Laboratory for Applied Ontology
Institute of Cognitive Science and Technology
Italian National Research Council

# Ontology in Formal Semantics and Lexical Semantics

ESSLLI 2005 introductory course on
Formal Ontology for Semanticists

Edinburgh – 10 August 2005

# Today’s goal



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At the end of the lecture, you should have

- a better grasp of the formalism,
- a hint on the relationships among primitives, and
- an idea of the questions one should keep in mind in formalizing ontological notions.



# Outline of the lecture

- Location



# Outline of the lecture

- Location
- Qualities



# Outline of the lecture

- Location
- Qualities
- Identity and Consitution



# Outline of the lecture

- Location
- Qualities
- Identity and Consitution
- Atomicity



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- Location
- Qualities
- Identity and Consitution
- Atomicity
- The “space” of ontological choices



# On Location



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**Source**

R. Casati and A. Varzi “Parts and Places”, MIT Press, 1999 (Chp. 7)



# Location: why?

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- Location and topological connection...



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Informally, we take $L(x, y)$ to mean “x is exactly located at y”

(we put no restriction on the ‘dimension’ of the entities...)



# Location: axioms (1)

$L(x,y) \wedge L(x,z) \rightarrow y = z$ (functionality)

$L(x,y) \rightarrow L(y,y)$ (conditional reflexivity)

Consequences:



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- $L(x,y) \wedge L(y,z) \rightarrow L(x,z)$ (transitivity)
- $L(x,y) \wedge L(y,w) \rightarrow y = w$ (no co-location of regions)



# Location: doubts

Do we want the followings?

$\forall x \exists y \, L(x, y)$ (everything is localized)

$\forall x \, (L(x, x) \rightarrow \exists y \, (x \neq y \wedge L(y, x)))$

(every region is the location of something)



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$WL(x,y) =_d \exists z\,.\,P(z,y) \wedge L(x,z)$ (whole location)
e.g. Italy is wholly located in (the location of) Europe

$GL(x,y) =_d \exists z,w\,.\,P(z,x) \wedge P(w,y) \wedge L(z,w)$ (generic location)
e.g. Museums are generically located in Berlin
(for instance, one would say: some museums are in Berlin)



# Exact and Broad Locations (2)

*...and other notions can be captured with the help of topology!*

Here is a simple example.
Let $TP$ be “tangential part”, then

$$TPL(x,y) =_d \exists z \,.\, TP(z,x) \wedge L(z,y) \qquad \text{(tangential PL)}$$

e.g. The Alps are tangentially partially located in Italy



# Exact and Broad Locations: axioms and consequences

New axioms:

A few consequences:



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A few consequences:



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A few consequences:

(i) $P(x,y) \wedge L(y,z) \rightarrow WL(x,z)$

(ii) $PL(x,y) \wedge P(z,y) \rightarrow PL(x,z)$



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A few consequences:

(i) $P(x,y) \wedge L(y,z) \rightarrow WL(x,z)$

(ii) $PL(x,y) \wedge P(z,y) \rightarrow PL(x,z)$

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# On Qualities



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**Source**

D. M. Amstrong “Four disputes about properties”, Synthese (2005) 144: 309-320



# Qualities

Let's concentrate on *qualities* !

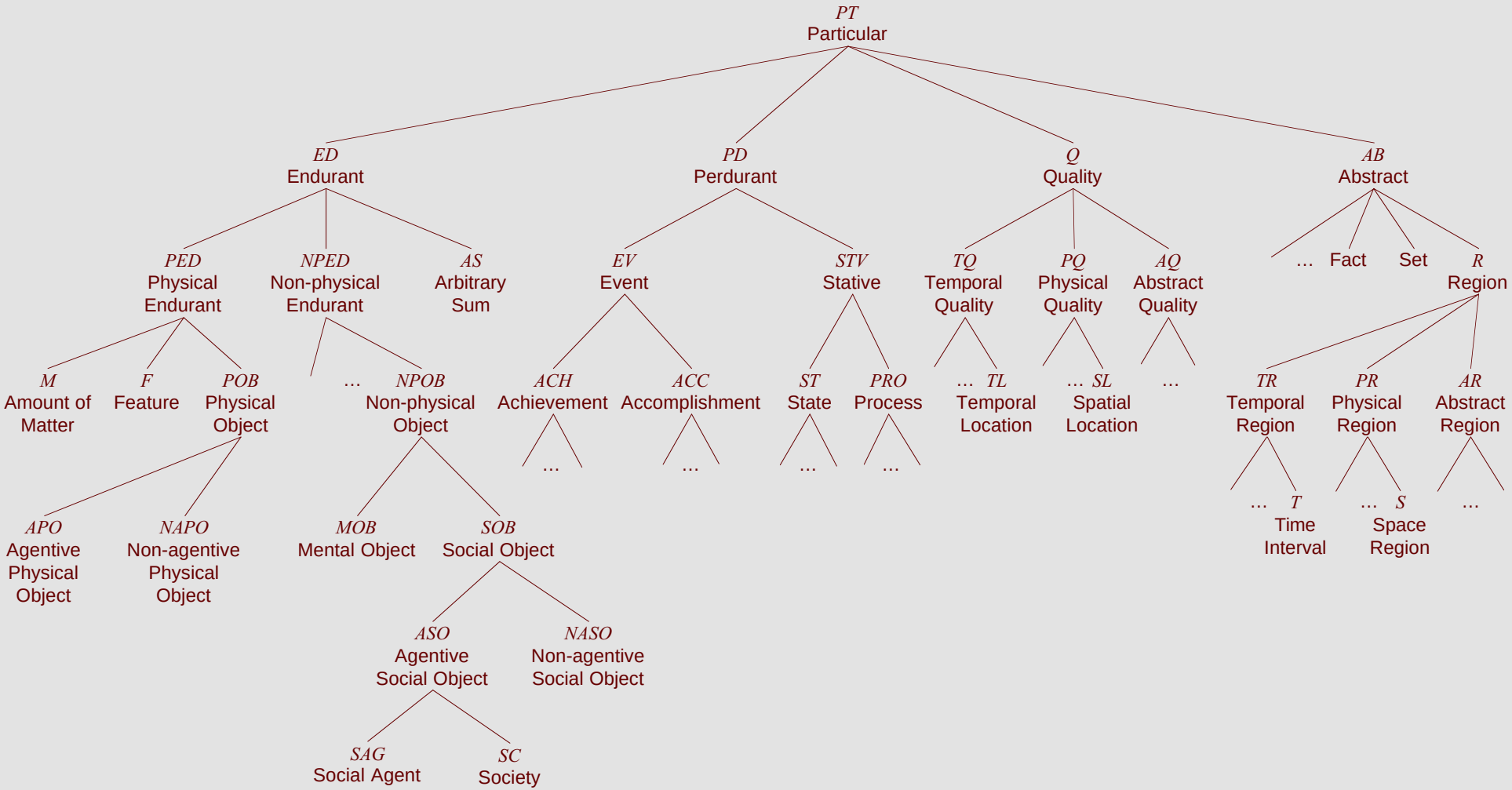
On this topic we follow the DOLCE ontology.

**Source**
http://www.loa-cnr.it/DOLCE.html

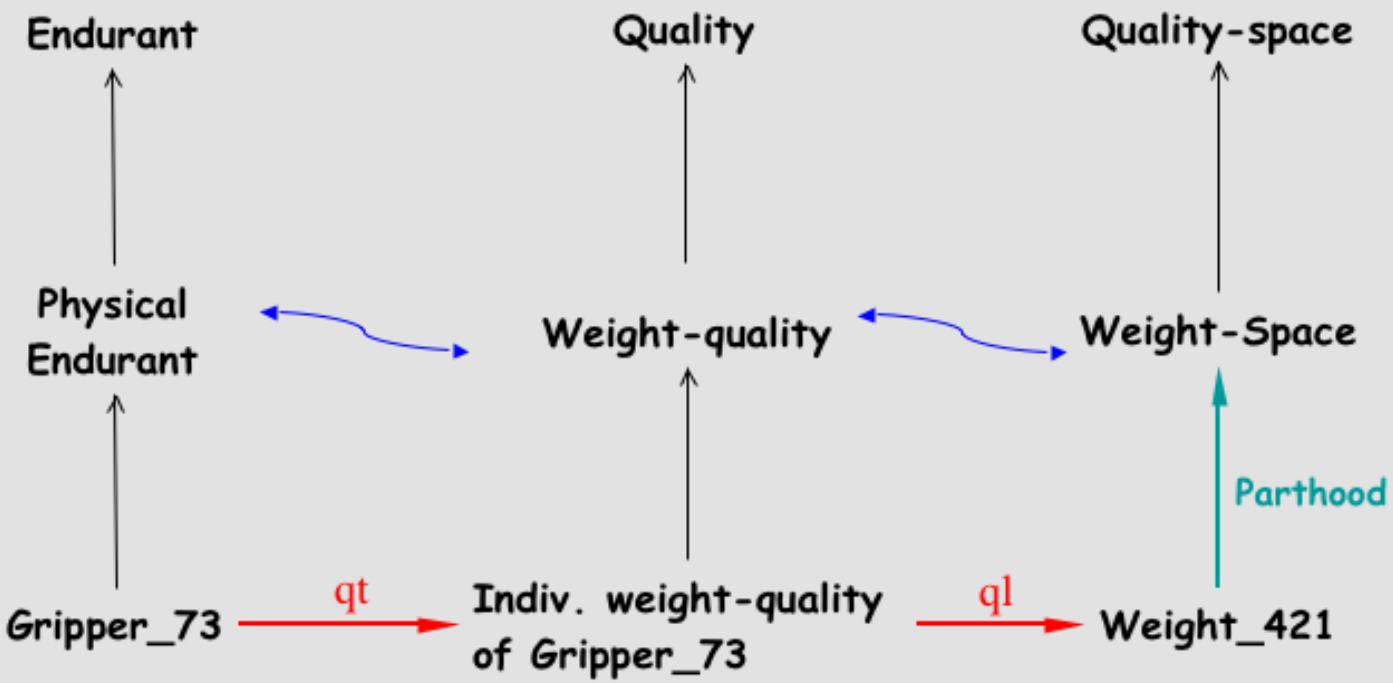
See also
C. Masolo and S. Borgo "Qualities in Formal Ontology" in Foundational Aspects of Ontologies (Ws Font 2005), to appear



# Qualities: DOLCE Taxonomy



# Qualities, Qualia, and Hosts



# Qualities: formalization (1)

qt$(x, y)$ stands for "$x$ is a quality of $y$"

*Derived Relations*



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*Derived Relations*

- dqt$(x, y) =_d$ qt$(x, y) \wedge \neg\exists z(\text{qt}(x, z) \wedge \text{qt}(z, y))$

(*Direct Quality*)



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*Derived Relations*

- dqt$(x, y) =_d$ qt$(x, y) \wedge \neg\exists z(\text{qt}(x, z) \wedge \text{qt}(z, y))$
  (*Direct Quality*)
- qt$(\phi, x, y) =_d$ qt$(x, y) \wedge \phi(x) \wedge \text{SBL}_x(Q, \phi)$
  (*Quality of type* $\phi$)



# Qualities: formalization (2)

*Argument Restrictions*

*Ground Axioms*



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*Argument Restrictions*

- $\mathrm{qt}(x, y) \rightarrow (Q(x) \wedge (Q(y) \vee ED(y) \vee PD(y)))$
- $\mathrm{qt}(x, y) \rightarrow (TQ(x) \leftrightarrow (TQ(y) \vee PD(y)))$
- $\mathrm{qt}(x, y) \rightarrow (PQ(x) \leftrightarrow (PQ(y) \vee PED(y)))$
- $\mathrm{qt}(x, y) \rightarrow (AQ(x) \leftrightarrow (AQ(y) \vee NPED(y)))$

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*Ground Axioms*

- $(\mathsf{qt}(x,y) \wedge \mathsf{qt}(y,z)) \rightarrow \mathsf{qt}(x,z)$
- $(\mathsf{dqt}(x,y) \wedge \mathsf{dqt}(x,y')) \rightarrow y = y'$
- $(\mathsf{qt}(\phi,x,y) \wedge \mathsf{qt}(\phi,x',y)) \rightarrow x = x'$
- $(\mathsf{qt}(\phi,x,y) \wedge \mathsf{qt}(\psi,y,z)) \rightarrow \mathsf{DJ}(\phi,\psi)$



# Qualities: formalization (3)

*Existential Axioms*

*Consequence*



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*Existential Axioms*

- $TQ(x) \rightarrow \exists! y(\mathsf{qt}(x, y) \wedge PD(y))$
- $PQ(x) \rightarrow \exists! y(\mathsf{qt}(x, y) \wedge PED(y))$
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- $PD(x) \rightarrow \exists y(\mathsf{qt}(TL, y, x))$
- $PED(x) \rightarrow \exists y(\mathsf{qt}(SL, y, x))$
- $NPED(x) \rightarrow \exists \phi, y(\mathsf{SBL}(AQ, \phi) \wedge \mathsf{qt}(\phi, y, x))$

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*Consequence*

- $\neg \mathsf{qt}(x,x)$



# Qualia: formalization (1)

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ql$(x, y, t)$ stands for "$x$ is the quale of $y$ (during $t$)"

PC$(x, y, t)$ stands for "$x$ participates in $y$ during $t$"

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- $\mathrm{ql}_{T,PD}(t, x) =_d PD(x) \wedge \exists z(\mathrm{qt}(TL, z, x) \wedge \mathrm{ql}(t, z))$



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- $\mathrm{ql}_{T,ED}(t, x) =_d ED(x) \wedge t = \sigma t'(\exists y(\mathrm{PC}(x, y, t'))$
- ...



# Qualia: formalization (2)

*Argument restrictions*

*Functionality Axiom*

*Existential and Structuring Axioms*



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*Existential and Structuring Axioms*

- $TQ(x) \rightarrow \exists y(\mathsf{ql}(y,x))$
- $(\mathsf{L}_X(\phi) \wedge \phi(x) \wedge \phi(y) \wedge \mathsf{ql}(r,x) \wedge \mathsf{ql}(r',y)) \rightarrow$
  $\exists\psi(\mathsf{L}_X(\psi) \wedge \psi(r) \wedge \psi(r'))$



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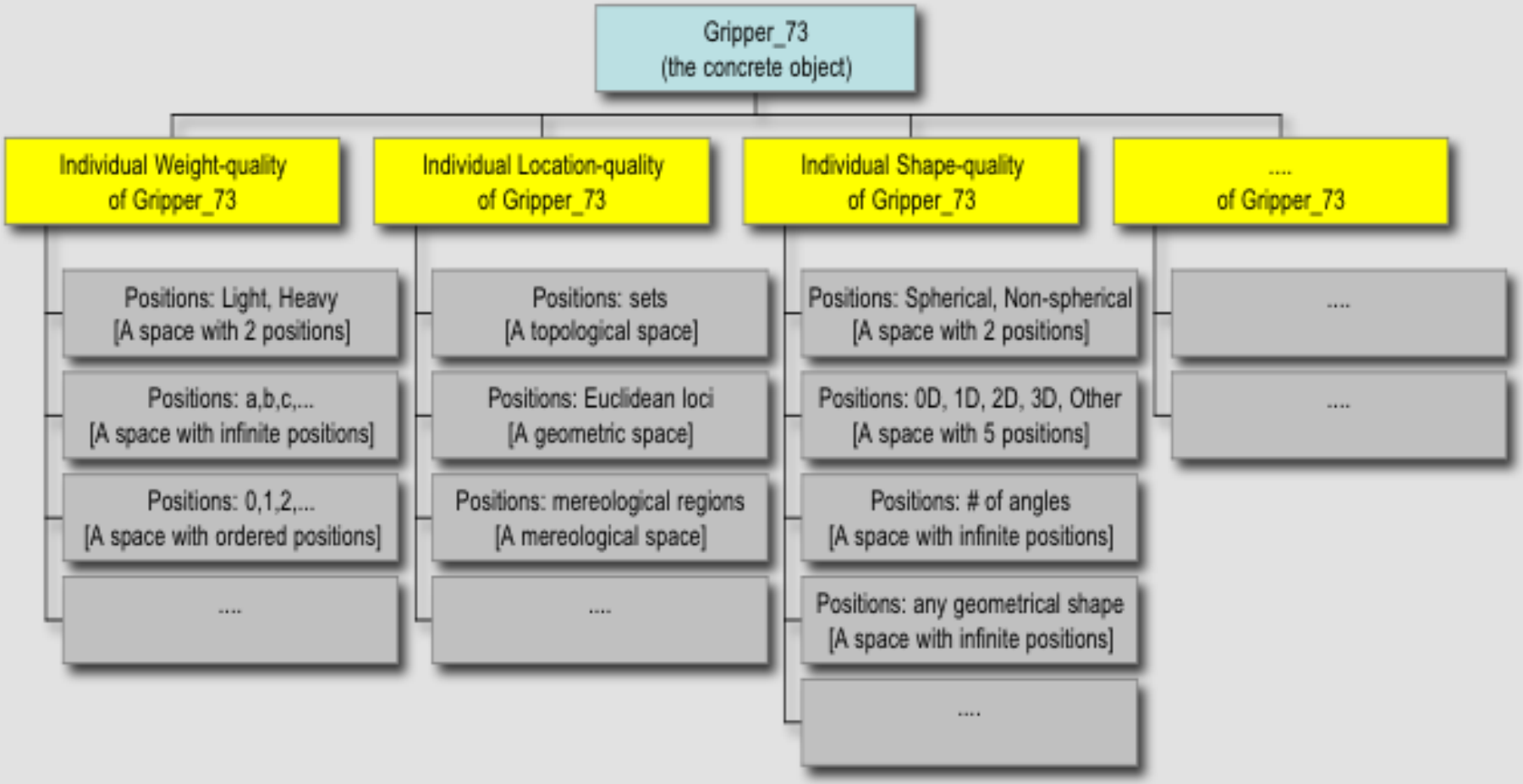
- $(\mathsf{L}_X(\phi) \wedge \phi(x) \wedge \neg\phi(y) \wedge \mathsf{ql}(r,x) \wedge \mathsf{ql}(r',y)) \rightarrow$
  $\neg\exists\psi(\mathsf{L}_X(\psi) \wedge \psi(r) \wedge \psi(r'))$



# Qualities and Qualia



# Identity and Constitution



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*A motivating example*



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*A motivating example*

- Assume I borrow from you £10 today to give it back in a week.
- A week later, we meet and I refuse to return the money. Before you start calling me names, I add that you should agree with me and I explain why.
- After a while you accept my argument and leave.



# Identity and Constitution

There are two issues here:

1) how can this conclusion happen?
2) how can we avoid an automatic system to end up throwing away your money as you just did?



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**Source**

M. Rea “Introduction” in Material Constitution - A Reader, R. C. Rea (ed.), Rowman & Littlefield Publishers, Inc., 1997



# Identity and Constitution

## Assumptions (I)

Esistence Assumption

$$\exists x, ps, t \,.\, F(x) \wedge K(ps, x, t)$$

Essentialist Assumption

$$\forall x, ps, t \,.\, (F(x) \wedge K(ps, x, t)) \rightarrow \exists z[K(ps, z, t) \wedge \Box \, \forall qs, t \,.\, K(qs, z, t) \rightarrow R(z, qs)]$$



# Identity and Constitution

## Assumptions (II)

Principle of Alternative Compositional Possibilities

$$\forall x, ps, t\,[(F(x) \wedge K(ps, x, t)) \rightarrow \exists z[K(ps, w, t) \wedge \Diamond\,(\exists qs, t\,(K(qs, w, t) \wedge \neg R(w, qs)))]]$$

Identity Assumption

$$\forall x, y, ps, t\,[K(ps, x, t) \wedge K(ps, y, t) \rightarrow x = y]$$

Necessity Assumption

$$\forall x, y\,[x = y \rightarrow \Box\,((E(x) \vee E(y) \rightarrow x = y)]$$



# Identity and Constitution

*Motivations for dropping the Essentialist Assumption.*



# Identity and Constitution

*Motivations for dropping the Necessity Assumption.*



# On Atomicity



# Atomicity

**Source**

C. Masolo and L. Vieu “Atomicity vs. Infinite Divisibility of Space”, COSIT ’99



# Atomicity



# Ontology as a Space of Choices



# Space of Ontological Choices (1)

Universals, Particulars and Individual Properties
Properties are universals (repeatables), e.g. “redness”, that apply to different entities OR properties are tropes (non-repeatables), i.e. “individual” properties inhering only in a specific entity, e.g. “the red of this particular rose”? Are entities the substrates of their properties or are they the aggregations of their properties?
Persistence of entities
How do entities persist? What does it means for an entity to change maintaining its identity? Are entities spatio-temporal worms that change because they present different phases OR are they three-dimensional extended entities changing because they instantiate different properties at different times? Is it possible to have at the same time the two kinds of entity connected by a participation relation?



# Space of Ontological Choices (2)

Space and Time

Are space, time and space-time absolute (i.e. regions of space, time and space-time are assumed in the ontology) OR are they relative (i.e. we can consider only spatial, temporal and spatio-temporal relations between entities)? Is space-time Newtonian, Galilean, . . . ?

Localization

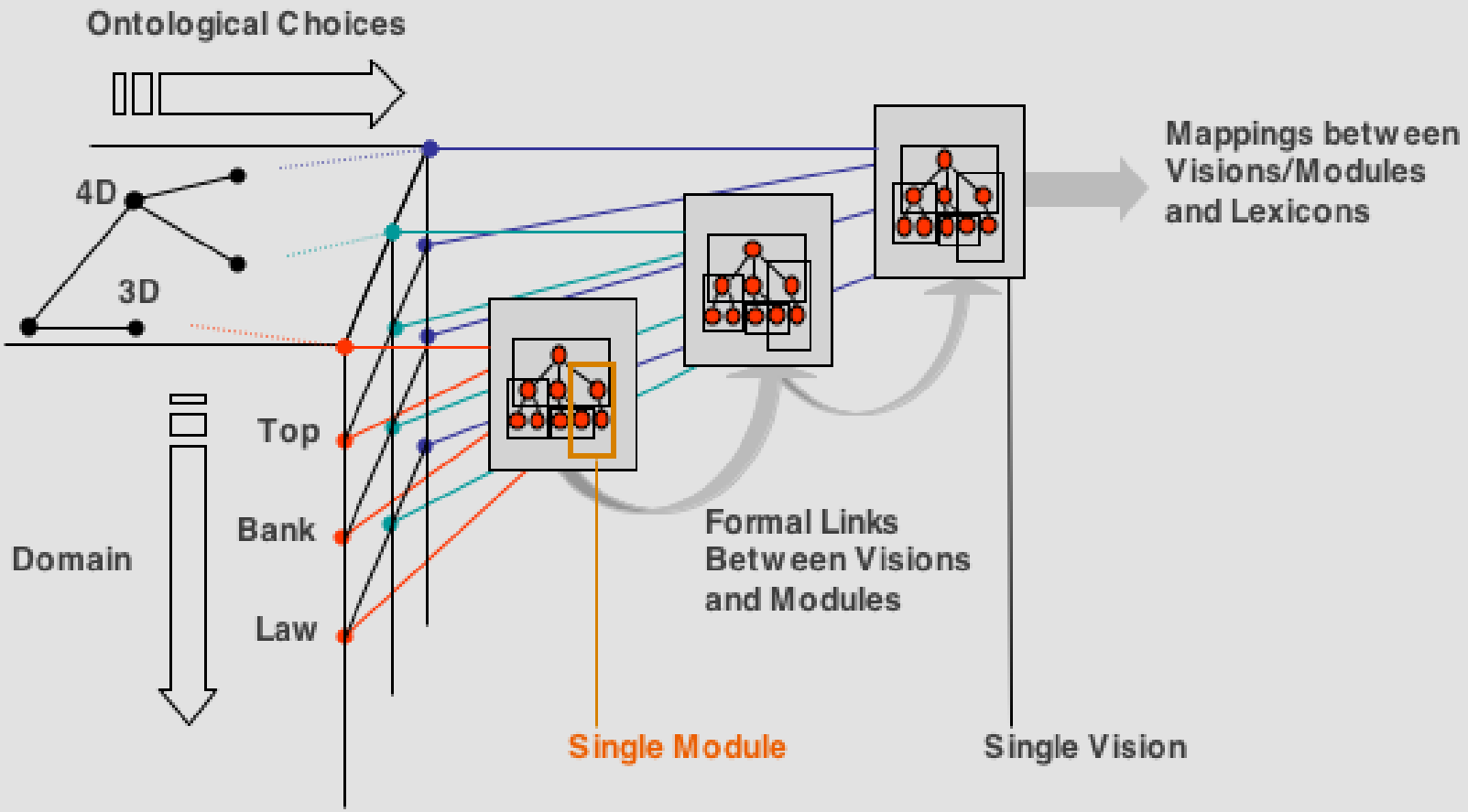
Are all the entities localized in space (concrete) OR there exist entities that are not in space (abstract) Is it possible to have different entities that are (spatially or spatio-temporally) co-localized?



# Space of Ontological Choices (3)

Two dimensions:

- *visions*, corresponding to basic ontological choices;
- *specificity*, corresponding to the domains



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