Laboratory for Applied Ontology

Institute of Cognitive Science and Technology
Italian National Research Council

Knowledge Representation and Formal Ontologies

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Course summary

- 1. Focusing on content; meanings and signs
- 2. Modal logics
- 3. What is an ontology
- 4. The ontological level
- 5. The basic tools of formal ontology
- 6. Roles and types
- 7. OntoClean
- 8. Foundational ontologies: objects and events
- 9. Foundational ontologies: qualities
- 10. Ontology of services and organizations

1. Focusing on content

The focus of ontological analysis: from form to *CONTENT*

- The key problems
  - content-based information access *(**semantic matching**)*
  - content-based information integration *(**semantic integration**)*
- To approach them, content must be studied, understood, analyzed ***as such***, independently of the way it is represented.
- Traditionally, computer technologies are not really good for that...
- …and users of computer systems are often ***confused by technology***

Ontologies: a ***magic solution?***

The emergence of ontologies in AI
(a very short story)

- The old days:
  - Semantic networks based on conceptual primitives
  - A progressive ***ontological neutralization*** of AI languages:
    - from conceptual primitives to *epistemological primitives*
    - the move towards ontologically neutral formalisms (DLs)
  - The short ***commonsense summer***
- The New Wave:
  - 80's: knowledge ***sharing*** and reuse
  - 90's: enterprise ***integration***
  - 2000: ***semantic*** web

The same problems are still there!

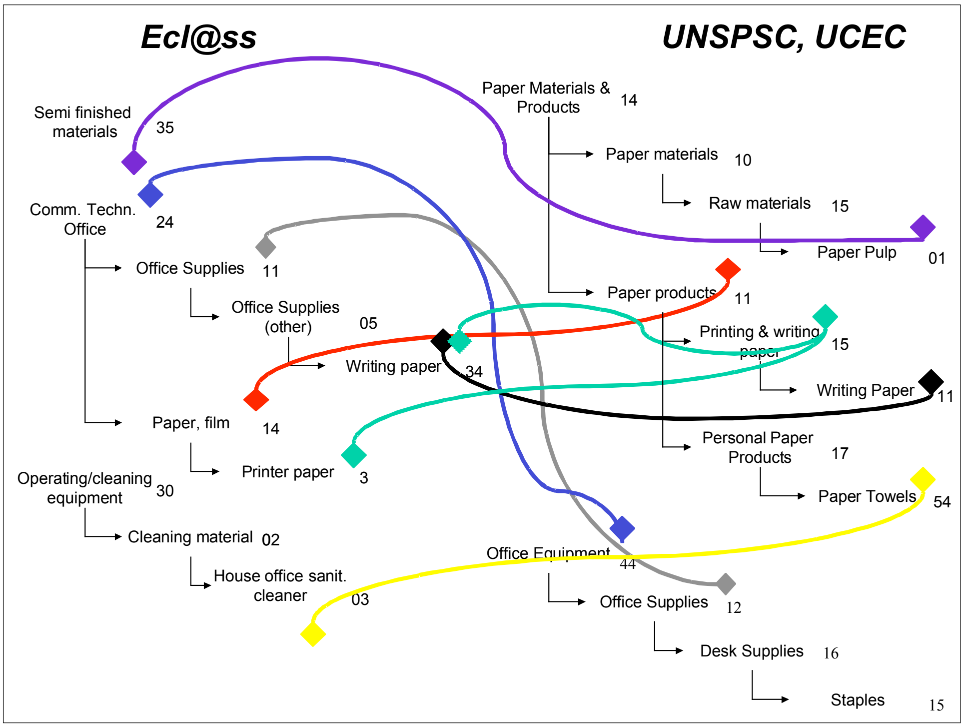
The problem: subtle distinctions in meaning

The e-commerce case:

"Trying to engage with too many partners too fast is one of the main reasons that ***so many online market makers have foundered***.

The transactions they had viewed as simple and routine actually involved many ***subtle distinctions in terminology and meaning***"

Harvard Business Review, October 2001



Subtle distinctions in meaning...

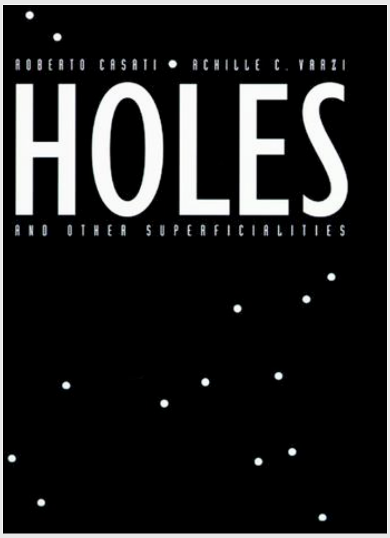
- What is an ***application*** to a public administration?
- What is a ***service***?
- What is a ***working place***?
- What is an ***unemployed person***?
- What is a ***customer***?
- What is a ***passenger***?
- What is an ***organization***?
- What is a ***document***?
- What is a ***contract***?
- What is a ***spare part***?
- What is a ***missing part***?
- What is a ***hole***?

Where subtle distinctions are important

- 2000 US Presidential elections: is there a ***hole***?
- 2001 twin towers catastrophe: how many ***events***?

…only ***ontological analysis*** solves these problems!!

The ontology of holes



Books by Roberto Casati and Achille C. Varzi (MIT Press):

- Holes and other superficialities
- Parts and places

A common alphabet is not enough…

- "XML is only the first step to ensuring that computers can communicate freely. ***XML is an alphabet for computers*** and as everyone who travels in Europe knows, knowing the alphabet doesn't mean you can speak Italian or French"

Business Week, March 18, 2002

Standard glossaries can help, but…

- Defining standard vocabularies is ***difficult and time-consuming***
- Once defined, standards ***don't adapt well***
- Heterogeneous domains need a ***broad-coverage vocabulary***
- People don't implement standards correctly anyway
- Vocabulary definitions are often ***ambiguous or circular***

Representation vs. Reasoning

- Representation comes first!
- The very task of representation (i.e. ***modelling***) is left to the user
- AI researchers focus more on the ***nature of reasoning*** than in the ***nature of the real world***

Essential ***ontological promiscuity*** of AI: any agent creates its own ontology based on its usefulness for the task at hand (Genesereth and Nilsson 1987)

Do we know what to REpresent?

- ***First*** ontological analysis,
- ***THEN*** knowledge representation…

Unfortunately, this is not the current practice…

No ontology without ***ontological analysis!***

The need to focus on content

- Philosophers have generally stopped short of trying to actually specify the truth conditions of the basic atomic propositions, dealing mainly with the specification of the meaning of complex expressions in terms of the meanings of elementary ones. ***Researchers in artificial intelligence are faced with the need to specify the semantics of elementary propositions*** as well as complex ones.

  [Woods 1975]

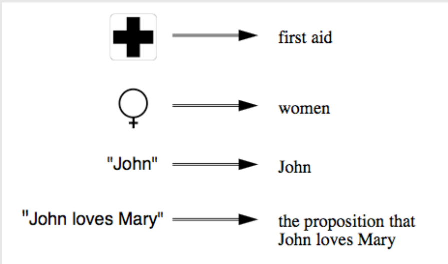
- The majority of work in knowledge representation has been concerned with the technicalities of relating predicate calculus to other formalisms, and with the details of various schemes for default reasoning. There has been almost an aversion to addressing the problems that arise in actually representing large bodies of knowledge with content. The typical AI researcher seems to consider that task to be 'just applications work'. But there are deep, important issues that must be addressed [...]: What ontological categories would make up an adequate set for carving up the universe? How are they related? What are the important things most humans today know about solid objects? And so on. In short, we must ***bite the bullet***.

  [Lenat&Guha 90] (our italics).

2. Meanings and signs

Signs and their content

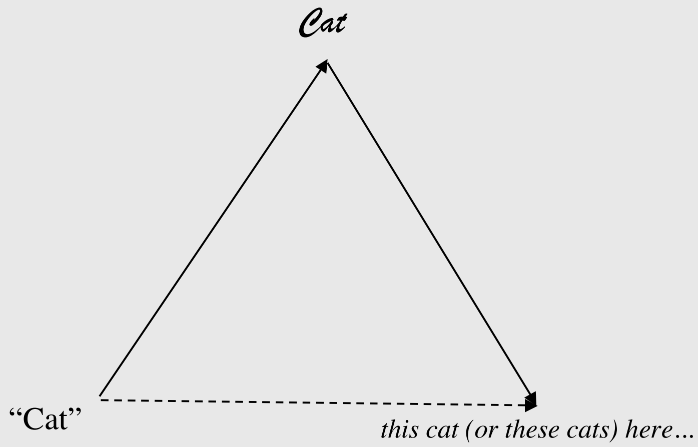
- Sign kinds in Peirce:
  - icon: **analogic** association with content
  - indexes: ***causal*** association
  - symbols: ***conventional*** assotiation



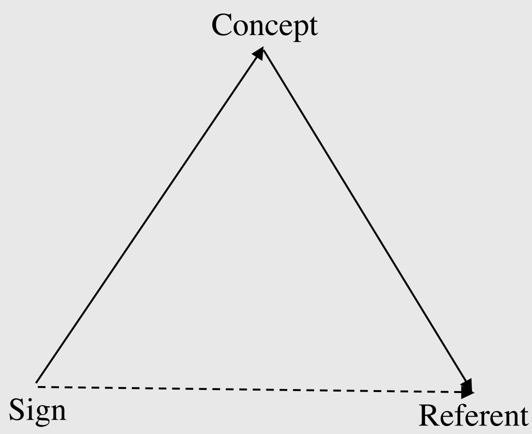
Signs and concepts

- Episodic memory vs. semantic memory:
  - we memorize both specific ***facts*** and general ***concepts***
- But what is a ***concept***?
- What does it mean to represent it?

The triangle of meaning - 1



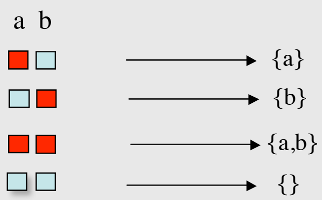
The triangle of meaning - 2



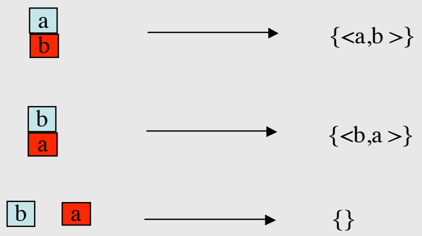
Intension ed extension

- Intension (concept): part of meaning corresponding to general principles, rules to be used to determine reference (typically, abstractions from experience)
- Extension (object): part of meaning corresponding to the effective reference
- Only by means of the ***concept*** associated to the ***sign*** “cat” we can correctly ***interpret*** this sign in various ***situations***
- The sign’s referent is the result of this interpretation
- Such interpretation is a ***situated intentional act***

Example 1: the concept of *red*



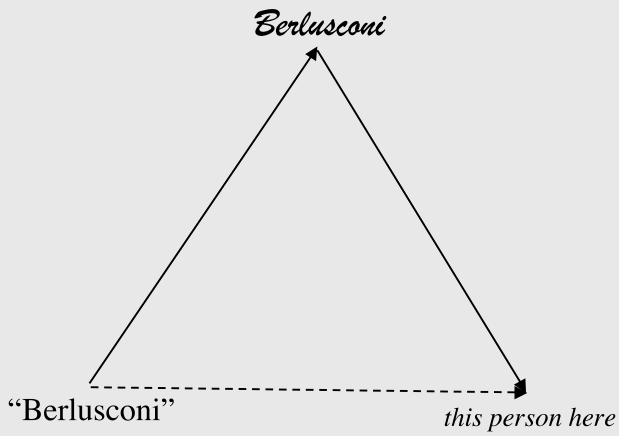
Example 2: the concept of *on*



Concepts, properties, and relations: terminology issues

- Non-relational concepts are often called ***properties***
- Relational concepts are often called ***relations***
- ...but properties and relations can be understood as intensional or extensional... Concepts are always **intensional**!!
- We also assume that properties are always intensional.
- To stress the difference between intensional and extensional relations, we shall call the former ***conceptual relations***

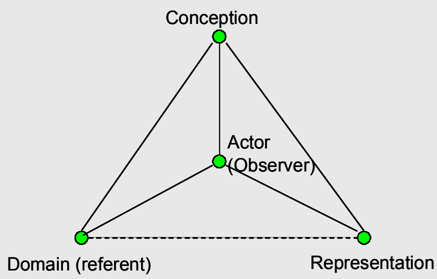
The triangle of meaning - 3



Again on intension and extension

- Concepts with zero extension
  - square circle, unicorn (different cases!)
- Concepts with same extension and different intension
  - equilateral triangle and equiangular triangle
  - president of Council of Ministers and president of Milan (*definite descriptions)*
  - morning star and evening star

The FRISCO tethraedron



E. Falkenberg, W. Hesse, P. Lindgreen, B.E. Nilsson, J.L.H. Oei, C. Rolland, R.K. Stamper, F.J.M. Van Assche, A.A. Verrijn-Stuart, K. Voss: FRISCO - A Framework of Information System Concepts - The FRISCO Report. IFIP WG 8.1 Task Group FRISCO. Web version: http://www.mathematik.uni-marburg.de/~hesse/ papers/fri-full.pdf (1998)

3. Concepts and Conceptualizations

Representing Intensional Relations

ordinary (extensional) relations are defined on a ***domain*** D:

$r_1 \subseteq D \qquad r_2 \subseteq D \times D \qquad r_n \subseteq D^n \qquad r_n \in 2^{D^n}$

intensional relations are defined on a ***domain space*** <D, W>

$\rho_n : W \rightarrow 2^{D^n}$ *(Carnap, Montague)*

But what are possible worlds?
What are the elements of a domain of discourse?

What is a *conceptualization?* A cognitive approach

- Humans isolate ***relevant invariances*** from physical reality (quality distributions) on the basis of:
  - Perception (as resulting from evolution)
  - Cognition and cultural experience (driven by actual needs)
  - (Language)
- ***presentation***: atomic event corresponding to the perception of an external phenomenon occurring in a certain region of space (the *presentation space*).
- ***Presentation pattern*** (or *input pattern*): a pattern of ***atomic stimuli*** each associated to an atomic region of the presentation space. (Each presentation tessellates its presentation space in a sum of atomic regions, depending on the granularity of the sensory system).
- Each atomic stimulus consists of a bundle of ***sensory quality values*** (qualia) related to an atomic region of timespace (e.g., *there is red, here; it is soft and white, here*).
- Domain elements corresponds to invariants ***within and across*** presentation patterns

The basic ingredients of a conceptualization (simplified view)

- *cognitive objects (and events)*: mappings from (sequences of) presentation patterns into their ***parts***
  - for every presentation, such parts constitute the ***perceptual reification*** of the object.
  - multiple objects in a single presentation: equivalence relationship among parts based on ***unity criteria***
- ***concepts and conceptual relations***: functions from (sequences of) presentation patterns into ***sets of (tuples of) cognitive objects***
  - if the value of such function (the concept's ***extension***) is not an empty set, the correponding perceptual state is a (positive) ***example*** of the given concept
  - ***Rigid concepts:*** same extension for all presentation patterns (possible worlds)

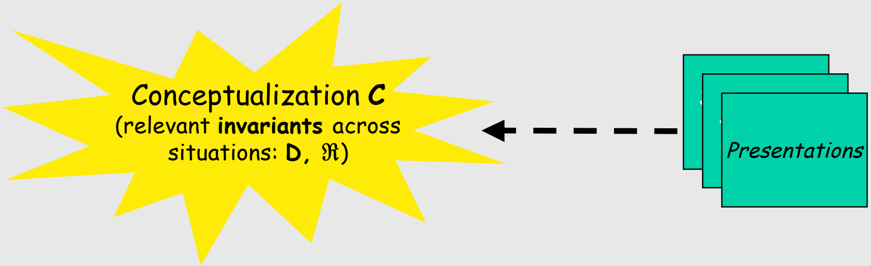
Possible worlds as presentation patterns (or sensory states)

Presentation pattern: unique (maximal) pattern of *qualia* ascribed to a spatiotemporal region tessellated at a certain granularity

...This corresponds to the notion of *state* for a sensory system (maximal combination of values for sensory variables)

Possible worlds are (for our purposes)
sensory states
(or if you prefer, [maximal] sensory *situations*)

From experience to *conceptualization*



D : cognitive domain

$\mathfrak{R}$: set of *conceptual relations* on elements of D