Laboratory for Applied Ontology

Institute of Cognitive Science and Technology
Italian National Research Council

Professional master on technologies for e-government

Conceptual modelling, ontology design, and semantic interoperability

Lecture 1

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Summary

- Course introduction
- Students presentation
- Introduction to knowledge representation, conceptual modeling, and semantic interoperability

Course plan

- Monday, October 1 [Guarino]
  - Course introduction
  - Introduction to knowledge representation and conceptual modeling
- Wednesday, October 3 [Borgo]
  - Introduction to first order logic
- Monday, October 8
  - Introduction to logic-based knowledge representation
  - Knowledge representation and conceptual modelling
- Wednesday, October 10
  - Introduction to ontologies
- Monday, October 15
  - Modal logics

Course plan (continued)

- Wednesday, October 17 [Guarino]
  - Identity, essence, dependence: the OntoClean methodology
- Monday, October 22 [Masolo]
  - Orders, mereology, time
- Wednesday, October 24 [Ferrario]
  - Space, location, constitution, qualities
- Monday, October 29 [Ferrario]
  - Roles, social entities, organizations
- Wednesday, October 31 [Ferrario]
  - Ontologies and interoperability for e-government
- Monday, November 5 [Oltramari]
  - Exercises using the Protege platform
- Wednesday, November 7 [Oltramari]
  - Exercises using the Protege platform

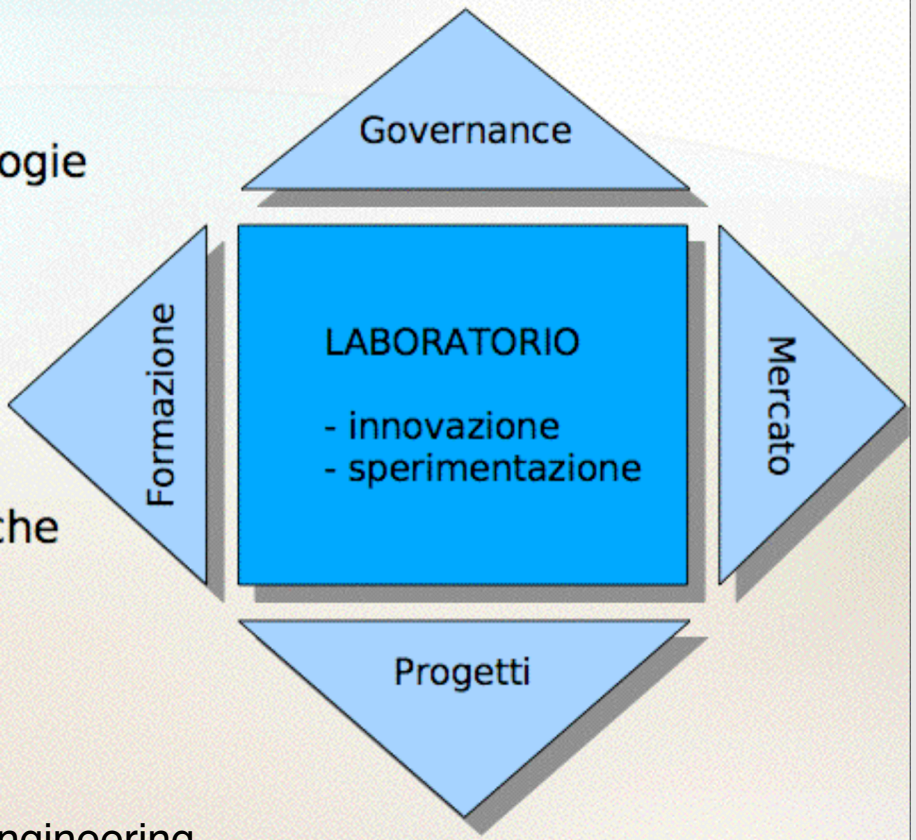
L’esperienza del sistema Trentino: il nuovo laboratorio di interoperabilita’ e e-government

Obiettivi specifici:

- sviluppare idee innovative
- sperimentare nuove tecnologie

Obiettivi strategici:

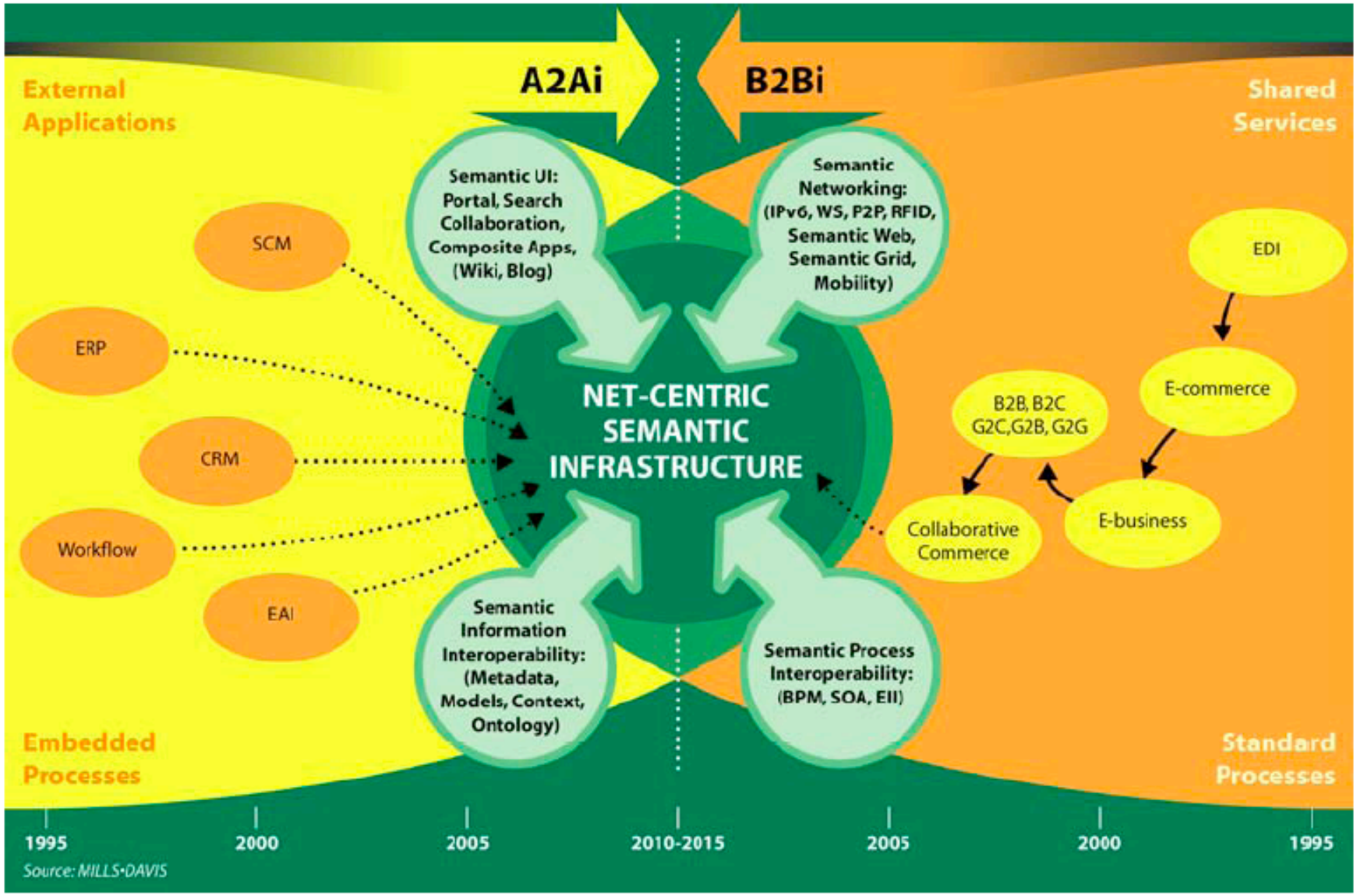
- incubare idee progettuali
- identificare opportunita' di mercato
- proporre soluzioni strategiche per il Trentino
- supportare iniziative di formazione



Partners:

- FBK-IRST
- UniTN-DIT
- CNR-ISTC
- Engineering
- DeltaDator
- GPI
- Informatica Trentina

Semantics for infrastructure

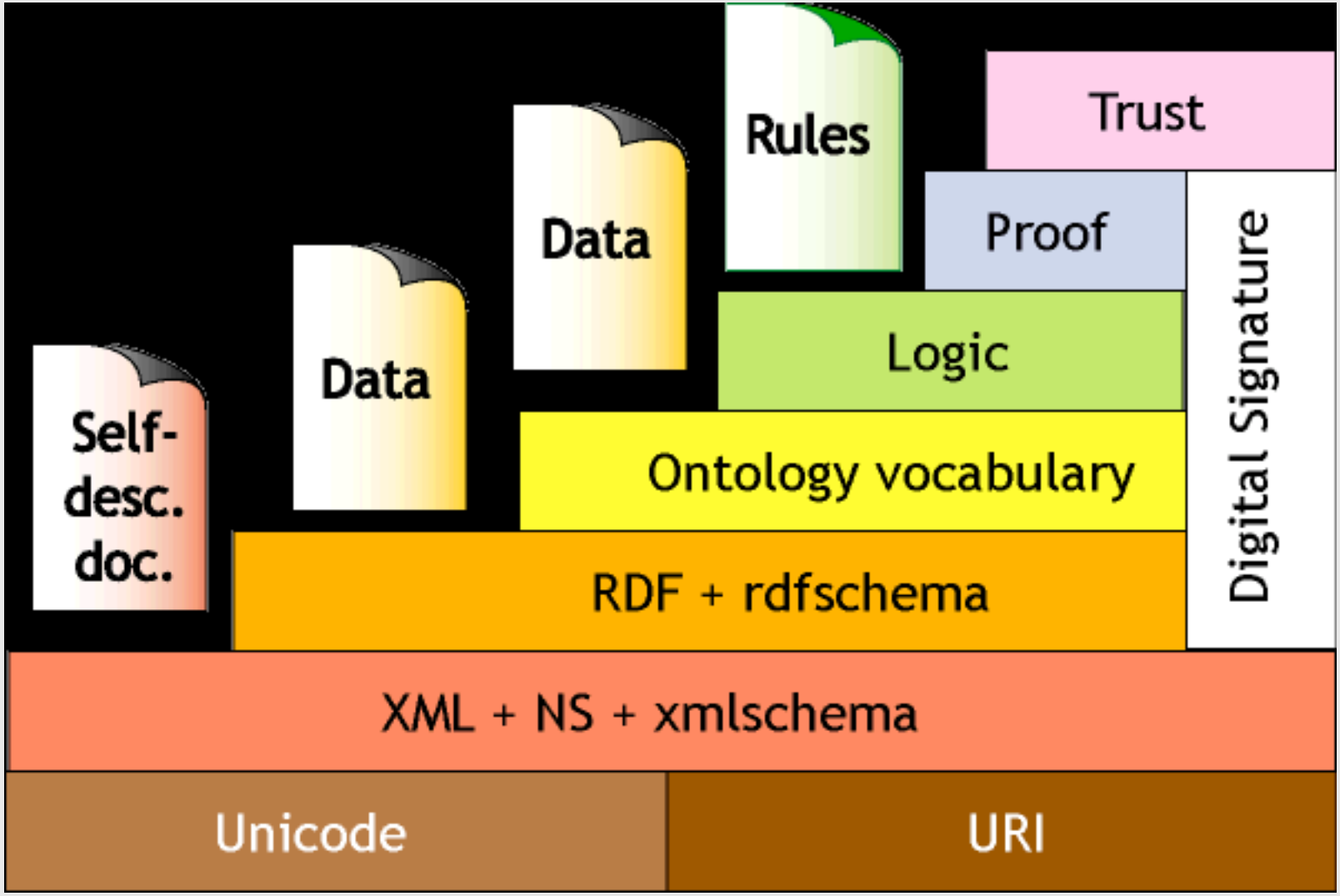


Supply-Chain Modeling
Enterprise Resource Planning
Customer Relationship Modeling

Enterprise Architecture Integration
Electronic Data Interchange
Internet Protocol V6

Business Process Management
Service-Oriented Architecture
Enterprise Information Integration

The semantic web architecture [Tim Berners Lee 2000]

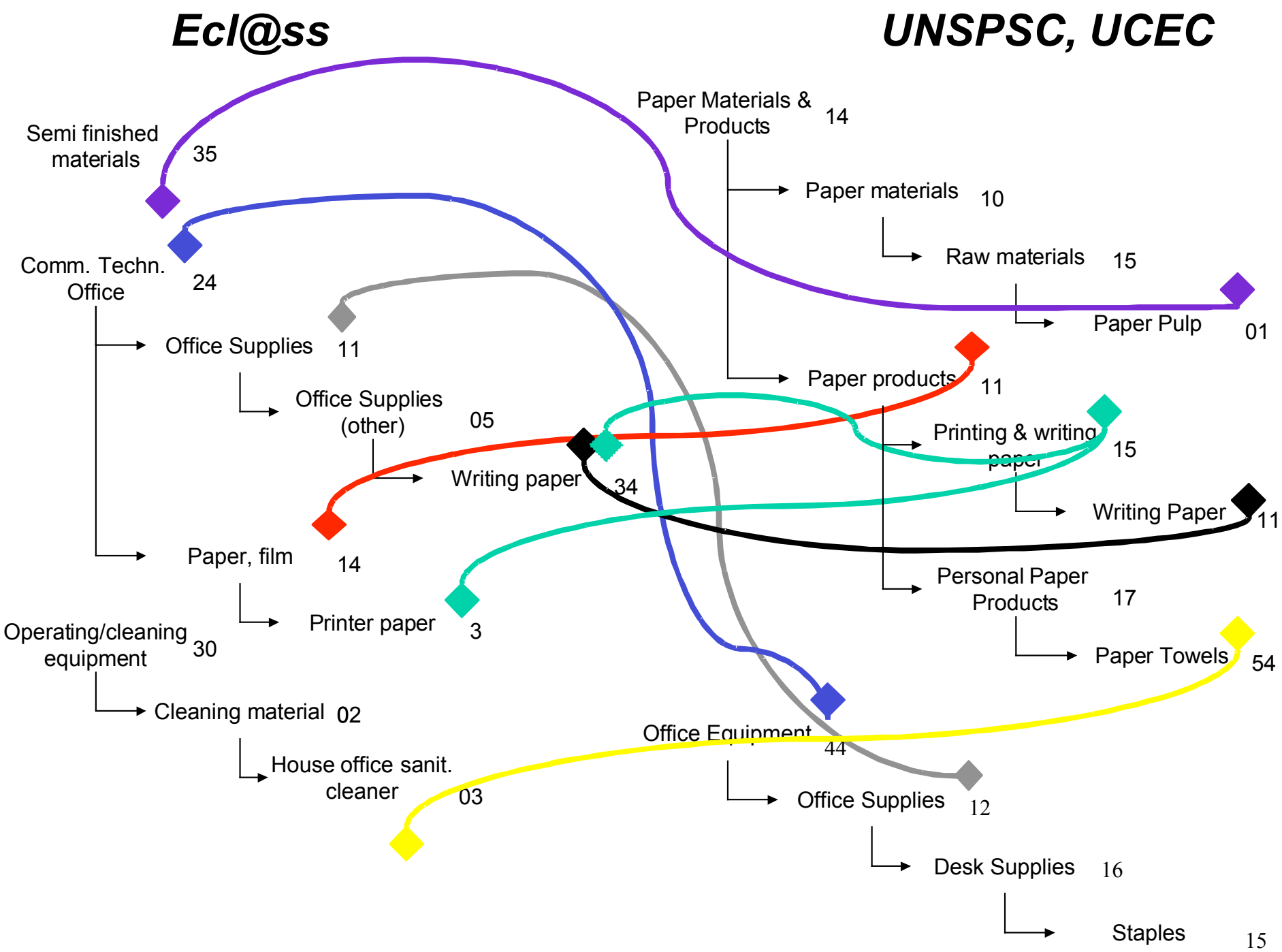


The problem: subtle distinctions in meaning

"Trying to engage with oo 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


Ecl@ss
UNSPSC, UCEC
Semi finished materials 35
Comm. Techn. Office 24
Office Supplies 11
Office Supplies (other) 05
Paper, film 14
Writing paper 34
Printer paper 3
Operating/cleaning equipment 30
Cleaning material 02
House office sanit. cleaner 03
Paper Materials & Products 14
Paper materials 10
Raw materials 15
Paper Pulp 01
Paper products 11
Printing & writing paper 15
Writing Paper 11
Personal Paper Products 17
Paper Towels 54
Office Equipment 44
Office Supplies 12
Desk Supplies 16
Staples 15

Subtle distinctions in meaning...

- What is an ***application*** to a public administration?
- What is a ***working place***? an ***address***?
- 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 **lake**, a **river**, a **valley**?
- What is a ***population****?* a ***species****?*
- What is a ***service****?*

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***

Do we know what to REpresent?

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

Unfortunately, this is not the current practice…

Representation vs. Reasoning, Data vs. Procedures...

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

- Databases where introduced to recognize the ***primacy of data*** wrt procedures

- Exagerate emphasis on ***services*** may re-introduce the same problems databases intended to solve...

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.

- Computer technologies are not really good for that (focus is usually on representation and reasoning)
- …and users of computer systems are often ***confused by technology***

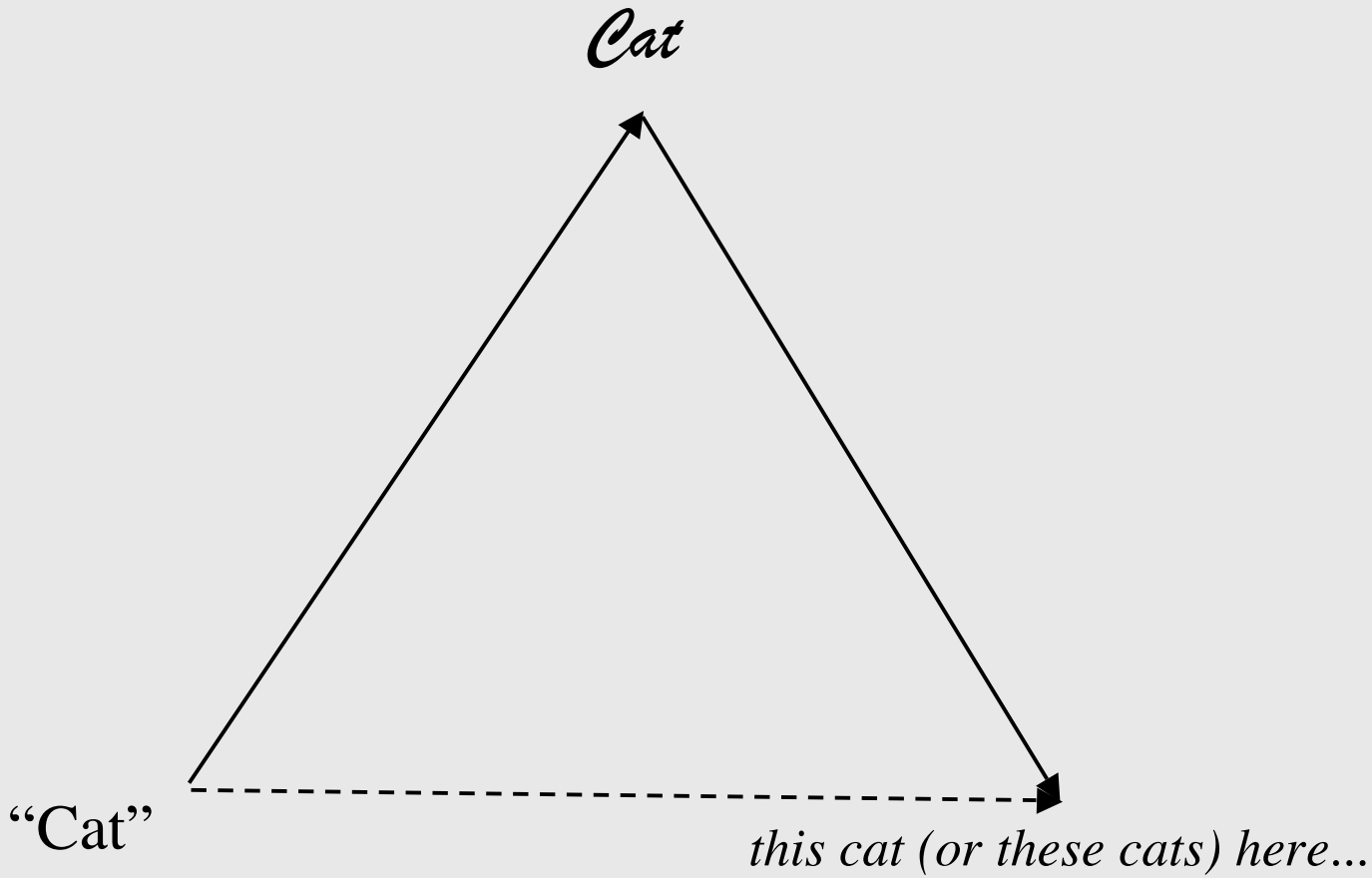
Ontology, lexicon, semantics

- Distinctions among contents: ***Ontology*** (capital ‘o’)
- Reference to content: ***Lexicon,*** via ***Semantics***

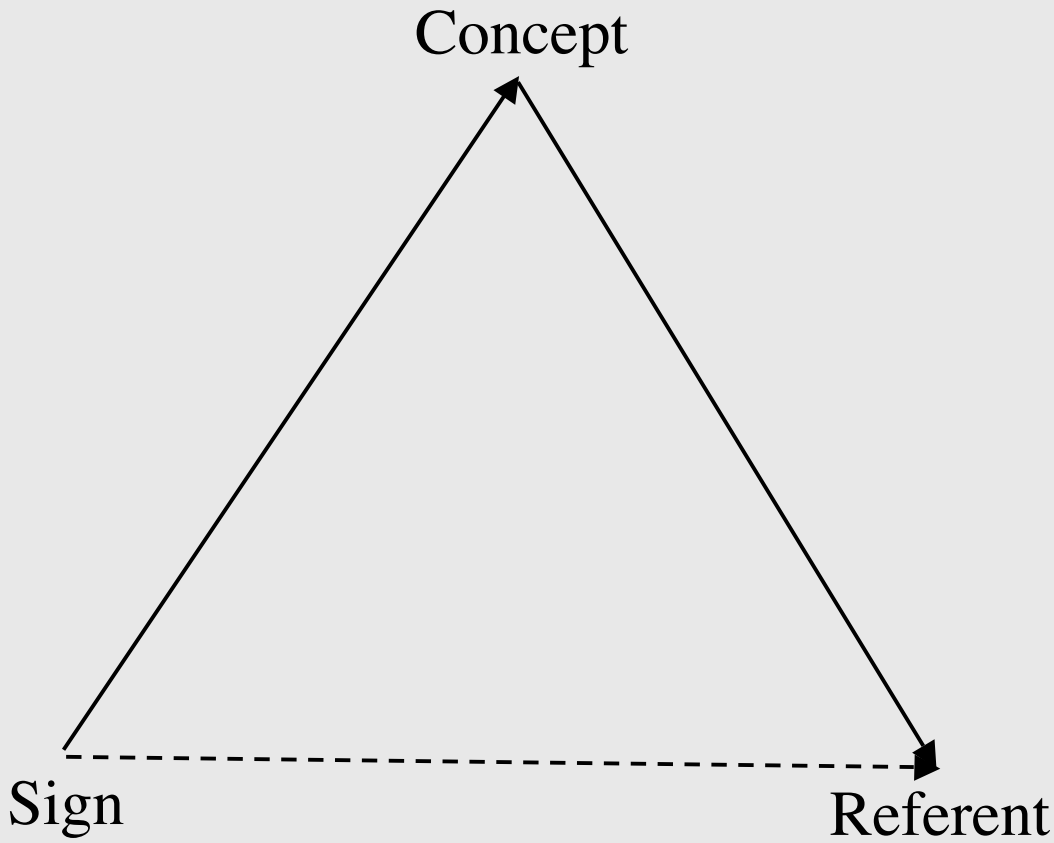
- Every organization, every computer system
  - Makes (implicit) ontologic assumptions
  - Adopt a certain lexicon, to which an ***intended semantics*** is ascribed.

Meanings and signs

The triangle of meaning - 1



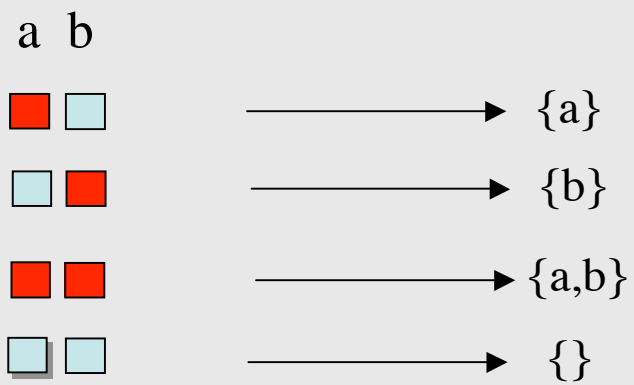
The triangle of meaning - 2



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***

An example: the concept of *red*



Concepts, properties, and relations

- By means of concepts, we ***ascribe*** properties and relations to things. We can say that concepts *describe* properties or relations.
- Concepts describing relations are also called ***conceptual relations:***
  - *friend-of, father-of...*
- Conceptual relations are NOT sets of tuples! Their extension is a set of tuples.

Relations vs. Conceptual Relations

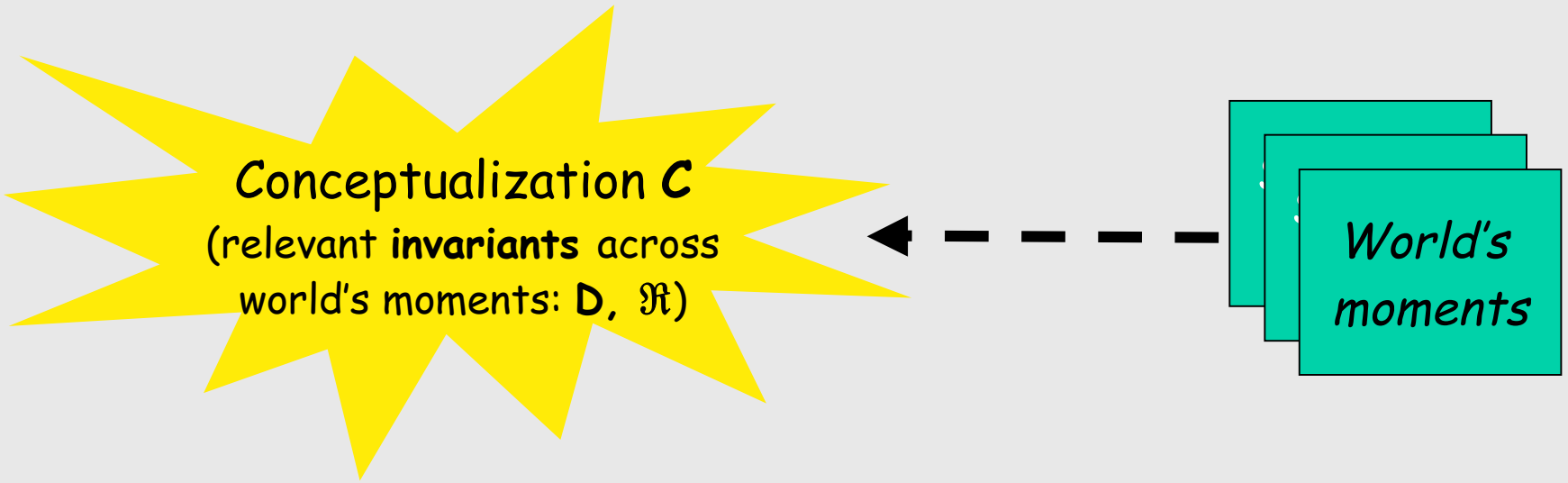
ordinary relations are defined on a ***domain*** D:

$$r_n \in 2^{D^n}$$

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

$$\rho_n : W \rightarrow 2^{D^n}$$ *(Montague's intensional logic)*

From experience to *conceptualization*

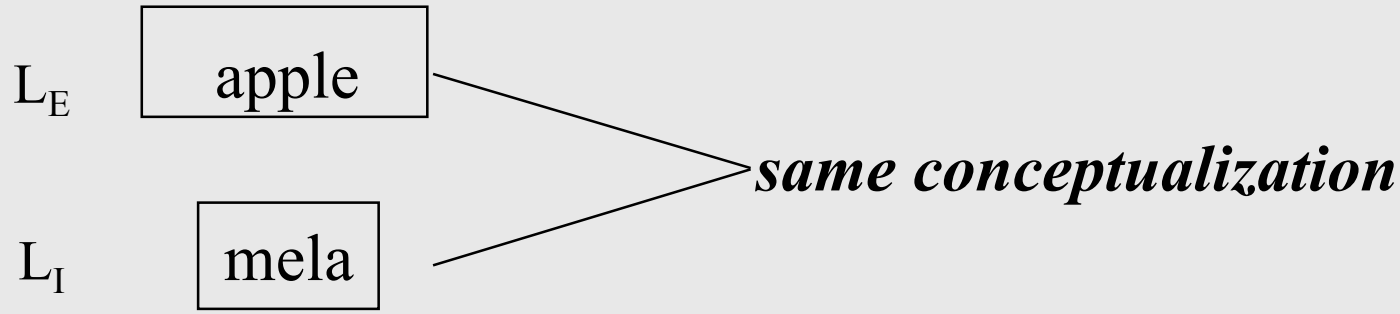


D : cognitive domain

ℜ : set of *conceptual relations* on elements of D

What is a conceptualization

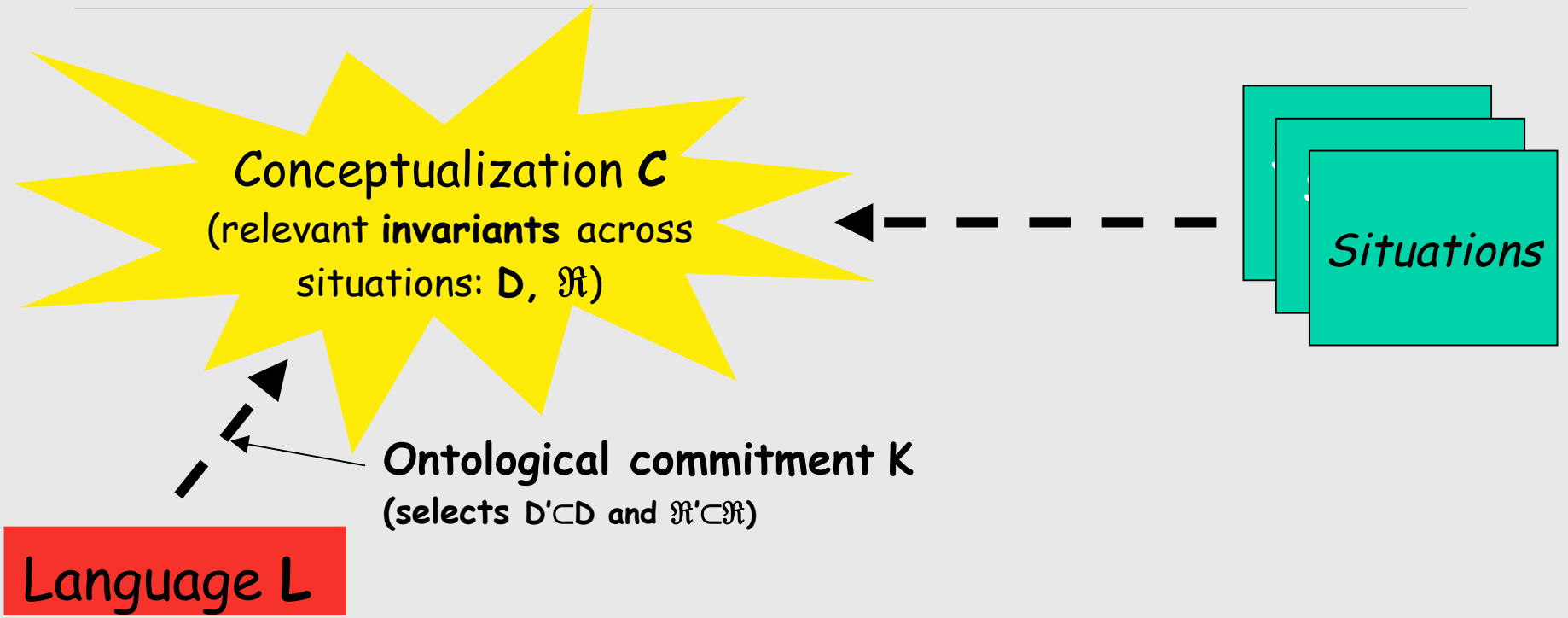
- Formal structure of (a piece of) reality *as perceived and organized by an agent*, *independently* of:
  - the ***vocabulary*** used
  - the actual occurence of a specific ***situation***
- Different situations involving same objects, described by different vocabularies, may share the same conceptualization.



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
  - Language
- A set of ***atomic stimuli*** (input pattern) is associated to each world's moment
- Synchronic level: ***spatial invariants***
  - Unity properties are *ascribed* to input patterns: topological and morphological wholes (***percepts***) emerge
- Diachronic level: ***temporal invariants***
  - ***Objects***: equivalence relationships among **percepts** belonging to different moments
  - ***Events:*** unity properties are ascribed to ***percept sequences*** belonging to different moments

The first steps of ontological analysis



- Be clear about the ***domain of discourse*** (existence...)
- Choose the relevant ***concepts and conceptual relations***
- Choose the ***primive relations***
- Choose meaningful ***names*** for these

Adequacy of KR formalisms

- Expressive adequacy
  - Ability to represent the all the necessary kinds of knowledge
- Inferencial adequacy
  - Ability to infer new knowledge from the given one
- Cognitive adequacy
  - Transparency with respect to humans
- Ontological adequacy
  - Ability to reflect ontological distinctions
  - Ability to reflect “reality”

Representation levels

(Brachman 1979)

Level	*Primitives*	*Interpretation*	*Main feature*
Logical	Predicates, functions	Arbitrary	Formalization
Epistemological	**Structuring relations**	**Arbitrary**	**Structure**
Conceptual	Conceptual relations	Subjective	Conceptualization
Linguistic	Linguistic terms	Subjective	Language dependence

From the logical level to the ontological level

- Logical level *(no structure, no constrained meaning)*
  - $\exists x\,(\text{Apple}(x) \wedge \text{Red}(x))$

- Epistemological level *(structure, no constrained meaning)*:
  - $\exists x{:}apple\ \text{Red}(x)$ *(many-sorted logics)*
  - ~~$\exists x{:}red\ \text{Apple}(x)$~~
  - a is a Apple with Color=red *(description logics)*
  - ~~a is a Red with Shape~~=apple

- Ontological level *(structure, constrained meaning)*
  - Some structuring choices are excluded because of ontological constraints: Apple carries an identiy condition, Red does not.

Ontology helps building "meaningful" representations

The Ontological Level

(Guarino 94)

Level	*Primitives*	*Interpretation*	*Main feature*
Logical	Predicates, functions	Arbitrary	Formalization
Epistemological	Structuring relations	Arbitrary	Structure
Ontological	**Ontological relations**	**Constrained** (meaning postulate s)	**Meaning**
Conceptual	Conceptual relations	Subjective	Conceptualization
Linguistic	Linguistic terms	Subjective	Language dependence

The source of all problems: different conceptualizations

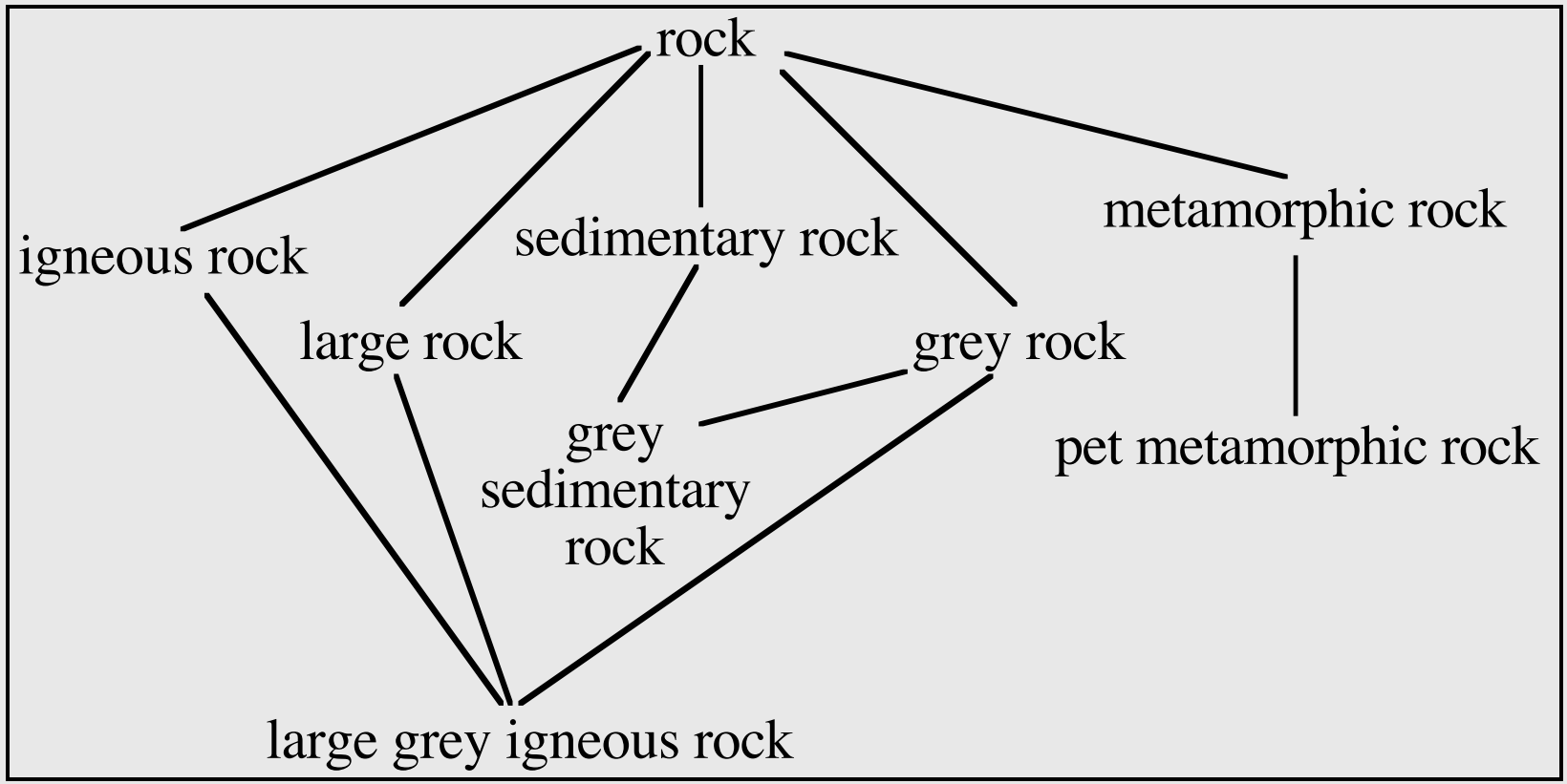
- A (very simple-minded) painter may intepret the previous expression in a completely different way:
  - Three different reds on my palette:
    - Orange
    - Apple
    - Cherry
- So an expression like ∃*x:red* Apple(*x*) may mean that the painter has just picked up an "Apple" red.

- Two different ontological assumptions behind the Red predicate:
  - adjectival interpretation: *being a red thing* doesn't carry an identity criterion (uncountable)
  - nominal interpretation: *being a red color* does carry an identity criterion (countable)

Formal ontological distinctions help making a conceptualization explicit

Kinds, roles, attributions

How many rock kinds are there?



[From Brachman, R ., R. F ikes, et al. 1983. "Krypton: A Functional Approach to Knowledge Representation", *IEEE Computer*]

The answer

- According to Brachman & Fikes 83:
  - It's a dangerous question, only "safe" queries about analytical relationships between terms should be asked
- In a previous paper by Brachman and Levesque on ***terminological competence*** *in knowledge representation* [AAAI 82]:
  - "an *enhancement mode transistor* (which is a *kind* of transistor) should be understood as different from a *pass transistor* (which is a *role* a transistor plays in a larger circuit)"
- These issues have been simply *given up* while striving for logical simplification and computational tractability
- The OntoClean methodology, based on formal ontological analysis, allows us to conclude: ***there are 3 kinds of rocks*** (appearing in the figure)

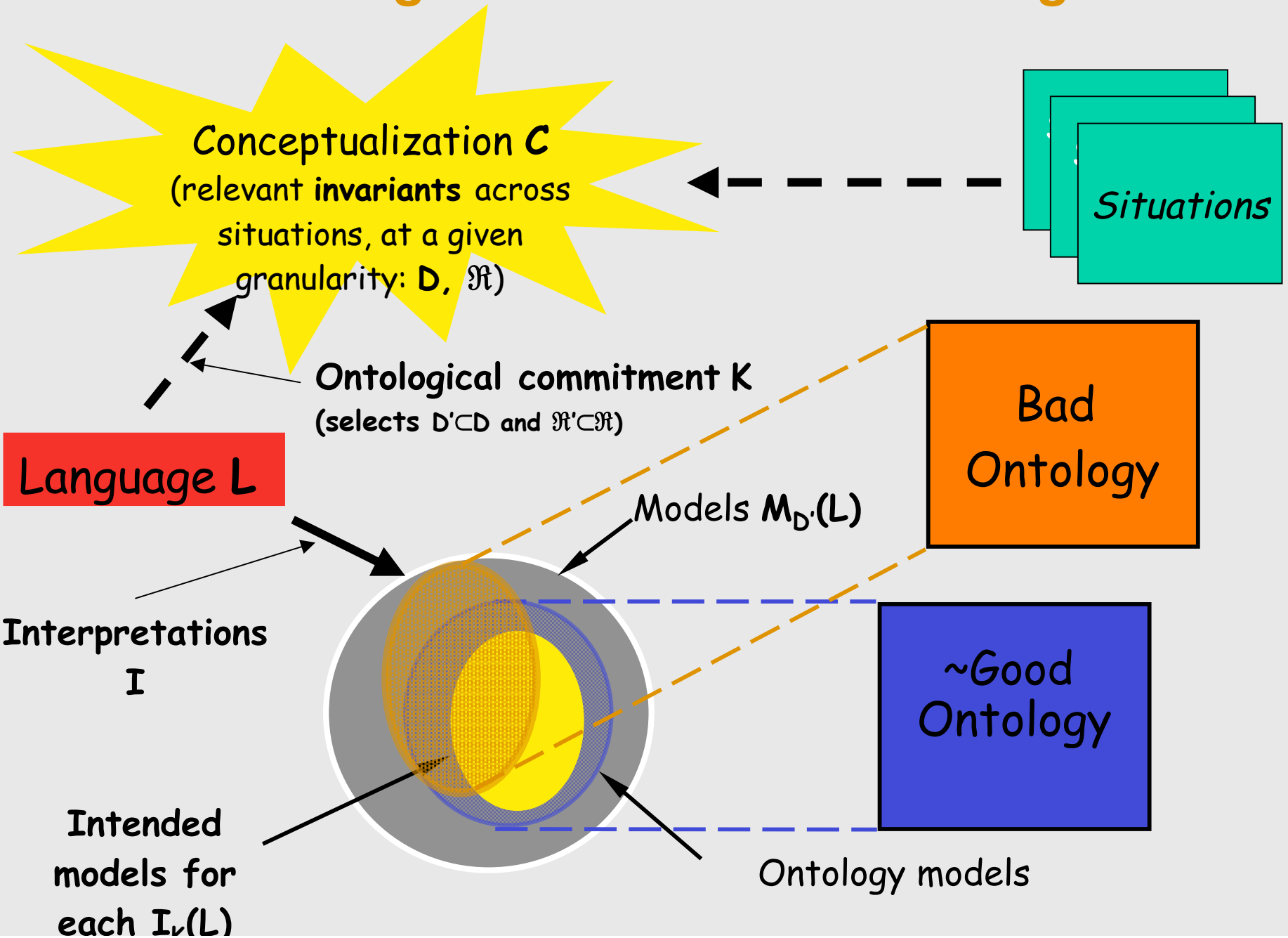
Ontology and Ontologies

- ***Ontology***: the philosophical discipline
  - Study of ***what there is***
    (content *qua* content, even independently of its existence...)
  - Study of the ***nature*** and ***structure*** of "reality"
- ***ontologies***:

Specific (theoretical or computational) artifacts
expressing the ***intended meaning*** of a ***vocabulary***
in terms of ***primitive*** categories and relations describing
the ***nature*** and ***structure*** of a ***domain of discourse***

Gruber: "Explicit and formal specifications of a ***conceptualization***"

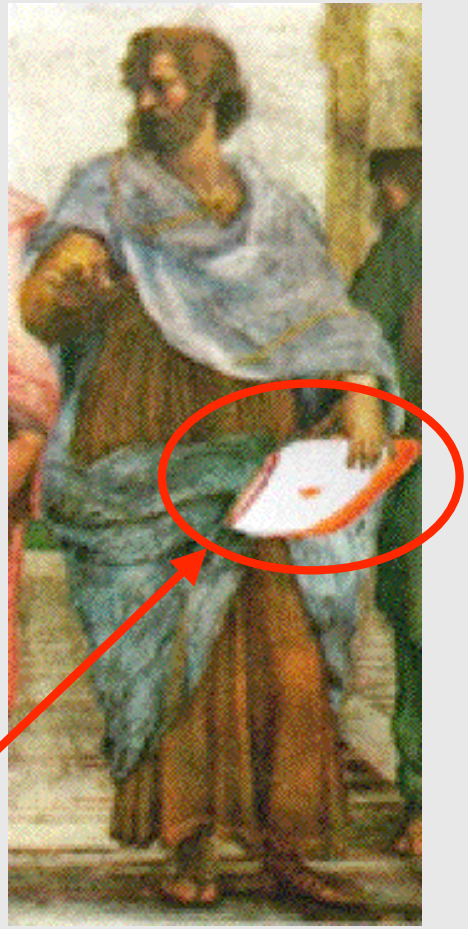
Ontologies and intended meaning



Which primitives?
The role of ontological analysis

- Theory of Essence and Identity
- Theory of Parts (Mereology)
- Theory of Wholes
- Theory of Dependence
- Theory of Composition and Constitution
- Theory of Properties and Qualities

The basis for a common ontology vocabulary



Idea of Chris Welty, IBM Watson Research Centre, while visiting our lab in 2000