World and representation

Representations

Sept 13,2023

The Semantic Gap

Human perceive reality, what we call the world, through the lenses of perception.

This process is not neutral. Different people perceive the world differently.

We talk of Semantic Gap relating to the impossibility for humans and machines to perceive the world as it really is, or even in the same way.

The Semantic Gap is the source of the pervasive misalignment of the mental models of the world that humans, and also machines, build.

We want to build CS/ AI systems which are more and more intelligent, and which pervasively interact with people. We need to have systems which are robust, trustable, and whose behavior we understand.

The Semantic Gap (continued)

Intuition 2.1 (World) The **world** is what we perceive through the five senses and assume it exists. It is the spatio-temporal dimension in which humans live and interact with other humans and everything else around them.

Intuition 2.2 (Memory) When we perceive the world we create in our mind a **memory** of what we have perceived, the memory being itself a part of the world.

Intuition 2.3 (Mental Representations) Mental representations are a part of a person's memory. Mental representations are such that there is a correspondence between their contents and what is the case in the world they describe.

Intuition 2.4 (Semantic gap) The **semantic gap** is the difference between the world and a human's mental representation of the world itself, what (s)he has perceived.

The semantic Gap (continued)
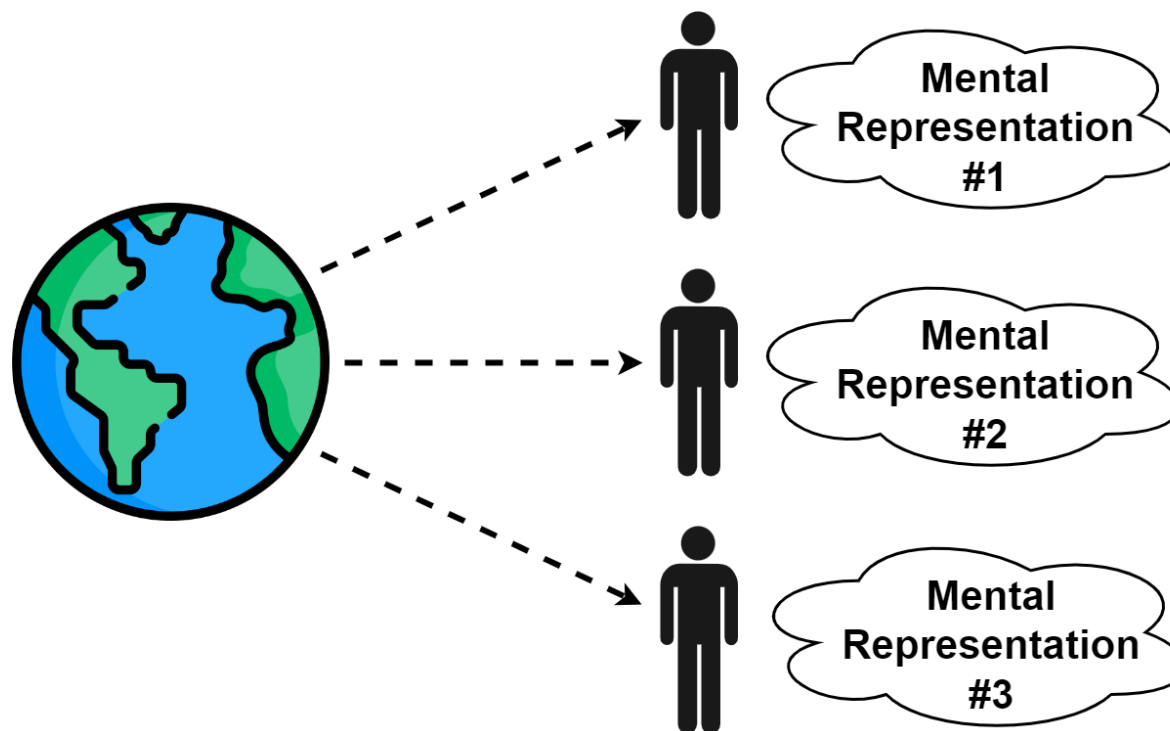
Mental representations

Intuition 2.5 (Analogical mental representations) Analogical mental representations are mental representations that **depict** the world as we perceive it through the five senses.

Observation 2.3 (Analogical mental representations) Analogical mental representations enable us to acquire information about the world, directly from the world. They are used to act in the world, to learn from what has been previously perceived and to build an understanding of the world itself.

Mental representations (continued)

Intuition 2.6 (Language) A **language** is any notation, generated by humans, agreed upon by humans, which allows to describe analogical representations, to reason about them, and to communicate about them to other humans.
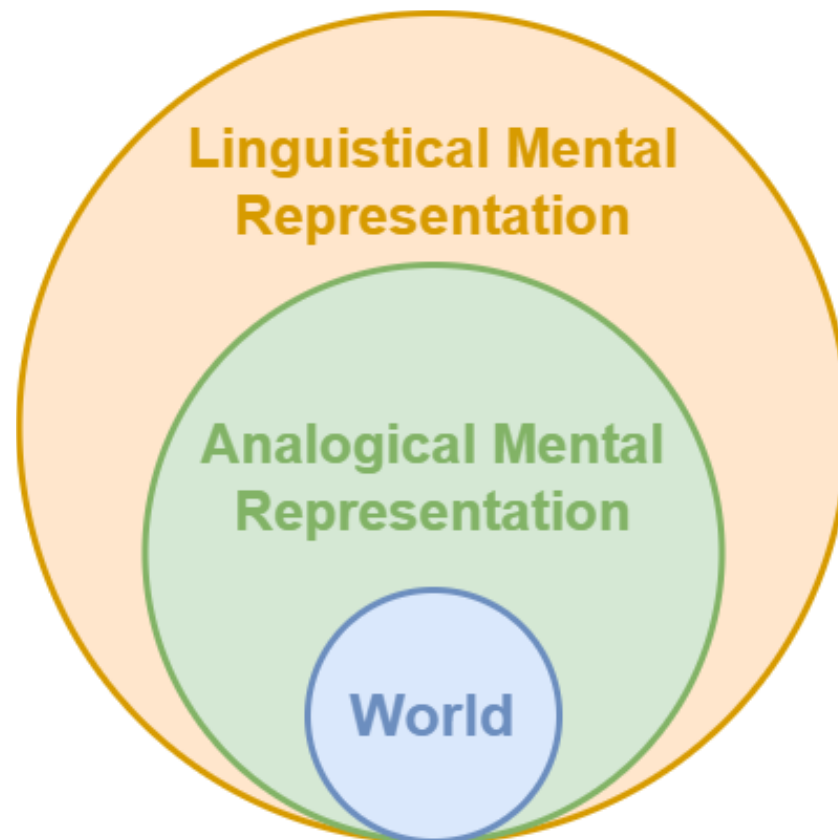
Intuition 2.7 (Linguistic mental representations) Linguistic mental representations are mental representations that **describe** mental analogical representations using language.

Observation 2.4 (Linguistic mental representations) Linguistic mental representations are used to describe what is happening in analogical mental representations. They allow to communicate to other humans about our mental representations (and,thus, indirectly about the world), to learn from what has been previously described or perceived, and to reason in order to derive unknown facts from what we already know.

Intuition 2.8 (Represent, depict, describe) To **represent** the world means anyone of two things: to depict it or to describe it.

Mental representations (continued)

Mental representations (continued)

Observation 2.6 (Partiality of mental representations)

Because of the semantic gap, mental representations never describe the world completely. This has consequences.

First, there are indefinitely many analogical mental representations that describe the same real world situation.

Similarly, there is an indefinite number of linguistic mental representations for the same analogical representation.

Mental representations (continued)

Observation 2.7 (Number of mental representations)

Because of partiality there are indefinitely many analogical mental representations that describe the same real world situation.

Furthermore, there is an indefinite number of linguistic mental representations for the same analogical representation.

Mental representations (continued)

Observation 2.8 (Diversity of mental representations) Because of partiality, any two mental representations are necessarily different, depending on the spacetime coordinates under which they are generated, and the purpose of the person who generates them.

Intuition 2.9 (Consistency and inconsistency of mental representations) We say that any two mental representations are **inconsistent** when it is impossible for those two mental presentations to represent the (same part of the) world, as he know it. **Consistency** means absence of inconsistency. Two consistent mental representations are still diverse but they are compatible in the sense that there is a (analogical representation of the) world which is described by both.

Mental representations (continued)

Observation 2.9 (Subjectivity of mental representations) Given the world they perceive, humans build one or more among the many possible mental analogical and linguistic representations of what they have perceived.

Observation 2.11 (Subjectivity, inconsistency and objectivity) Two subjective mental representations may be (mutually) inconsistent. The presence of inconsistency provides evidence of the subjectivity of the mental representations involved.
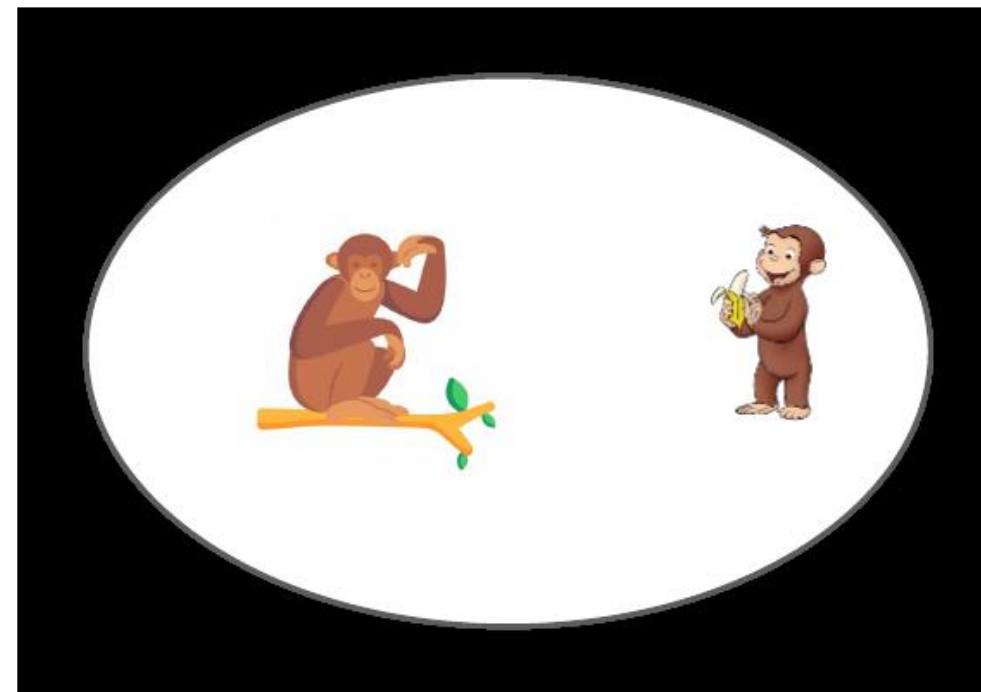
Representations

Intuition 2.10 (Representations) A **representation** is a part of the world, developed by the mind of a human, that represents that human's mental representation, and is made accessible, via one of the five senses, to other humans.

Intuition 2.11 (Analogical Representations) Analogical representations depict analogical mental representations.

Intuition 2.12 (Linguistic Representations) Linguistic representations describe linguistic mental representations.
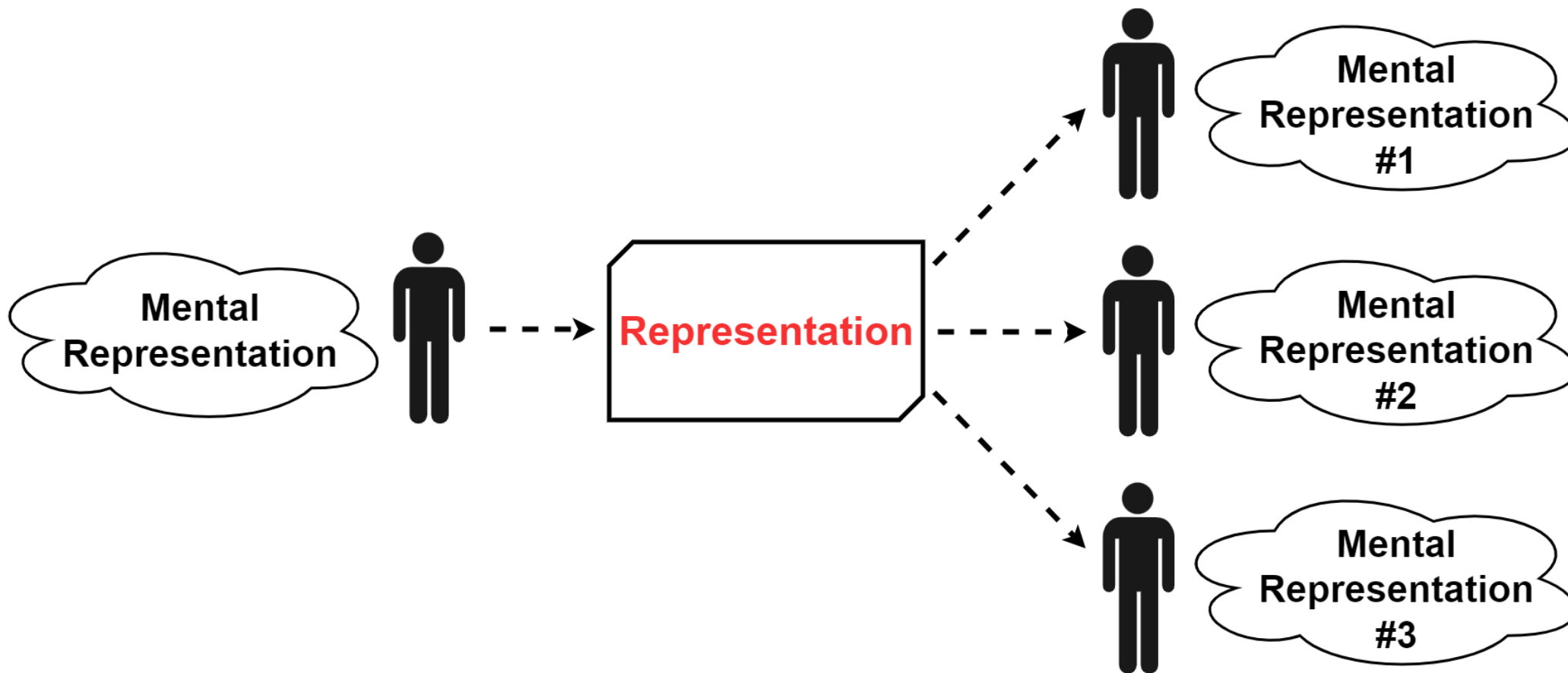
Representations (continued)

- There is a tree
- There is a banana
- The monkey is eating a banana
- The monkey is sitting on a tree
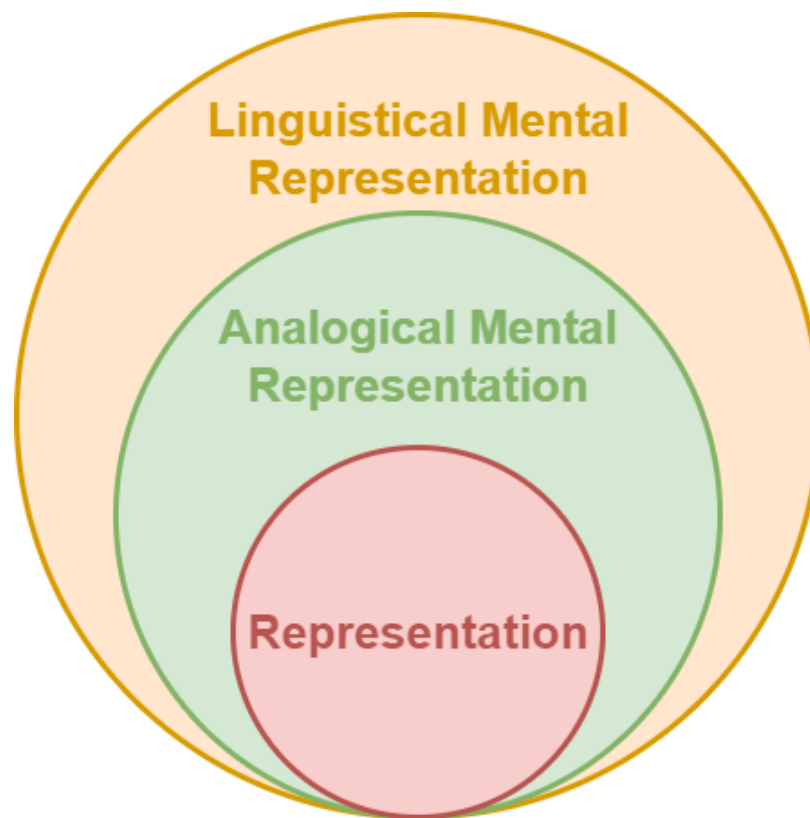- The monkey is scratching his head

Representations (continued)

Representations (continued)

Representations (continued)

Linguistical Mental Representation
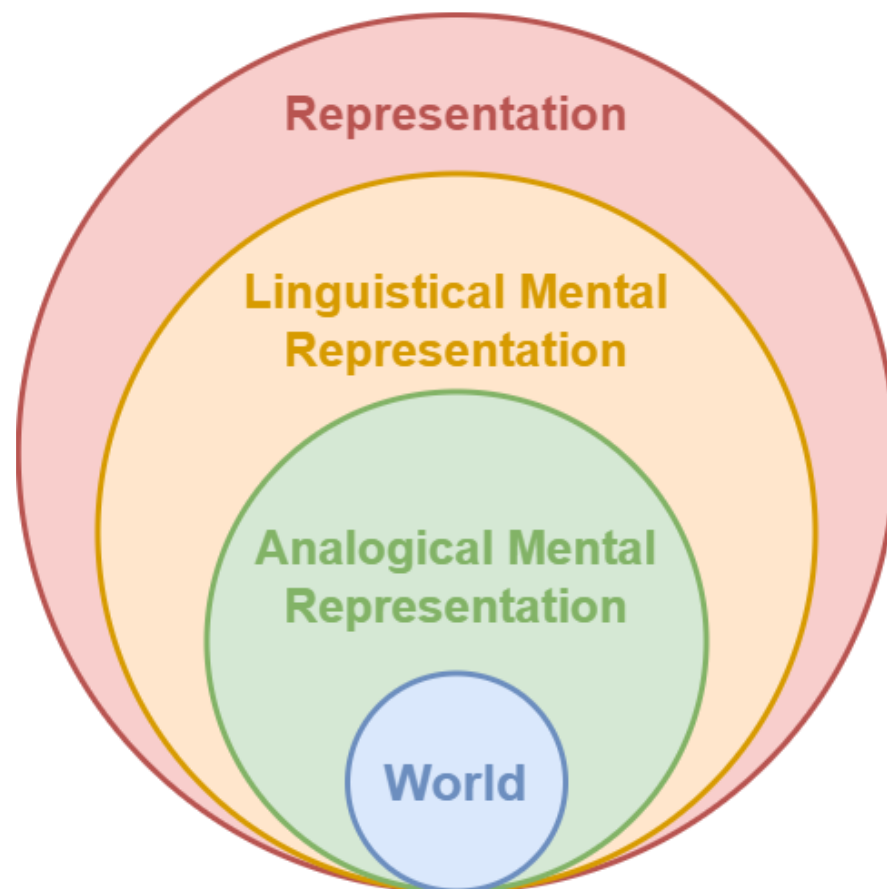
Analogical Mental Representation

Representation

Representations (continued)

The previous slide may suggest that there is no solution to the problem of subjectivity of mental representations.

However this is not the case.

Representations are built with the goal of making mental representations of the same representation converge as much as possible, minimizing in particular the probability of inconsistencies.

Sources of inconsistencies: what you see, the language used, the knowledge used, the data used.
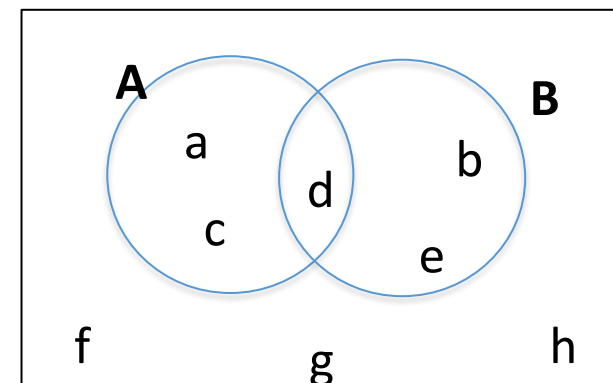
The question to be answered is how to build such representations. This in a way to enable (syntactic and semantic) interoperability.

Solution: use logic or logic-based approach (**modeling + reasoning**).

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What do you see?

Semantics!

- Elements with properties,
- Sets of elements with the same properties,
- Relations among elements,
- … which elements, properties, relations?

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Facts

Intuition 3.1 (Fact) A **fact** f is something happening at certain spacetime coordinates.

Example: *Sofia is a person, Paolo is a man, Rocky is a dog, Sofia is near Paolo, Sofia has blond hair, Sofia is a friend of Paolo, Rocky is an animal, Rocky is the dog of Sofia, ...*

Facts – Tractatus Logico-philosophicus (Wittgenstein)

1 The world is everything that is the case.

1.1 The world is the totality of facts, not of things.

1.11 The world is determined by the facts, and by these being all the facts.

1.12 For the totality of facts determines both what is the case, and also all that is not the case.

…

2 What is the case, the fact, is the existence of atomic facts.

3 The logical picture of the facts is the thought.
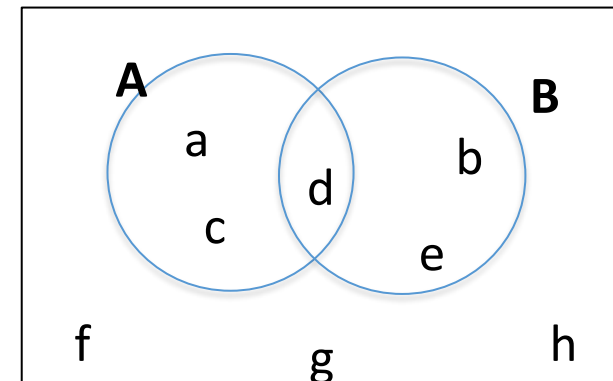
…

Facts and models

Intuition 3.1 (Fact) A **fact** f is something happening at certain spacetime coordinates.

Definition 3.1 (Model) A **model** M is a set of facts M = {f}

$$M = \{f\}$$

Semantics *modeled as* Set theory!!!

Example: M = {*Sofia is a person, Paolo is a man,***
Rocky is a dog, Sofia is near Paolo,
Sofia has blond hair, Sofia is a friend of Paolo,
Rocky is an animal, Rocky is the dog of Sofia, ...}

A
B
a
b
d
c
e
f
g
h

Facts and models

Observation 3.2 (Facts and models) Facts are the atomic, not further decomposable, elements of a model. Note that, contrary to models, facts are a primitive notion and therefore cannot be formally defined

Observation 3.3 (The subjectivity of facts) Facts are what is observed and is also described, e.g., to third parties. Facts are subjective.

Observation 3.4 (Mutually (in)consistent facts in a model) The example model above could be extended by asserting the fact that Sofia is a woman. But NOT by adding the fact that Paolo is a woman, as we would have two mutually inconsistent facts, something that we know cannot happen in the world. A model cannot contain facts which are mutually inconsistent. How to formalize this intuition and then how to detect it by reasoning about models.

Facts and assertions

Observation 3.5 (Facts and assertions) A fact, to be a fact, must be linguistically described as such.

It is not by chance that in Example 3.2 we pointed to facts via a set of natural language descriptions. We call such descriptions, **assertions**.

The simplest way to think of an assertion is as a declarative natural language sentence articulated in terms of a *subject* being in some more or less complex *relation* with an *object* (as in, e.g., "Stefania is walking with the dogs towards the city center"), or of a *subject* holding a certain more or less complex property (as in, e.g., "Stefania has blond long hair").

Assertional theories

Observation 3.6 (Assertions and assertional theories) Assertions are indivisible, we say atomic, descriptions of fact. **Assertional theories** are descriptions of models

Intuition 3.2 (Assertion) An **assertion** a is an atomic **linguistic** representation of some fact f.

Definition 3.2 (Assertional theory) An **assertional theory** TA is a set of assertions

$$TA = \{a\}$$

Interpretation function

Definition 3.3 (Interpretation function) Let I$_A$ be an **interpretation function** of an assertional theory, defined as

$$I_A : TA \rightarrow M$$

We say that a fact f $\in$ M is the **interpretation** of $a \in$ I$_A$, and write

$$f = I_A(a) = a^I$$

to mean that a **is a linguistic description of** f.

We say that f is the **interpretation of** a, or, equivalently, that a **denotes** f.

Interpretation function (example)

Example.

- I_A(Sofia è una persona) = *Sofia is a person*
- I_A(Paolo è un uomo) = *Paolo is a man*
- I_A(Rocky is a dog) = *Rocky is a dog*
- I_A(Sofia is near Paolo) = *Sofia is near Paolo*
- I_A(Rocky è il cane di Sofia) = *Rocky is the dog of Sofia*
- I_A(Sofia è un'amica di Paolo) = *Sofia is a friend of Paolo*
- I_A(Sofia ha i capelli biondi) = *Sofia has blond hair*
- *….*

Analogical *and* linguistical representation
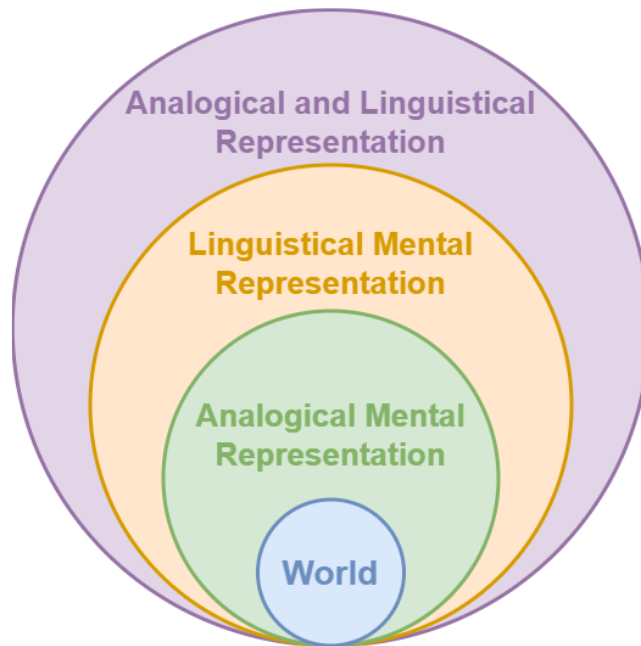
We need to provide formalisms for representing:
- **Models**
- **Assertional theories**
- **Interpretation functions**

What is above allows to model /formalize representations.

We still need to model/ formalize reasoning
- **Models**
- **Assertional theories**
- **Interpretation functions**

Interpretation function - polisemy

Observation 3.7 (Interpretation function, polysemy) I_A is assumed to be a function, that is, for any fact there is only one assertion describing it.

In fact, we must guarantee that, if two facts $f1$ and $f2$ are different then they cannot both be the result of the interpretation of the same assertion a, i.e., it cannot be that if $I_A(a) = f1$ then also $I_A(a) = f2$.

This phenomenon, called *polysemy* is pervasive in natural languages.

Interpretation function - synonymity

Observation 3.9 (Interpretation function, synonymity) Two assertions are synonyms when they have the same meaning, that is, the interpretation of two different assertions $a1$ and $a2$, may denote the same fact f, i.e., $I_A(a1) = I_A(a2) = f$.

Synonymous words are again pervasive in natural languages.

In logic synonymity is not a problem.

However, in relational databases synonymity is not allowed, essentially for efficiency reasons. Databases are developed based on the *unique name assumption*, that is, in databases, different strings and assertions always mean different things.

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