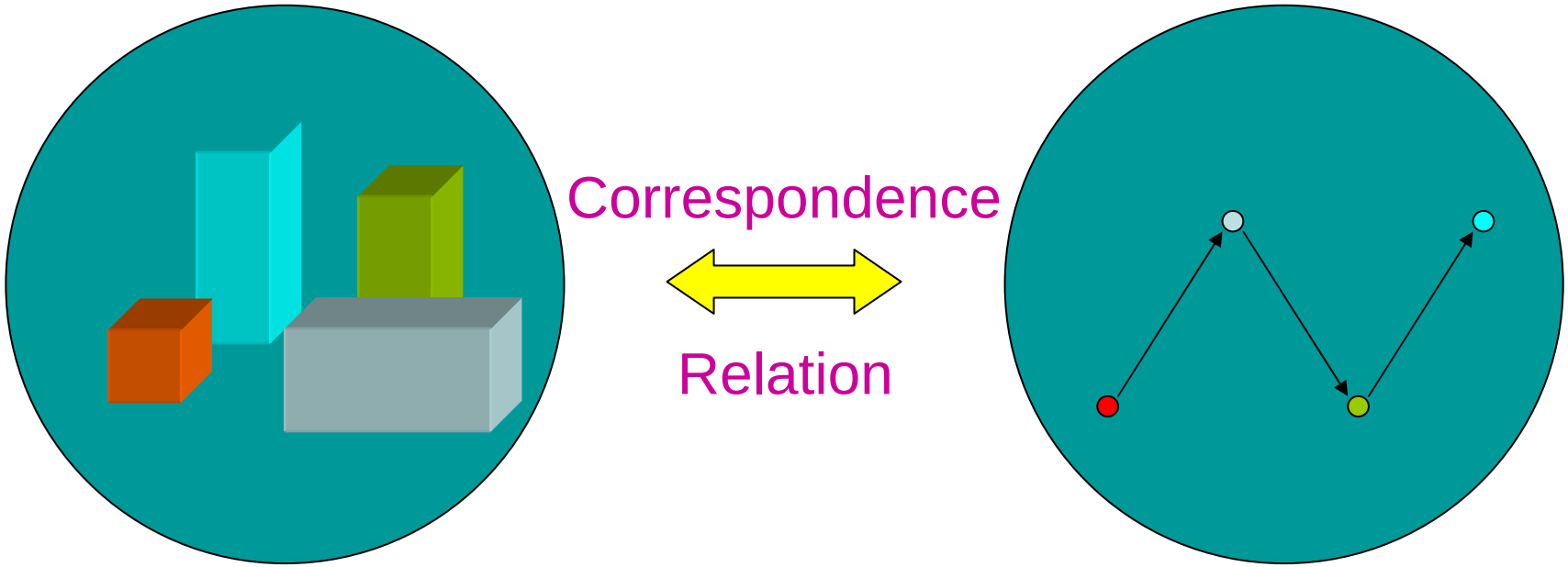
- Meta-Theory of representations to describe properties of representations

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

Representation Theory

Represented World

Representing World



[Palmer, 1978]

Representation System

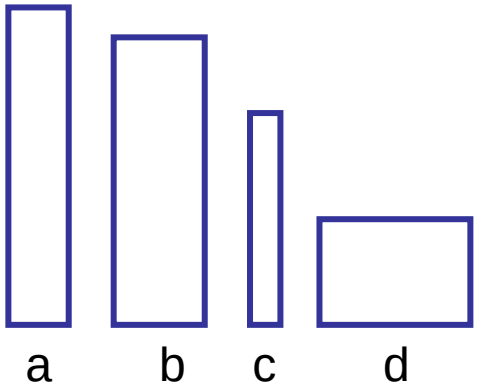
Five components of a representation system:

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?

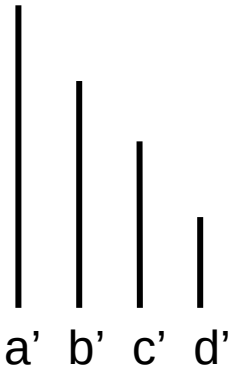
Two Worlds and their Relations

- 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?

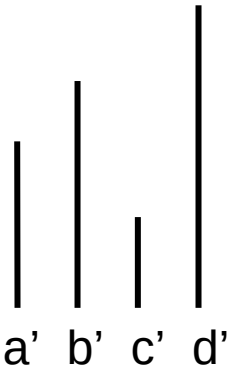
Examples of Spatial Representation



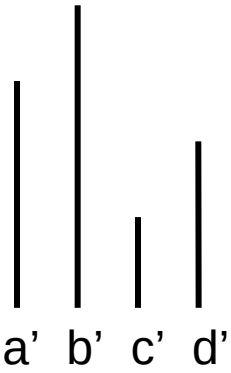
A Represented world



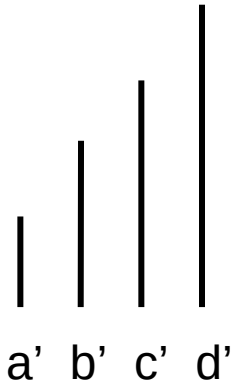
B Taller than
=> Longer than



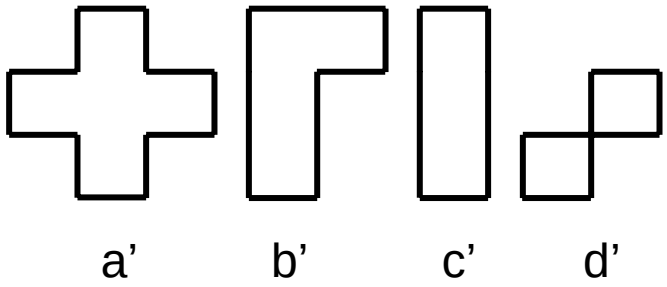
C Wider than
=> Longer than



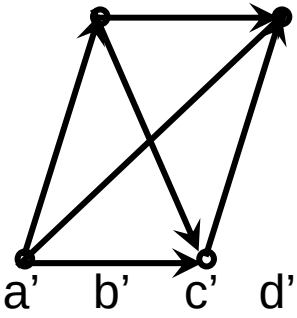
D Larger than
=> Longer than



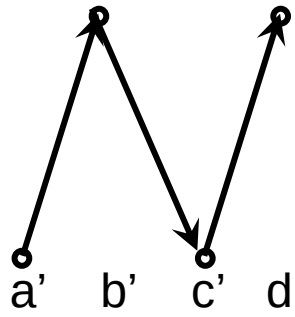
E Taller than
=> Shorter than



F Taller than
=> Larger than



G Taller than
=> Points to

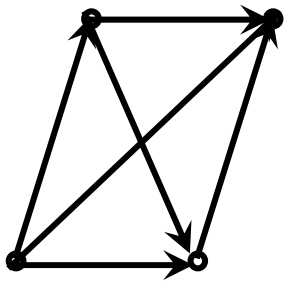
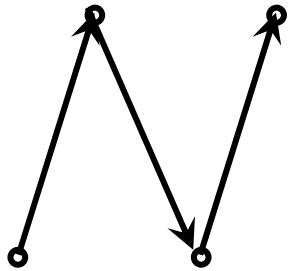


H Taller than
=> Chains to

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:

‘points to’   ‘chains to’

extrinsic *intrinsic*

representation of transitivity
of the relation “taller than”

Analogical Representations

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

Intuitive Reasoning

- Non-logic-based reasoning
  = illogical reasoning ???
- Non-linguistic representations

- Analogical representations,
  e.g. maps or scaled models

“Analogical” and “Analog”

- Analog-ical vs. Frege-an
  (structure-preserving – not structure-preserving)

- Analog vs. Digital
  (continuous – discrete)

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

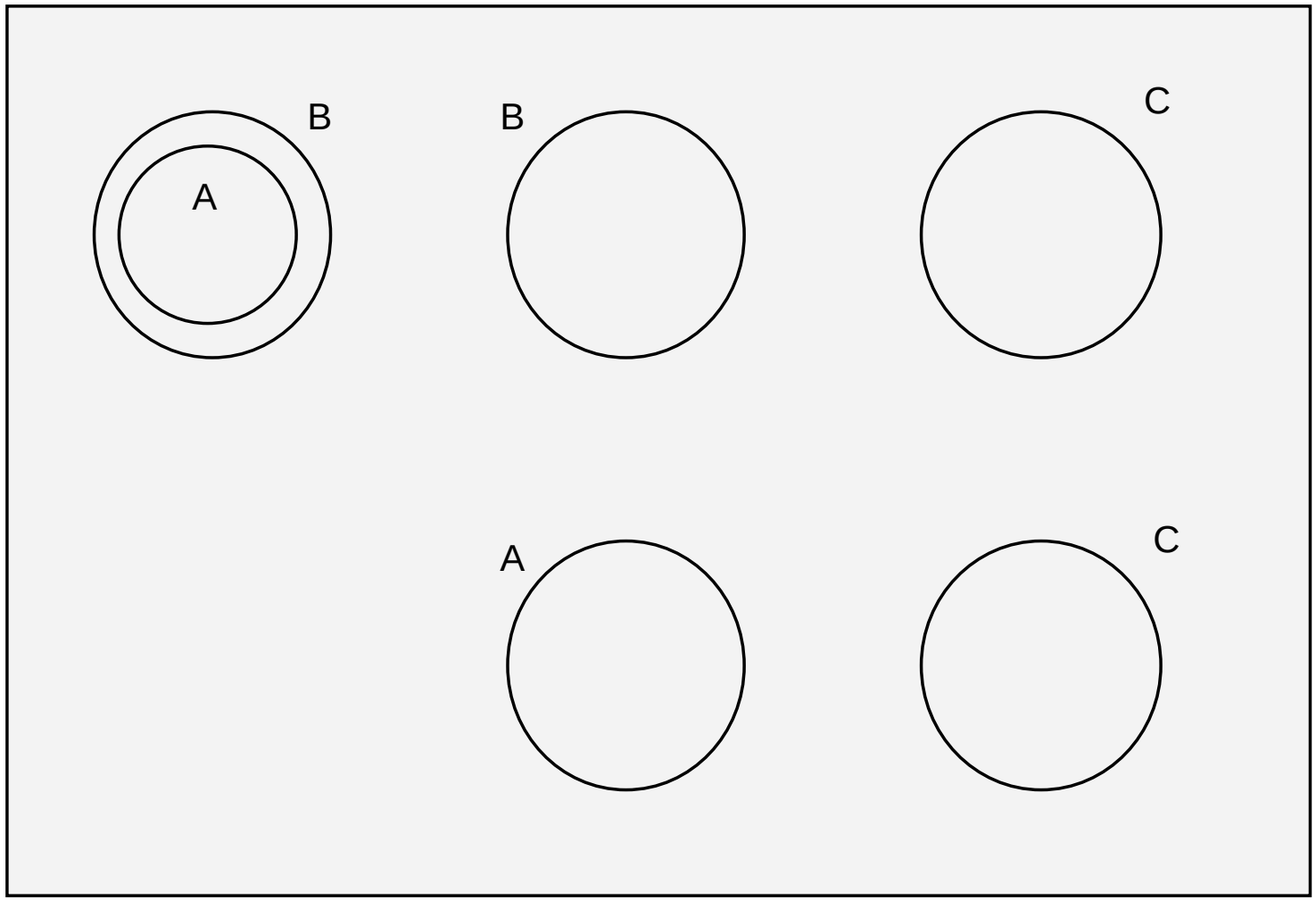
- They require a suitable conceptual and perceptual apparatus
- External and internal representations (in the world / for thinking / in the computer
- Are diagrams essential for a proof or are they merely psychological padding?

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*

What means *Valid Inference*?



Analogical vs. Fregean Forms of Representation

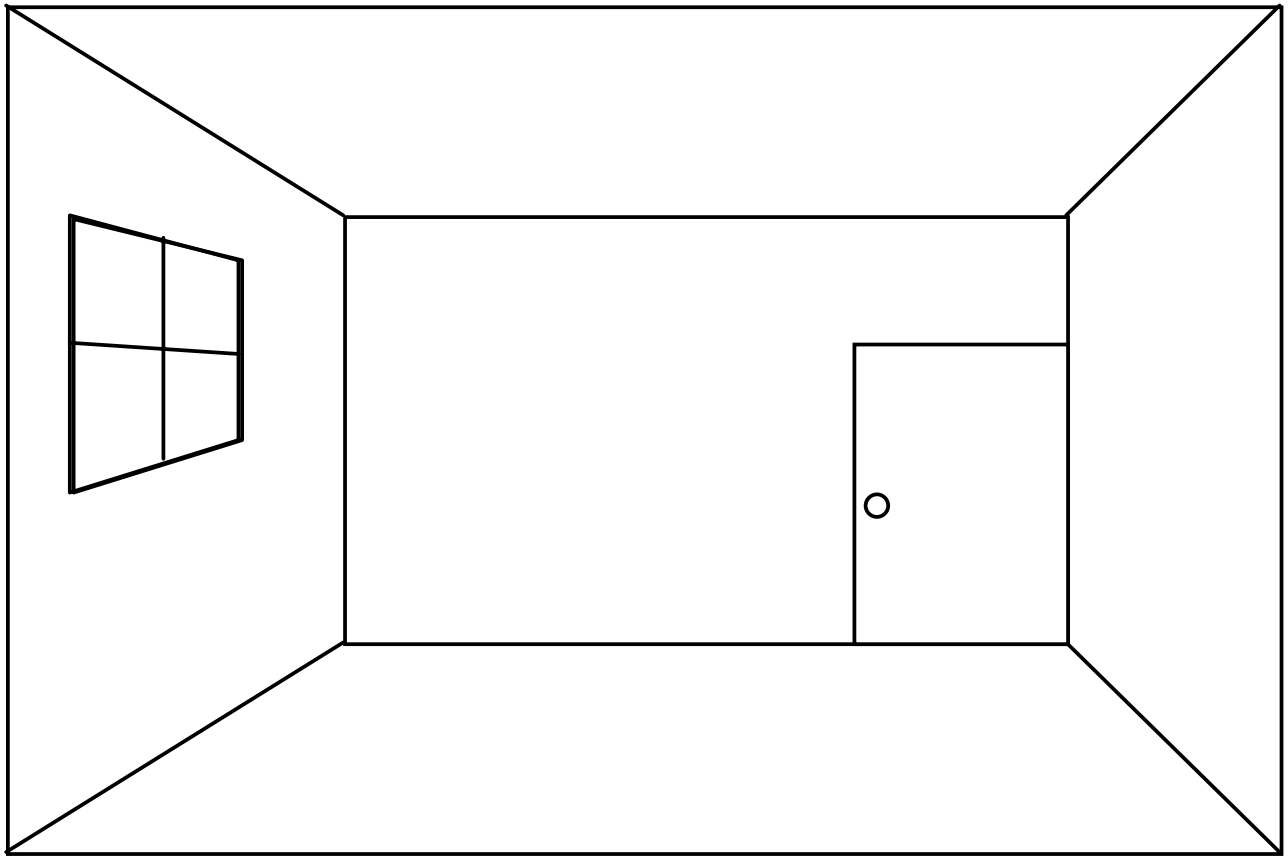
- How can we decide which type of representation system to use in a given situation?
- Specific problem-dependent vs. general problem-independent strategies
- Images, maps, scaled models are largely *analogical*, predicate calculus (invented by Gottlob Frege), programming languages, natural languages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

Difference between Analogical an 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

Example



Correspondence Relation my 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

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))

Fregean Representations

- No correspondence between representing and represented configuration necessary
- 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.

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

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

Sloman's Afterthoughts

- Terminological Explanation:

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

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 not.”

  Counter-example:

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

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

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*)

- 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

- See (1) and (2) above.

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.

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

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

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

Discussion

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

Next week

- Mental images
  - mental rotation
  - mental scanning
  - attention