



Center for Advanced Studies of Rome

Meaning Theories and the Semantic Web

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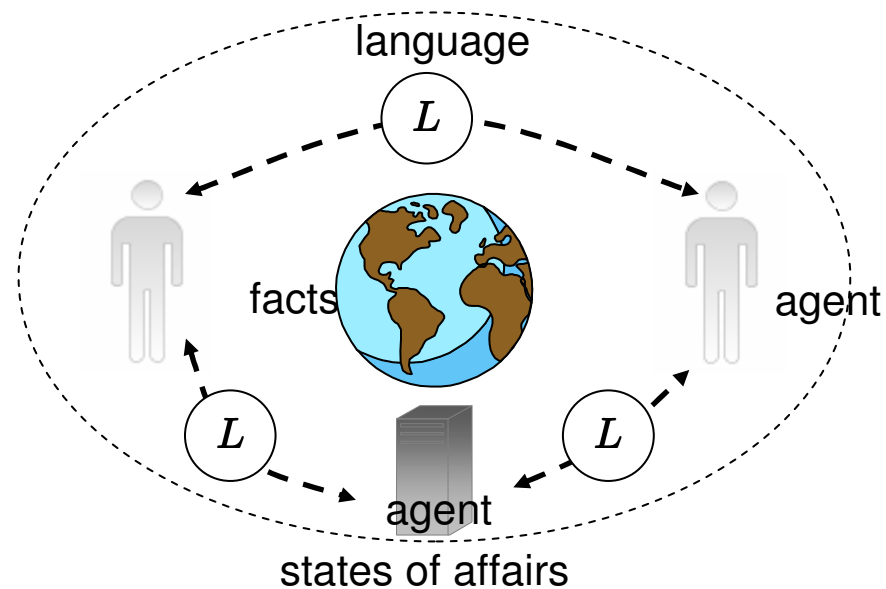


Outline

- **Semantics and Meaning Theories**
- **Semantics for Natural and Formal Languages**
- **Semantics for the Semantic Web**
- **The Web as a “natural” System**
- **Meaning Theories for Natural Languages**
- **Meaning Theories and the Semantic Web**

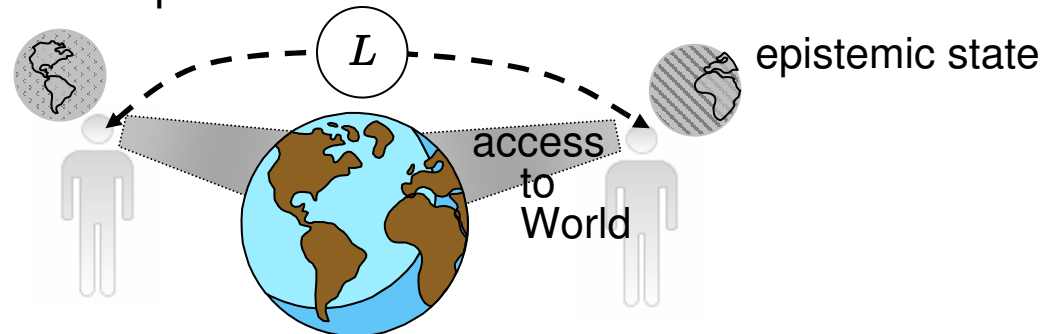
Semantics

- **The study of language meaning, i.e. the relation between**
 - languages (either natural or formal) and
 - epistemic states of agents (either natural or artificial) that use them
 - to manipulate (e.g. share knowledge) states of affairs in the World



Meaning Theory

- **The study of conditions that make meaning happen**
 - Ontology of (successful) communication: what kind of things meanings are? Objects? Procedures? Abilities?
 - What entities and processes are they related to? How do they relate to facts and agents' epistemic states respectively?
 - In particular, what is the relation (if any) between meanings and our access to Truth in the World?
 - Do meanings depend the one another? Are they modular? How meaning units compose broader forms?



Semantics in Natural Languages

- **Investigation of the meaning of linguistic units (lexemes)**
 - Generally related to lexicology
 - Semi-formal account of *senses* of lexical units (lexical words, multiword expressions)
 - Main driver: substitution analysis (synonymy, hyponymy, antonymy)

Semantics in Natural Languages - Example

Senses of the verb 'love' (WordNet)

1. love -- (have a great affection or liking for; "I love French food"; "She loves her boss and works hard for him")
 - Antonym: hate
 - Troponyms: care for, adore, ...
 - Related to noun love (a strong positive emotion, a beloved person or object, ...)
2. love, enjoy -- (get pleasure from; "I love cooking")
3. love -- (be enamored or in love with; "She loves her husband deeply")
4. love, make out, make love, sleep with, ... -- (have sexual intercourse with; "This student sleeps with everyone in her dorm"; ..)

Semantics in Formal Languages

- **Formal setting to map logic formulas over a given (artificial) domain of discourse (discrete objects)**
 - Model-theoretic semantics (Tarski)
 - Each n-ary predicate is programmatically assigned a truth value with respect to each object n-uple in the domain (interpretation). Propositions are evaluated on the basis of the correspondence between logic operators (e.g. conjunction) and set operations (e.g. intersection)
 - Modal semantics (Kripke)
 - Extends model-theoretic semantics to encompass *attitudes* (e.g. *knowledge, belief*) of agents towards propositions whose interpretation is given in many different *possible worlds*.

Semantics in Formal Languages - Example

- **Δ (domain)**
 - {JOHN, MARY}
- **L (language)**
 - Alphabet = {PERSON(), LOVE(,), HATE(,)}
 - Connectives { \neg , \rightarrow }
- **T (theory)**
 - {LOVE(x,y) \rightarrow (PERSON(x) \wedge PERSON(y)), LOVE(x,y) \rightarrow \neg HATE(x,y)}
- **\mathcal{I} (interpretation)**
 - {PERSON(JOHN), PERSON(MARY), LOVE(JOHN,MARY), HATE(MARY,JOHN)}
- Proposition: \neg LOVE(MARY,JOHN)

Natural Language vs. Formal Logic Semantics

- **Natural Language semantics is descriptive (ex-post)**
 - Meanings take place in communication processes
 - Linguists observe, collect, describe, classify, and (try to) explain these meanings
 - Logic consistency is not an issue
- **Formal Logic semantics is prescriptive (ex-ante)**
 - Meanings are assigned by convention (truth assignments)
 - Logicians are not concerned with explanations or motivations of meanings
 - Logic consistency is the main issue

Semantics for the Semantic Web

- **Which Semantics the Semantic Web should care about?**
 - Are meanings assigned to the Web by conventional interpretations established beforehand or they freely come up with practices within Web communities?
 - Should we focus on capturing and describing meanings *ex-post* or should we focus on their formal specification *ex-ante*?

Semantics of the Semantic Web: the “mainstream”

- Semantic Web aims at enabling mutual *understanding* among machines (besides users)
- Web resources can be made *automatically understandable* by describing them with *ontologies*
- Ontologies are sources of *precisely defined terms* that can be *shared across applications and humans*
- Ontologies are assigned model-theoretic interpretations over the shared *domain of discourse* of the Web
- Understanding is *closely related to reasoning* on ontology descriptions

(Ian Horrocks, Logical Foundations for the Semantic Web. Seminar given at the University of Glasgow, March 10th, 2003)

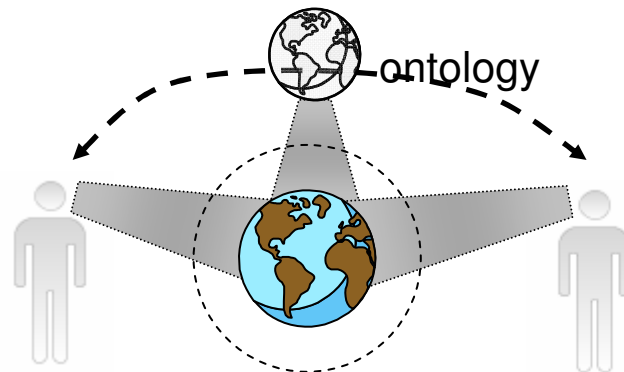
Semantics of the Semantic Web: the role of ontologies

- **Ontologies are logic theories about what exists**
- **They are interpreted by agents over a global domain of Web resources**
- **Predicates and axioms provide interpreters with semantic constraints**
- **Good ontologies are such that their sound interpretations (models) actually correspond to what agents *intend to mean*, and (possibly) nothing else**
- **If *intended meanings* overlap, then the communication succeeds**

(Guarino, The Ontological Level, 1994)

Semantics of the Semantic Web: the basic assumption

- **The use of ontologies by Semantic Web applications is based on the assumption of**
 - uniform, consistent interpretations of
 - predicate symbols and individual constants over a
 - common fixed domain
 - across users and machines on the Web



Semantics of the Semantic Web: does the Web fit the assumption?

✓ **Shared domain**

- ✓ Addressable resources
- ✓ Strings (e.g. words in documents)
- ✓ Multimedia objects

✓ **Shared ontologies**

- ✓ Foundational ontologies, Domain ontologies, XML Business Standards, Database schemas, UML class diagrams, Taxonomies, ...

✗ **Shared interpretations**

- ✗ General methods to check actual interpretations (without breaking systems' boundaries)
- ✗ General methods to enforce ontology interpretations on the Web

Semantics of the Semantic Web: begging the question?

- **Ontology-based, model-theoretic account of the Semantic Web *requires* what it wants to *achieve*, i.e. shared meanings on the Web**
- **This roots in the fact that the formal semantics of description logics is noncommittal w.r.t. truth assignments, thus is lacking when truth assignments are *in question***
- **On the Web, however, truth assignments are *always* in question (hopefully!)**
- **Thus, to capture *commonly intended meanings*, the Semantic Web cannot be agnostic (or simplistic) about what meanings are and what conditions must be fulfilled in order to share them**
- **That is: the Semantic Web needs a Meaning Theory**

The Web as a “natural” System

- **After 10 years of research, the Semantic Web remains largely a ‘vision’**
- **In the meanwhile, the Web has changed**
- **The Web 2.0 conveys a non-prescriptive, ‘natural’ approach to semantics**
 - “Group of users do not have to agree on a hierarchy of tags or detailed taxonomy, they only need to agree, in a general sense, on the ‘meaning’ of a tag enough to label similar material with terms for there be cooperation and shared value”
 - Adam Mathes: “Folksonomies: Cooperative classification and communication through shared metadata”, 2004.
 - “Because it’s difficult to specify a formalism that will capture all the knowledge in a particular domain, there are other approaches to inference on the Web”

Nigel Shadbolt and Wendy Hall, *University of Southampton*, Tim Berners-Lee, *Massachusetts Institute of Technology*, “The Semantic Web Revised” IEEE Intelligent Systems MAY/JUNE 2006

The Web as a “natural” System

- **Today’s Web shares with Natural Language a number of key features:**
 - Free use of structured languages
 - Peer to peer communication
 - Distributed (*rules-changing*) creativity
 - Free sense invention
 - Free sense interpretation
- **Humans use Natural Language without knowing about meaning theories. Unfortunately, artificial systems can’t do the same.**
- **Thus, we need a meaning theory to understand the *conditions of possibility* for the Semantic Web**

Meaning Theories for Natural Language: main roots

- **Realism**

- World → Thought → Language
- Root: Plato, Aristotle
- Wittgenstein: Tractatus Logicus-Philosophicus (1921)
- E.g. Leibniz: “Characteristica Universalis” (XVII century)

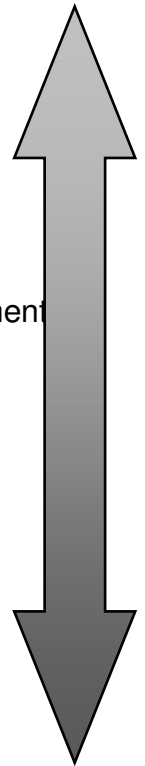
- **Anti-realism**

- Language → Thought → World
- Root: Pyrrho
- Wittgenstein: Philosophical Investigations (1953)
- E.g. Orwell’s 1984: “Newspeak” (1948)

Meaning Theories for Natural Language: analytic philosophy (sketch)

- **Verification**
 - Aristotelism, logical positivism, L. Wittgenstein (Tractatus)
 - Speakers and listeners can verify truth conditions for sentences (“snow is white” iff snow is white)
 - There’s a common access to a common World
 - Ontology is given for all (realism)
- **Interpretation**
 - D. Davidson, H. Putnam
 - Listeners ascribe speakers consistent beliefs and honest communication intentions (principle of charity)
 - Listeners make hypotheses about speakers’ meaning intentions based on their own ontological commitment
 - Ontology (conditions in the World) allows verifying interpretation hypotheses (externalism)
- **Interplay**
 - L. Wittgenstein (Investigations), D.K. Lewis
 - Listeners and speakers share linguistic rules by virtue of social exchanges (e.g. feedbacks)
 - Listeners understand speakers by making explicit reasoning on these rules
 - Ontology is shared as long as Entities work within social linguistic rules (intersubjectivity, constructivism)
- **Translation**
 - W.V.O. Quine
 - Speakers’ ontological commitments are not accessible by listeners
 - Listeners assign meanings to expressions on the basis of speakers’ observable behaviors
 - There are not shared ontologies (relativism)

Realism



Anti-Realism

Meaning Theories for Natural Language: cognitive semantics

- **Meaning theories should explain understanding**
- **Understanding is a cognitive process that takes place for somebody in a given context at a certain time, not a formal truth-assignment**
- **Meanings are regularities in mental constructs, not in the World (mentalism)**
- **Mental constructs don't need interpretation: they *are* interpretations (Jackendoff)**
- **Interpretative constructs can be modeled and shared**
- **Semantic Networks and Frames in AI (Quillian, Minsky, Woods, Winograd)**
- **Frame Semantics for Natural Language (Fillmore)**

Meaning Theories and the Semantic Web

- **Which assumptions are at the basis of current semantic integration practices?**
 - Use of folksonomies
 - Constructivism or realism?
 - Use of linguistic ontologies (e.g. business vocabularies)
 - Strong realism or cautious externalism?
 - Use of foundational ontologies
 - Moderate realism or Platonism?
 - Peer to Peer information integration and exchange
 - Relativism?
- **Depending on positioning, concrete approaches can change**
- **Need for more (multidisciplinary) investigation!**

Conclusion

- **Fortunately, humans can communicate (with success) without knowing why and how**
- **Unfortunately, machines cannot do the same**
- **Semantic Web people have adopted a formal-logic approach to semantics, that does not provide convincing results for natural language (as Tarski warned)**
- **However, the Web is much like a natural linguistic system**
- **We must be aware of what meaning is in human communication if we want to turn the Semantic Web vision into reality**
- **And be aware of our limits ...**