Formal Ontologies, Prototypes, Exemplars

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Ontocom 2011

31 October –03 November 2011, Brussels, Belgium

Outline

- Concept Representation (CR) in Artificial Intelligence (AI) and Cognitive Science (CS).
- Knowledge Representation Systems (KRS) evolution
- CR in ontologies.
- Architecture proposal for non classical CR and reasoning in formal ontologies.

Concept Representation (CR)

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Compositionality

In compositional systems the meaning of a complex symbol *s functionally depends on the syntactic* structure of *s and from the meaning of primitive symbols* in it.

[Frege]

Concept Representation (CR)

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Classical Concept Theory (e.g.TRIANGLE = Polygon with 3 corners and sides	Compositionality (Frege Principle)
Typality Effects: (e.g. CHAIR, GAME = ??)	Representing Prototypical Information

KRs in AI

	Early KRs (cognitively inspired)	KRs Evolution
Systems	E.g. **Semantic Networks** (Quillian, 1967), **Frame Systems** (Minsky, 1975), ...	
Pros +	Allowed to represent and reasoning on tipicality.	
Cons -	Lack of a formal characterization and a clear semantics.	

KRs in AI

	Early KRs (cognitively inspired)	KRs Evolution
Systems	E.g. **Semantic Networks** (Quillian, 1967), **Frame Systems** (Minsky, 1975), ...	e.g. **KL-ONE** Systems (Brachman & Schmoltze, 1985) and their descendants : e.g **OWL** .
Pros +	Allowed to represent and reasoning on tipicality.	Formal characterization.
Cons -	Lack of a formal characterization and a clear semantics.	Prototypical representation and approximate reasoning not allowed

CR & Ontologies

CR is a central problem in **Ontology Engineering** and for the development of semantic technologies.

The way in which **knowledge** is represented even impacts on **reasoning** capabilities of the systems.

Problems

Computational ontologies are often assumed to represent **common sense concepts**.

Most common sense concepts cannot be represented in terms of necessary/sufficient conditions (classical concept theory) and the **common sense reasoning** often is non monotonic.

Ex. Common Sense Reasoning - **Categorization**

An element X is categorized as a DOG because:

X {hasFur, WagTail, Woof}

No one of these traits is definitory of DOG

Problems/2

Open Problems: **representation** (of) and **reasoning** (on) prototypical information in formal ontologies.

Proposed Solutions

a) **fuzzy approaches** => fuzzy approaches to prot. effects based encounter some difficulty with compositionality (Osherson and Smith 1981).

a) **probabilistic generalization** of ontology language => e.g. BayesOWL. Problem: translation from an OWL semantics to a statistical one.

a) **non-monotonic extensions of DLs** => computational difficulties (Baader and Schmolze1995) and extremely complicated semantics.

Our Proposal

Takes into accounts information coming from the **Cognitive Science**:

	Dual Process Theory	**Pseudo Fodorian Theory**	**Prototype vs Exemplars**
[Considered aspects]	Dual architecture	Modularity	Different forms of tipicality

Why a Cognitive Background

In our opinion artificial systems designed taking into account evidence coming from experimental psychology may give better results in real life "intelligent" applications.

Ex. in category representation: We know that **WATER** = **H_2O**

But when we categorise a sample of stuff as **WATER**, we use such prototypical traits such as the fact that (liquid) water is usually a **colourless**, **odourless** and **tasteless fluid**.

Dual Process Theory

Hypothizes the existence of **two** different types of cognitive systems.

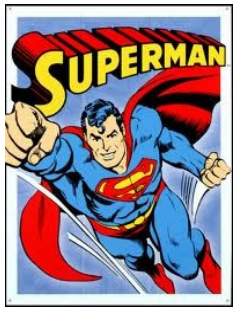
- **Type 1** => automatic, associative and fast, non monotonic => [**Categorization**]

- **Type 2** => conscious, sequential and slow, based on explicit rule, monotonic => [**Classification**]

Categorization

Categorization: assignment of an individual to a class.

e.g. SUPERHEROES ≡ BraveHUMANS ∧ HaveSuperpowers ∧ FightForJustice

SUPERHEROES (…. 

,…)

Classification

Classification: identification of subsumption relation between classes. For example:

DOMESTIC DOG ⊆ DOG

SAUSAGE DOG ⊆ DOG

DOMESTIC DOG ≡ DOG ∧ LivesinHouse

Adding:

DOMESTIC SAUSAGE DOG ⊆ SAUSAGE DOG and

DOMESTIC SAUSAGE DOG LivesinHouse

is possible to infer:

DOMESTIC SAUSAGE DOG ⊆ DOMESTIC DOG

Classification vs Categorization

In Humans:

Categorization is usually a common task and involves typical information (and therefore non monotonic forms of inference).

Classification is usually a (rare) form of monotonic, deductive reasoning.

Pseudo Fodorian Proposal

This proposal also, partially, follows the Fodorian one.

We borrow from Fodor the hypothesis that compositional representations and prototypical effects are demanded to different components of the representational architecture.

Prototypes vs Exemplars

Our proposal allows to take into account different aspects of concepts typicality:

Prototype view: knowledge about categories is stored in terms of prototypes. CAT = a prototypical cat.

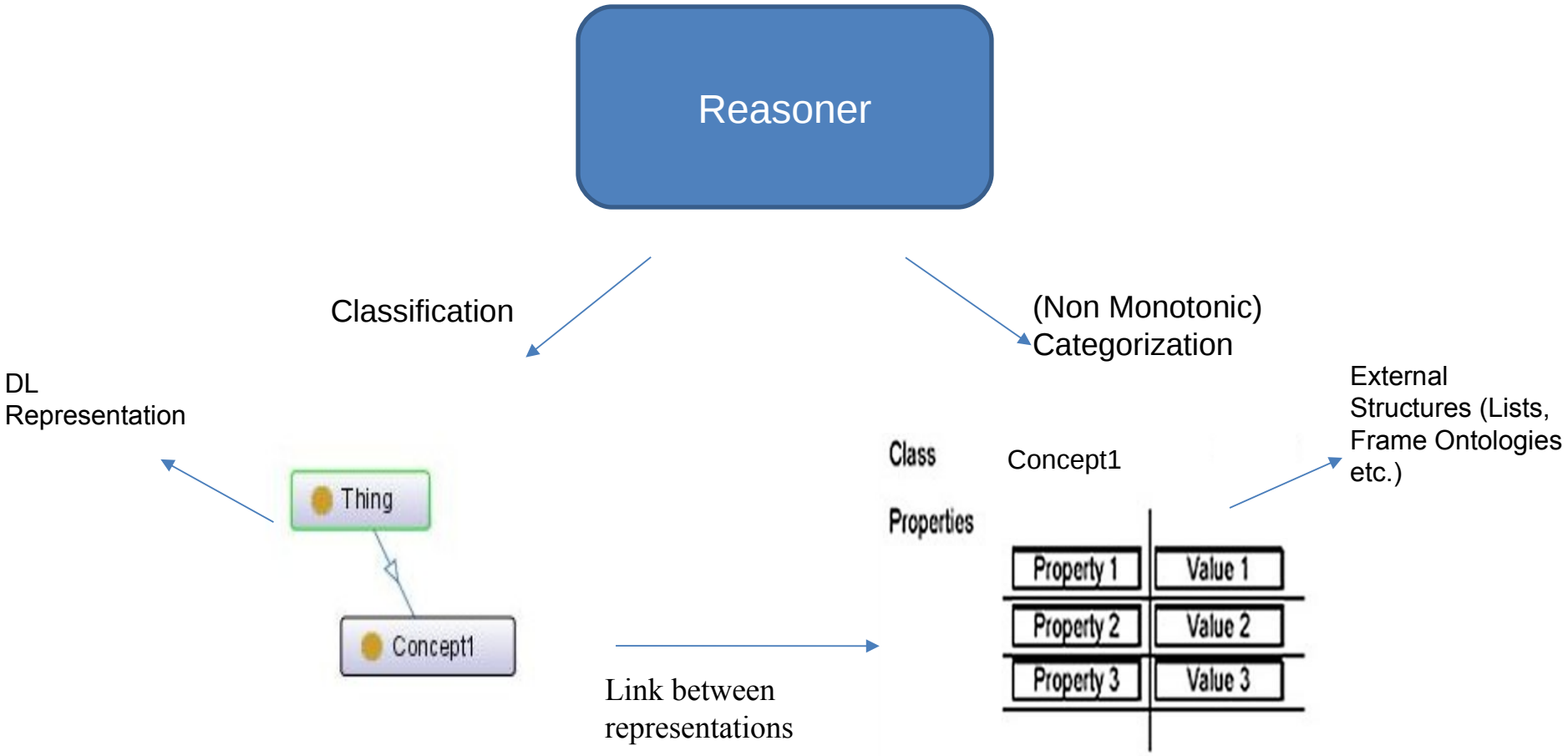
Exemplar view: the mental representation of the concept CAT is the set of the representations of (some of) the cats we encountered during our lifetime.

Our Proposal

Realization of a **dual architecture** with different "**modules**": a monotonic one (*classification*) and a non monotonic one involved in the management of exceptions *(categorization)*.

Presence of Hybrid (or "dual") concepts representation in the ontologies and hybrid reasoning systems.

Proposed Architecture



Evaluation

It is our intention to evaluate our proposal by comparing its performance with that of a traditional ontology based system representing the same domain.

We will evaluate the dual system with **property checking** and **instance checking** controls.

Expected Results

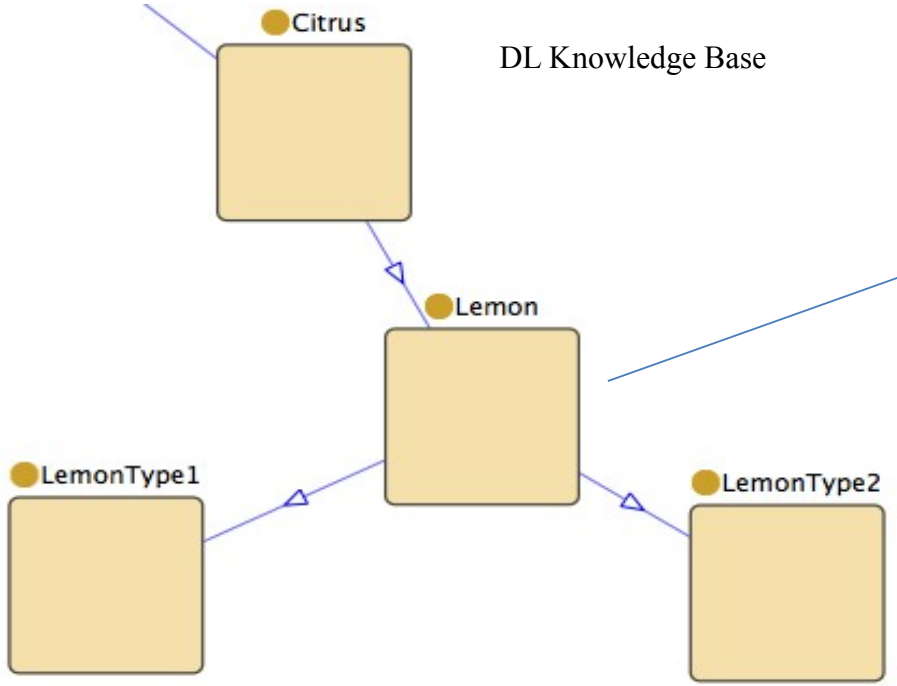
Property Checking (Sparql Query): “does the class A have the property b?”

We expect an **enriched query-answering mechanism** that should take advantage from the integration of different types and/or levels (DL and prototypical one) of information provided for the same concept.

SELECT? citrus
WHERE {?citrus :has colour : YELLOW .
}

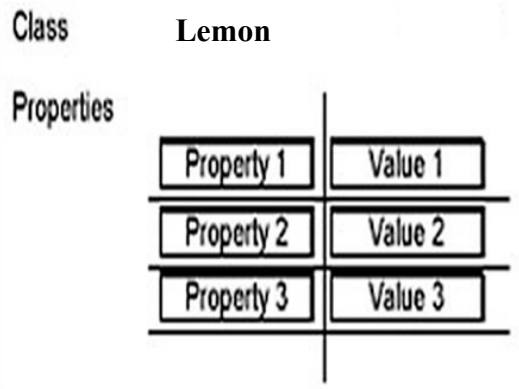
which citrus is yellow ?

= DOES ANY CITRUS HAVE THE PROPERTY YELLOW?



DL Knowledge Base

Typical
Knowledge Base



Expected Results/2

Instance Checking: is the instance X member of the concept Y?

It could be possible that an instance A will result as not a member of the Class A* in the DL component while and as instance of the Class A** in the prototypical representation of the same concept.

This result does not cause inconsistencies because of the separation of representation and reasoning process and allows, at least in principle, to enrich the answering capabilities of the system.

Future Work

Evaluation of the "dual architecture" compared with a classical representational structure for the property and instance checking tasks.

Feasibility study of the proposed architecture for real applications.

Formal Ontologies, Exemplars, Prototypes

Thank you !!!

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O&S clearly

show that fuzzy-set theory cannot support a compositional semantics

whose input consists of prototype concepts.

Pseudo “Fodorian”

We leave out the problem of the nature of semantic content of conceptual representations.

Fodor claims that concepts are compositional, and that prototypical representations, in being not compositional, cannot be concepts. We do not take any position on which part of the system we propose must be considered as truly “conceptual”.

Fodor claims that almost all the concepts that correspond to lexical entries have no structure. We maintain that many lexical concepts, even though indefinable in classical theory terms, should exhibit some form of structure.