

The role of well-founded ontologies for the Semantic Web (and beyond)

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Summary

- Why ontologies
- What ontologies are (or should be...)
- Ontology quality
- Foundational ontologies
- The DOLCE ontology

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- *Why ontologies*
- What ontologies are (or should be...)
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The importance of *subtle distinctions*

"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

Where subtle distinctions in meaning are important

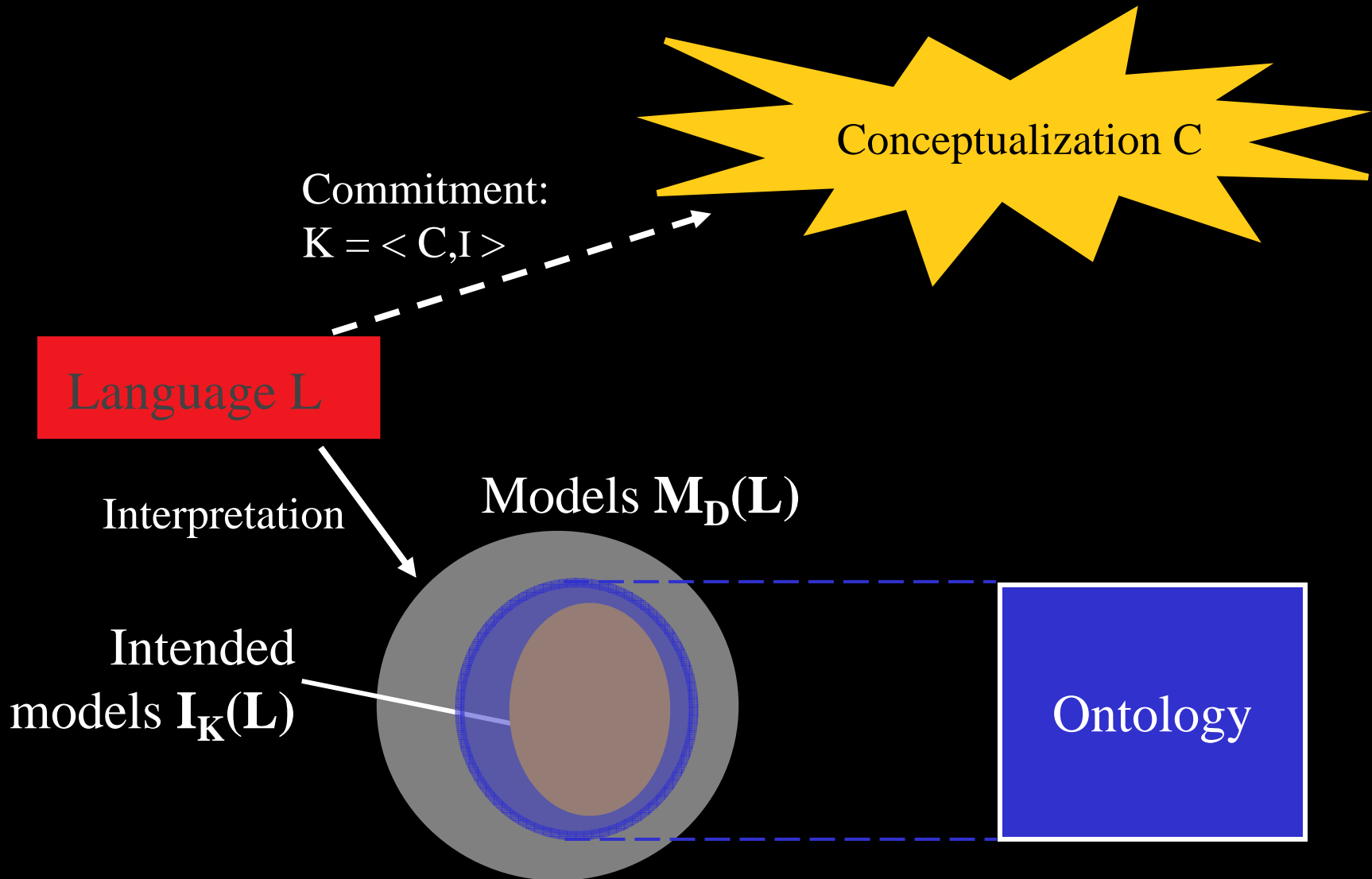
- US elections: how many *holes*?
- Twin towers catastrophe: how many *events*?

...only ontological analysis solves these problems!!

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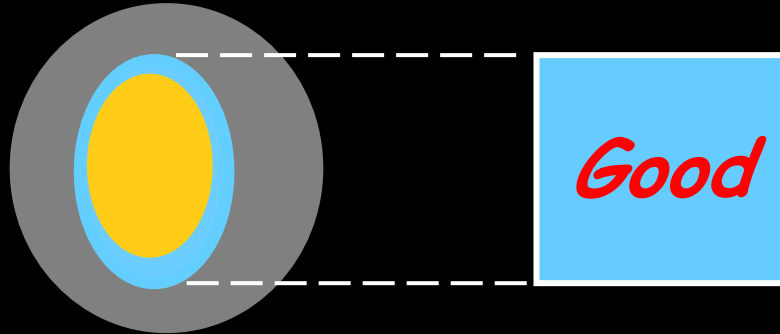
Ontologies and intended meaning



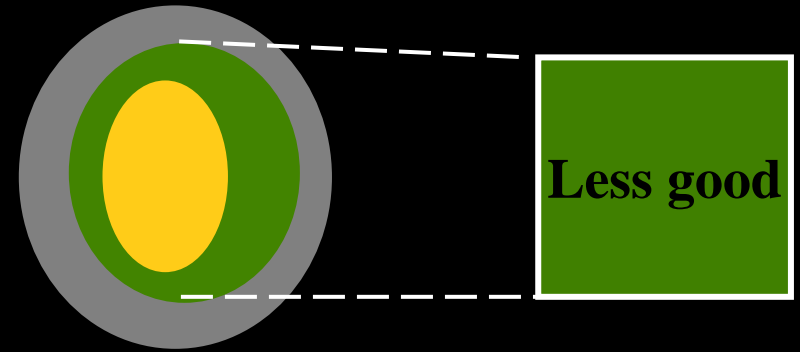
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- What ontologies are (or should be...)
- **Ontology quality**
- Foundational ontologies
- The DOLCE ontology

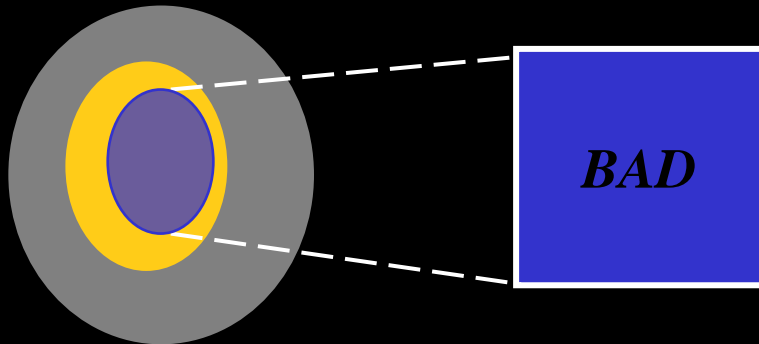
Ontology Quality: Precision and Coverage



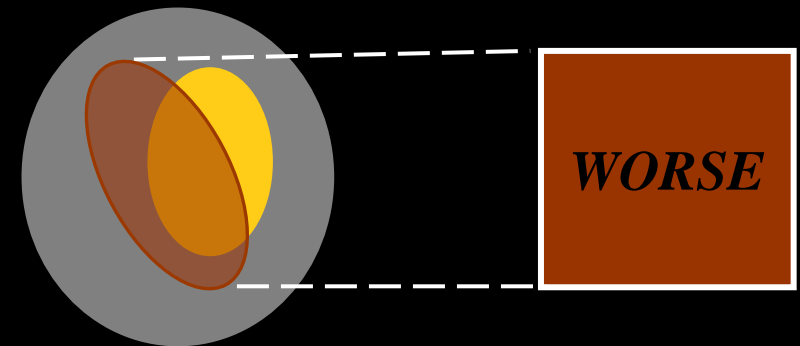
High precision, max coverage



Low precision, max coverage

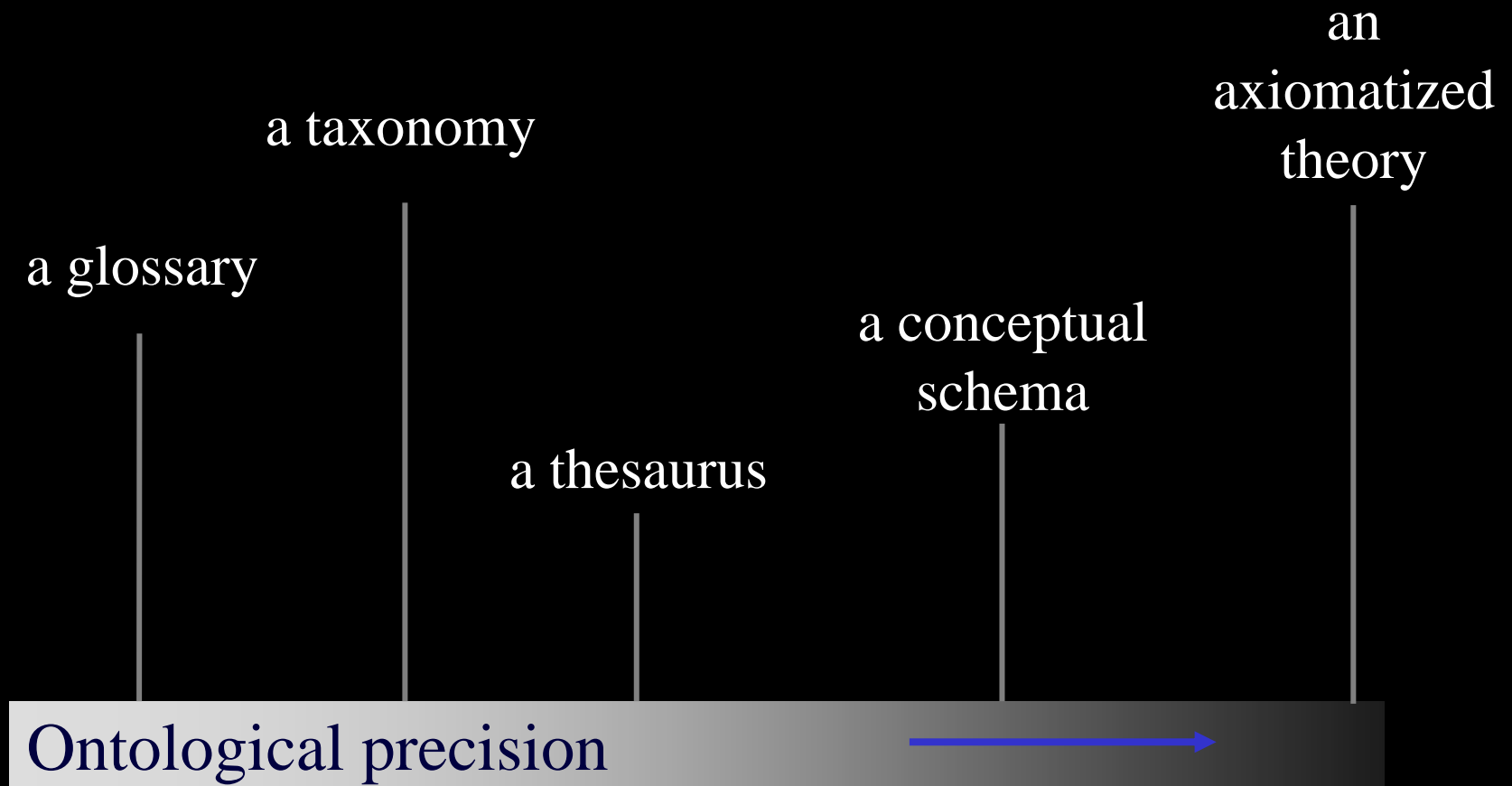


Max precision, limited coverage

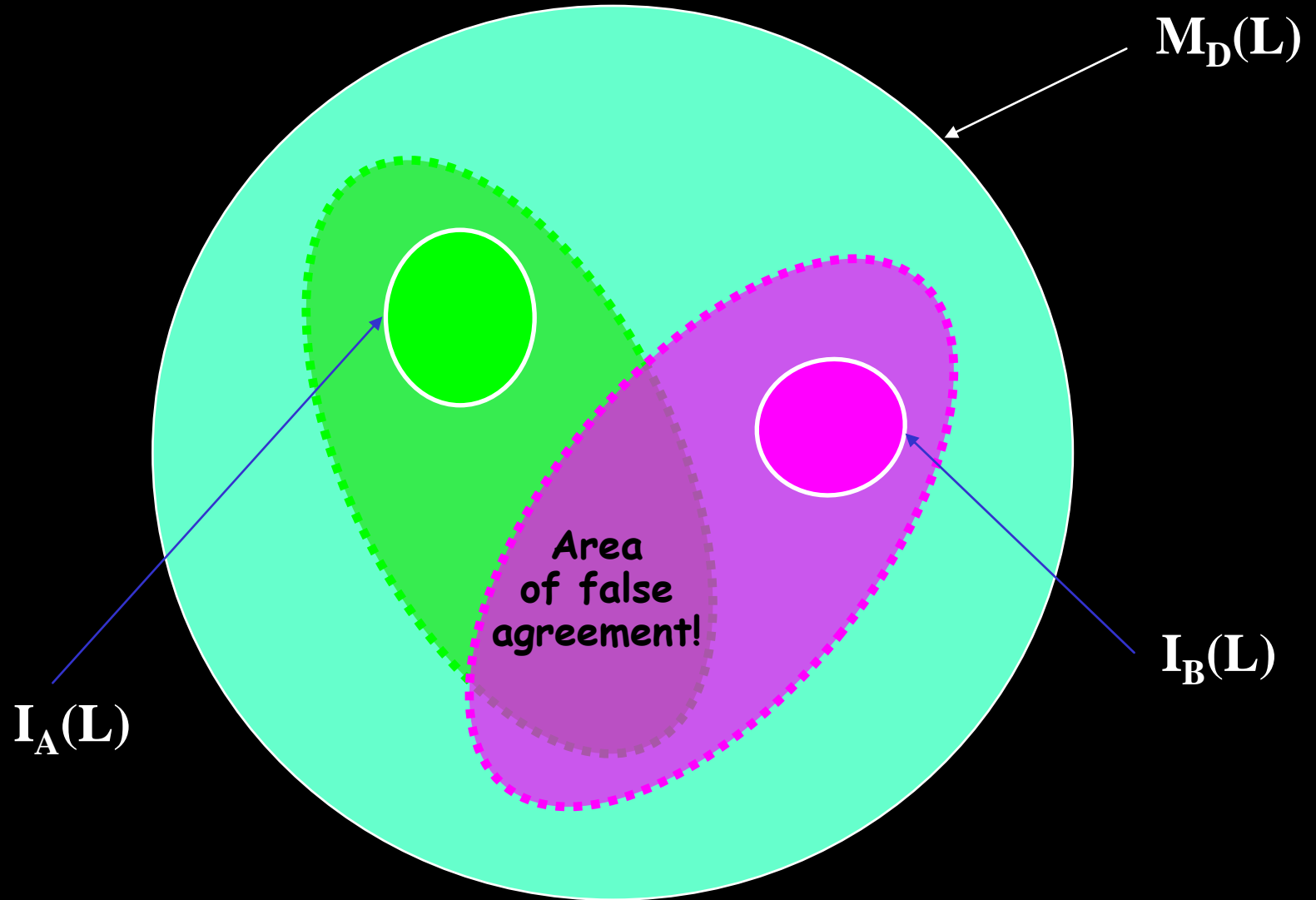


Low precision, limited coverage

Levels of Ontological Precision



Why precision is important



When precision is not enough

Only one binary predicate in the language: **on**

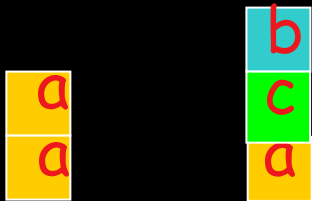
Only blocks in the domain: **a, b, c, ...**

Axioms (for all x, y, z):

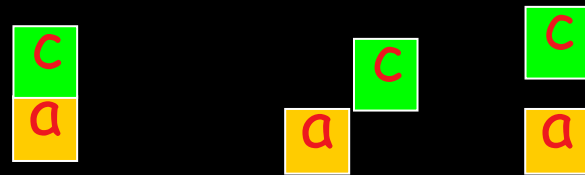
$$\text{on}(x, y) \rightarrow \neg \text{on}(y, x)$$

$$\text{on}(x, y) \rightarrow \neg \exists z (\text{on}(x, z) \wedge \text{on}(z, y))$$

Non-intended *models* are excluded, but the rules for the competent usage of **on** in different *situations* are not captured.



Excluded situations



Indistinguishable situations

Precision vs. Accuracy

- In general, a single intended *model* may not discriminate among relevant alternative *situations* because of
 - Lack of *primitives*
 - Lack of *entities*
- Capturing all intended models is not sufficient for a “perfect” ontology

Precision: non-intended *models* are excluded

Accuracy: non-intended *situations* are excluded

Towards a practical procedure for rigorous ontology evaluation

- Determine a list of *situations* which the ontology is supposed to cover
- Document these situations by means of *illustrations* (annotated multimedia documents) showing the *agreed intended use* of ontology terms
- Make sure that for each term multiple examples and *counter-examples* are given
- Establish the *correspondence* between situations and ontology models

Notes

- These methods are best applied to single properties or relations within an ontology
- The same ontology may have different metrics for each relation
- Improvement wrt these metrics can characterize *ontology change rationale*

Ontologies vs. Conceptual Schemas

- Conceptual schemas
 - not accessible at run time
 - not always have a formal semantics
 - constraints focus on *data integrity*
 - attribute values *taken out of the UoD*
- Ontologies
 - accessible at run time (at least in principle)
 - formal semantics
 - constraints focus on *intended meaning*
 - attribute values *first-class citizens*

Ontologies vs. Knowledge Bases

- Knowledge base
 - Assertional component
 - reflects *specific (epistemic) states of affairs*
 - designed for *problem-solving*
 - Terminological component (*ontology*)
 - *independent* of particular *states of affairs*
 - Designed to support *terminological services*

Ontological formulas are (assumed to be)
necessarily true

Different uses of ontologies

- Simple semantic access *(Processing time)*
 - Intended meaning of terms *known in advance* within a community
 - Only services relevant for the query are supported
 - *Limited expressivity* (stringent computational requirements)
- Meaning negotiation and explanation *(Pre-processing time)*
 - *Negotiate meaning* across different communities
 - *Establish consensus* about meaning of a new term within a community
 - *Explain meaning* of a term to somebody new to community
 - *Higher expressivity* and rich axiomatization needed to exclude ambiguities
 - The ontology is used *once*, before cooperation process starts

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Foundational ontologies

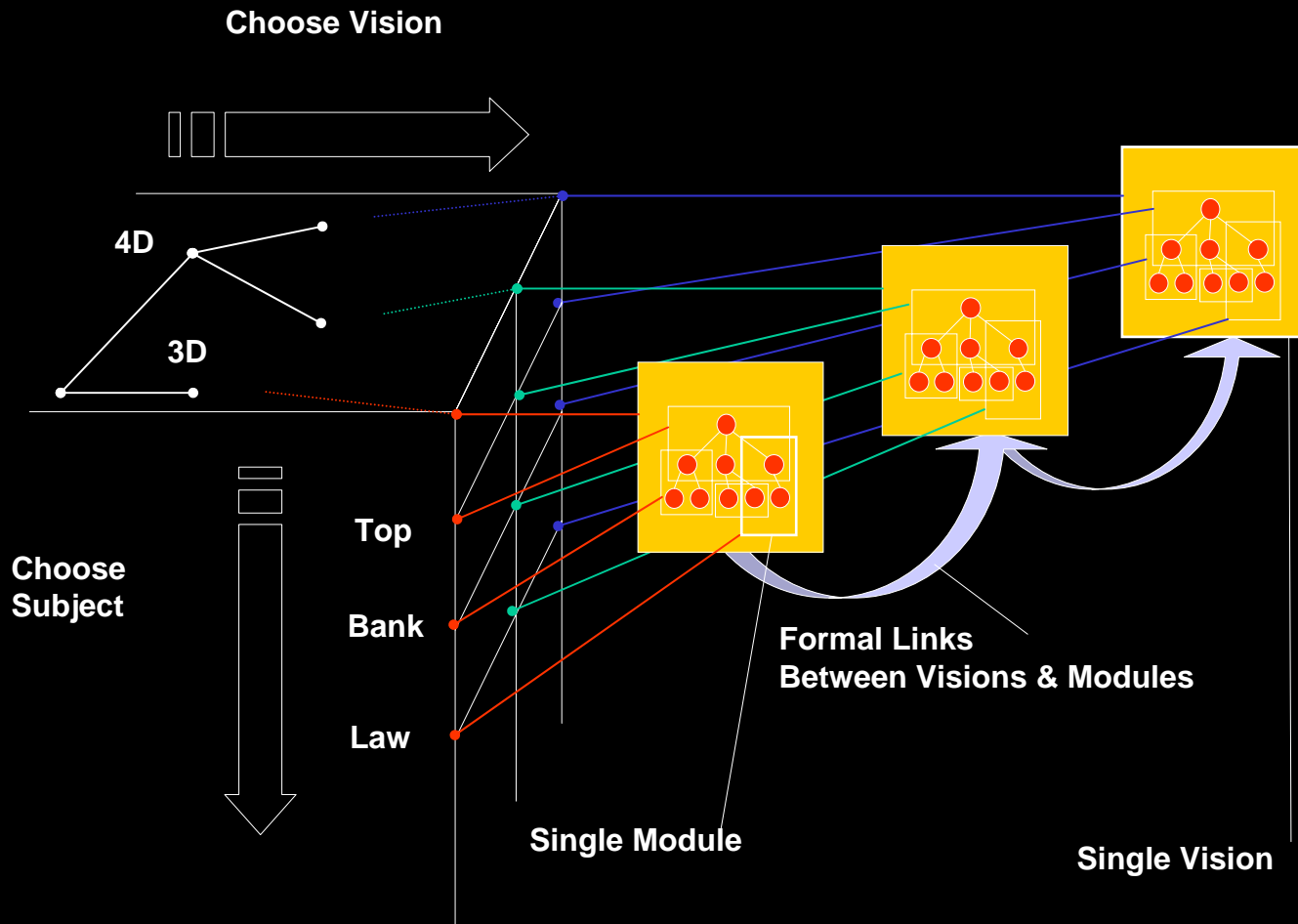
- Provide a *carefully crafted taxonomic backbone* to be used for domain ontologies
- Help recognizing and understanding *disagreements* as well as agreements
- Improve ontology development *methodology*
- Provide a principled mechanism for the semantic integration and *harmonisation* of existing ontologies and metadata standards
- Improve the *trust* on web services

Mutual understanding vs. mass interoperability

The WonderWeb Library of Foundational Ontologies

- No single upper level
- Rather, a (small) set of *foundational ontologies* carefully *justified* and *positioned* with respect to the space of possible choices
- *Basic options* clearly documented
- Clear *branching points* to allow for easy comparison of ontological options)

The WFO architecture



Formal Ontological Analysis

- Theory of Parts
- Theory of Wholes
- Theory of Essence and Identity
- Theory of Dependence
- Theory of Qualities
- Theory of Composition and Constitution
- Theory of Participation
- Theory of Description

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DOLCE

a Descriptive Ontology for Linguistic and Cognitive Engineering

- Strong cognitive bias: *descriptive* (as opposite to *prescriptive*) attitude
- Emphasis on *cognitive invariants*
- Categories as *conceptual containers*: no “deep” metaphysical implications wrt “true” reality
- Clear *branching points* to allow easy comparison with different ontological options
- *Rich axiomatization*
 - *37 basic categories*
 - *7 basic relations*
 - *80 axioms, 100 definitions, 20 theorems*

DOLCE's basic taxonomy

Endurant

Physical

Amount of matter

Physical object

Feature

Non-Physical

Mental object

Social object

...

Perdurant

Static

State

Process

Dynamic

Achievement

Accomplishment

Quality

Physical Qs

Spatial location

...

Temporal Qs

Temporal location

...

Abstract Qs

...

Abstract

Quality region

Time region

Space region

Color region

...

...

Endurants vs. Perdurants

- **Endurants:**
 - All proper parts are present whenever they are present (*wholly presence*, no temporal parts)
 - Exist in time
 - Can genuinely change in time
 - May have non-essential parts
 - Need a time-indexed parthood relation
- **Perdurants:**
 - Only some proper parts are present whenever the perdurant is present (*partial presence*, temporal parts)
 - Happen in time
 - Do not change in time
 - All parts are essential
 - Do not need a time-indexed parthood relation

Abstract vs. Concrete Entities

- Concrete: located in space-time (regions of space-time are located in themselves)
- Abstract - two meanings:
 - Result of an abstraction process (something common to multiple exemplifications)
 - * *Not located in space-time*
- Mereological sums (of concrete entities) are concrete, the corresponding sets are abstract...

Qualities and qualia

- Linguistic evidence
 - *This rose has a color*
 - *Red is a color*
 - *This rose is red*
 - *The color of this rose turned to brown in one week*
 - *Red is opposite to green and close to brown*
- Every entity comes with certain qualities that permanently *inhere* to it and are *unique* of it
- Qualities are perceptually mapped into *qualia*, which are regions of *quality spaces*.
- Properties hold because qualities have certain locations in their quality spaces.
- Each *quality type* has its own quality space

Qualities

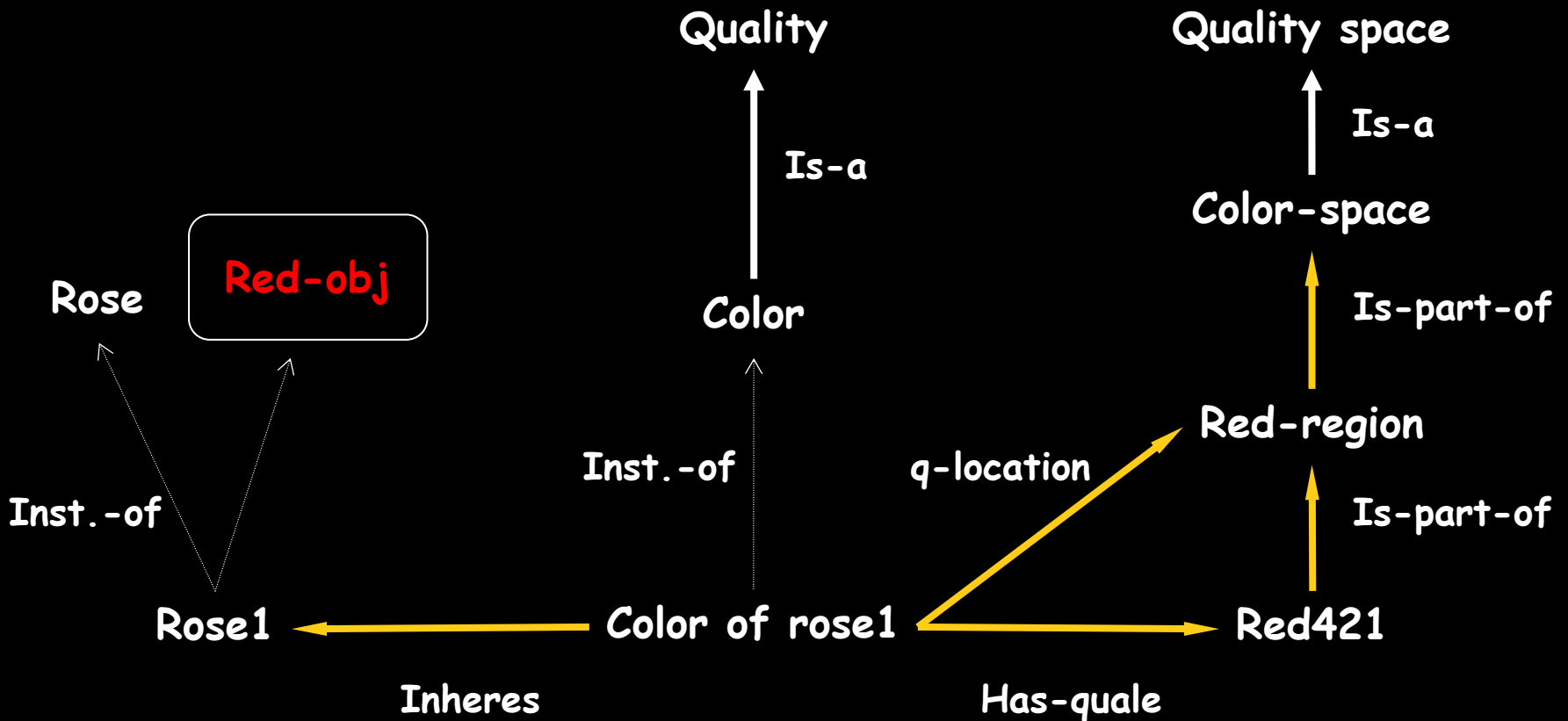


The rose and the chair have *the same color red*:

- different *color-qualities* inhere to them
- but these *color-qualities* are located in the same quality region (called *red*)

Therefore, the same color “attribute” (red) is ascribed to the two objects

Qualities



Qualities and quality spaces

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Qualities vs. Features



- **Features:** "parasitic" physical entities.
- **relevant parts** of their host...
... or **places**
- Features have qualities, qualities have no features.



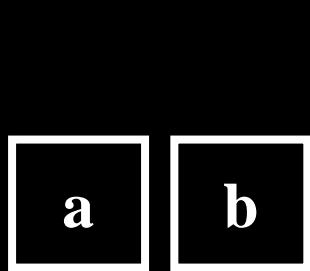
Basic Relations

- Parthood
 - Atemporal
 - Temporal
- Dependence
 - Specific/generic constant dependence
- Constitution (different from parthood)
- Inherence (between a quality and its host)
- Qualification (between a quality and its quale)
- Participation (between an endurant and a perdurant)

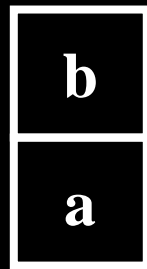
- Description
- Classification

Part, Constitution, and Identity

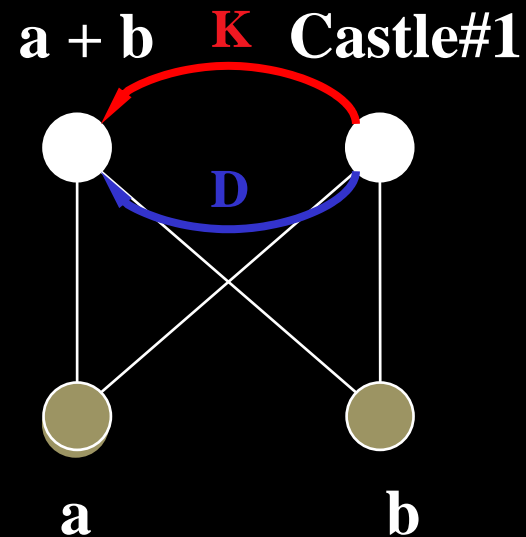
- *Structure* may change identity
- *Mereological extensionality* is lost
- *Constitution* links the two entities
- *Constitution* is asymmetric (implies *dependence*)



Two
blocks



A castle



Participation relations

- Hold between a perdurant and its involved endurants
- Extremely relevant for domain modeling
- Current axiomatization covers:
 - constant vs. temporary
 - complete vs. partial
- Further distinctions are currently primitive (thematic roles)
 - *Agent, Theme, Substrate, Instrument, Product*
 - More is needed on event structure, intentionality, and artifacts to produce analytic definitions

Applications of DOLCE: WordNet alignment and OntoWordNet

- synsets from WordNet directly subsumed by a DOLCE+D&S class
 - Whole WordNet linked to DOLCE+D&S
 - Lower taxonomy levels in WordNet still need revision
- Glosses being transformed into DOLCE+ axioms
 - Machine learning applied jointly with foundational ontology
- WordNet "domains" being used to create a modular, general purpose domain ontology

Applications: Core Ontologies based on DOLCE

(DOLCE+D&S+OntoWordNet)

- ✓ core ontol. of biomedical terminologies
- ✓ `` of plans and guidelines
- ✓ `` of (Web) services
- ✓ `` of service-level agreements
- ✓ `` of transactions (bank, anti-money-laundering)
- ✓ `` of regulatory compliance
- ✓ `` of fishery (FAO's Agriculture Ontology Service)
- ✓ `` for the Italian legal lexicon

Is the Semantic Web just Hype?

- Maybe yes...
- For sure, an "ontology vocabulary" is not enough
- And languages based on "semantic" primitives (OWL) are not enough (need for *ontological primitives*)

- Perhaps not, if the deep problems underlying ontology and semantics are attacked under an *interdisciplinary* and *rigorous* approach

Research priorities at the ISTC-CNR

Laboratory for Applied Ontology



- Foundational ontologies and ontological analysis
- Domain ontologies
 - Physical objects
 - Information and information processing
 - Social interaction
 - Ontology of legal and financial entities
- Ontology, language, cognition
- Ontology-driven information systems
 - Ontology-driven conceptual modeling
 - Ontology-driven information access
 - Ontology-driven information integration