Sweetening Ontologies cont'd: Aligning Bottom-up with Top-down Ontologies

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Content and goal of the talk

- We investigate an issue at the interface between language and ontology.
- We run an experiment in which we align the corpus-based (bottom-up) system of semantic types developed in the T-PAS resource with the upper-level foundational (top-down) ontology DOLCE.
- We limit the experiment to the Endurant domain.
- The goals is to highlight the distinctions and similarities between the two systems from a cognitive and application-based perspective.
- What we learned and future work.

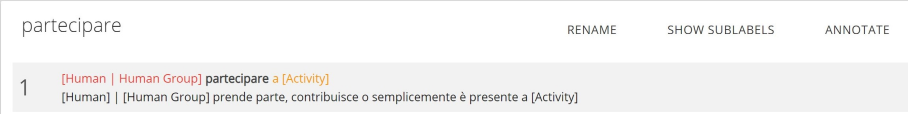
Background

- By applying the methodology of Corpus Pattern Analysis (Hanks 2013) to the analysis of corpus evidence for about 1600 average polysemy Italian verbs, with the goal of acquiring their recurrent semantic structures (e.g. HUMAN partecipa in ACTIVITY), we have compiled a list of 180 **semantic types** to characterize the semantic preferences of verbs for each argument position in each verb sense.

Background

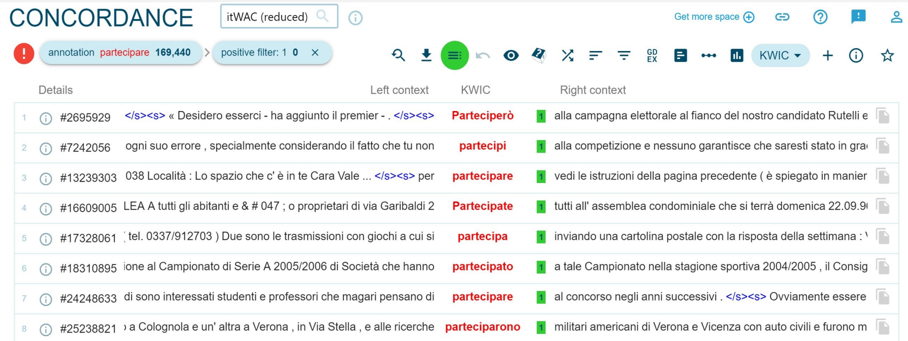
- These semantic types (EVENT, LOCATION, FOOD, VEHICLE, etc.) are obtained from manual clustering of lexical items found in the argument positions of verbal structures in the corpus: they can thus be seen as **human judgments** about the selectional preference of verbs.

T-pass 1 for *partecipare* ‘to take part’



1 [Human | Human Group] **partecipare** a [Activity]
[Human] | [Human Group] prende parte, contribuisce o semplicemente è presente a [Activity]

Corpus annotations



CONCORDANCE

itWAC (reduced)

annotation partecipare 169,440 > positive filter: 1 0 ×

	Details	Left context	KWIC		Right context
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2	#7242056	ogni suo errore , specialmente considerando il fatto che tu non	partecipi	1	alla competizione e nessuno garantisce che saresti stato in gra
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6	#18310895	ione al Campionato di Serie A 2005/2006 di Società che hanno	partecipato	1	a tale Campionato nella stagione sportiva 2004/2005 , il Consig
7	#24248633	di sono interessati studenti e professori che magari pensano di	partecipare	1	al concorso negli anni successivi . </s><s> Ovviamente essere
8	#25238821	a Colognola e un' altra a Verona , in Via Stella , e alle ricerche	parteciparono	1	militari americani di Verona e Vicenza con auto civili e furono m

Ontological categories vs. Semantic types

- These types look very much like ontological categories; however, instead of being stipulated, they are induced by the analysis of selectional properties of verbs.
- Despite the obvious correlations, the methodology underlying the identification of semantic types in T-PAS differs from the way categories are defined in resources such as the DOLCE ontology.
- While "aiming at capturing the ontological categories underlying natural language and human common sense" (cf. Masolo, Borgo, Gangemi, Guarino, Oltramari 2003) DOLCE does not derive the categories from systematic observation and clustering of linguistic data.

Research questions

- Are semantic types obtained through corpus analysis of selectional preferences of verbs similar to speculative categories defined primarily on the basis of axiomatization?
- If not, how do they differ from a cognitive and application-based perspective?
- Aligning the semantic type inventory of T-PAS to the categories of DOLCE.

Why DOLCE?

- DOLCE does not commit to a strictly referentialist metaphysics and aims at capturing the ontological categories underlying natural language and human commonsense (Gangemi et al. 2002).
- It is not based on empirical evidence, but it has a formal structure defined on ontological principles and axioms that we the T-PAS system of semantic types does not possess.

Top level of the T-PAS System of Semantic Types

with a selection of leaf types

- ANYTHING
  - ENTITY
    - PHYSICAL ENTITY
      - INANIMATE
        - ARTIFACT
        - STUFF
        - LIGHT SOURCE [LOCATION, INANIMATE]
      - ANIMATE
        - HUMAN
        - HUMAN GROUP
        - ANIMAL
        - ANIMAL GROUP
      - BODY
      - PART OF BODY
      - PLANT
      - LOCATION
    - ABSTRACT ENTITY
      - INSTITUTION [ABSTRACT ENTITY, HUMAN GROUP]
      - INFORMATION SOURCE
        - DOCUMENT [ARTIFACT, INFORMATION SOURCE]
      - ......
  - EVENTUALITY
    - EVENT
    - STATE
  - PROPERTY
    - COLOUR
    - ROLE
    - WEIGHT
    - ......

The T-PAS System 1/4

- The starting point of the T-PAS taxonomy is the type ANYTHING.
- The top level has ENTITY, EVENTUALITY (in Emmond Bach's terminology) and PROPERTY as branches.
- The main distinction in the domain of the ENTITY is between PHYSICAL and ABSTRACT ENTITY.

The T-PAS System 2/4

- Physical Entity is further distinguished in Inanimate, Animate, Body, Part of Body, Plant and Location.
- Body,Part of Body andPlant are considered ambiguous with respect to animacy, and therefore classified as subtypes of Physical Entity.
- Artifact forms a large and articulated branch of Inanimate (34 nodes in total), together with the sister note Stuff (17 nodes).

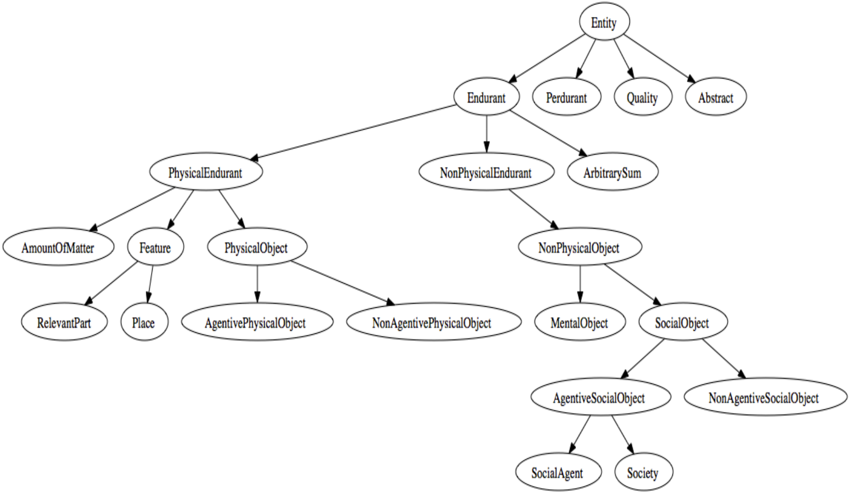
The T-PAS System 3/4

- The system contains no type for NATURAL KIND (as opposed to ARTIFACT) nor a type for INDIVIDUATED ENTITY (as opposed to STUFF).
- The prevailing distinction in the domain of PHYSICAL ENTITY is between ANIMATE and INANIMATE.
- This finds motivation in the role that this distinction plays in language, in particular in defining the semantic preferences that verbs impose on their arguments.

The T-PAS System 4/4

- The domain of EVENTUALITY has EVENT and STATE as main branches, whereas PROPERTY has, inter alia, COLOR, ROLE, and WEIGHT as subtypes.
- The system includes **multiple inheritance**.
- For our current purposes, we do not discuss the domains of EVENTUALITY and PROPERTY, and focus our attention on PHYSICAL ENTITY.

Taxonomy of DOLCE basic categories (excerpt)



DOLCE basic categories (excerpt)

- DOLCE top level distinguishes between *Endurant*, *Perdurant*, *Quality* and *Abstract*.
- An *Endurant* participates in a *Perdurant*: for example a *person* (*Endurant*) may participate in a *discussion* (*Perdurant*).
- *Qualities* inhere to entities; every entity comes with certain qualities (color, smell, size, weight etc.), which exist as long as the entity exist.
- *Abstracts* are entities with no spatial nor temporal qualities.

Further Distinctions in DOLCE 1/3

- Within *Endurant*, DOLCE distinguishes between *Physical* and *Non-physical* (according to whether they have direct spatial qualities).
- Within *Physical*, a distinction is drawn between between *Amount of Matter*, *Object*, and *Feature*, based on the notion of Unity and the relation of Dependence.
- *Object* are *Endurants* with Unity, *Amounts of Matter* are *Endurants* with no Unity (none of them is an essential whole).

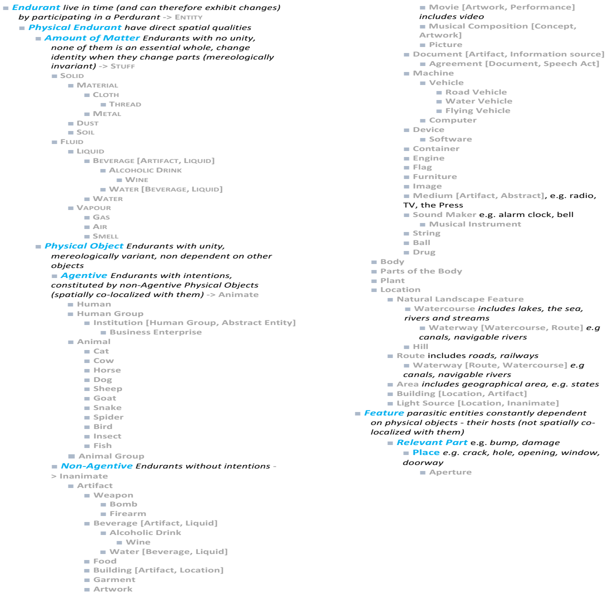
Further Distinctions in DOLCE 2/3

- *Objects* and *Amounts of Matter* are not dependent on other objects, while *Features* are dependent on another object, their host.
- Examples of *Features* are *Relevant Parts* such as a *bump*, and *Places* such as *a hole in a piece of cheese*, the *underneath of a table* etc.
- *Physical Objects* are divided into *Agentive* and *Non-agentive* according to whether or not they have intentions.
- *Agentive Objects* are constituted by *Non-agentive Objects*: for example, a *person* is constituted by an *organism*.

Further Distinctions in DOLCE 3/3

- *Non-physical Objects* ("abstracts" in common parlance) are divided into *Social Objects* and *Mental Objects* according to whether or not they are are generically dependent a community of agents.
- *Social Objects* are further divided into *Agentive* and *Non-agentive*.
- *Agentive Social Objects* are for example *Societies* such as *Sony*.
- *Non-agentive Social Objects* are *laws*, *norms*, *peace treaties* ecc., which are generically dependent on *Societies*.

Mapping T-PAS onto DOLCE (excerpt)



- ***Endurant*** *live in time (and can therefore exhibit changes) by participating in a Perdurant* -> Entity
  - ***Physical Endurant*** *have direct spatial qualities*
    - ***Amount of Matter*** *Endurants with no unity, none of them is an essential whole, change identity when they change parts (mereologically invariant)* -> Stuff
      - Solid
        - Material
          - Cloth
            - Thread
          - Metal
        - Dust
        - Soil
      - Fluid
        - Liquid
          - Beverage [Artifact, Liquid]
            - Alcoholic Drink
              - Wine
            - Water [Beverage, Liquid]
          - Water
        - Vapour
          - Gas
          - Air
          - Smell
    - ***Physical Object*** *Endurants with unity, mereologically variant, non dependent on other objects*
      - ***Agentive*** *Endurants with intentions, constituted by non-Agentive Physical Objects (spatially co-localized with them)* -> Animate
        - Human
        - Human Group
          - Institution [Human Group, Abstract Entity]
            - Business Enterprise
        - Animal
          - Cat
          - Cow
          - Horse
          - Dog
          - Sheep
          - Goat
          - Snake
          - Spider
          - Bird
          - Insect
          - Fish
        - Animal Group
      - ***Non-Agentive*** *Endurants without intentions* -> Inanimate
        - Artifact
          - Weapon
            - Bomb
            - Firearm
          - Beverage [Artifact, Liquid]
            - Alcoholic Drink
              - Wine
            - Water [Beverage, Liquid]
          - Food
          - Building [Artifact, Location]
          - Garment
          - Artwork
            - Movie [Artwork, Performance] *includes video*
            - Musical Composition [Concept, Artwork]
            - Picture
          - Document [Artifact, Information source]
            - Agreement [Document, Speech Act]
          - Machine
            - Vehicle
              - Road Vehicle
              - Water Vehicle
              - Flying Vehicle
            - Computer
          - Device
            - Software
          - Container
          - Engine
          - Flag
          - Furniture
          - Image
          - Medium [Artifact, Abstract], e.g. radio, TV, the Press
          - Sound Maker e.g. alarm clock, bell
            - Musical Instrument
          - String
          - Ball
          - Drug
        - Body
        - Parts of the Body
        - Plant
        - Location
          - Natural Landscape Feature
            - Watercourse *includes lakes, the sea, rivers and streams*
              - Waterway [Watercourse, Route] *e.g canals, navigable rivers*
            - Hill
          - Route includes *roads, railways*
            - Waterway [Route, Watercourse] *e.g canals, navigable rivers*
          - Area *includes geographical area, e.g. states*
          - Building [Location, Artifact]
          - Light Source [Location, Inanimate]
    - ***Feature*** *parasitic entities constantly dependent on physical objects - their hosts (not spatially co-localized with them)*
      - ***Relevant Part*** e.g. *bump, damage*
        - **Place** *e.g. crack, hole, opening, window, doorway*
          - Aperture

Endurant vs. Entity

- DOLCE *Endurant* category is a node that aligns very well with the T-PAS organization.
- DOLCE *Endurant* corresponds to ENTITY in CPA.
- On the other hand, *Entity* is the label used in DOLCE for the top node, which corresponds to ANYTHING in T-PAS. We regard Anything as a better term for the top node as Entity is often used in linguistics in a way which excludes Events.
- ANYTHING is T-PAS stands for all semantic types that play the role of participant in the event described by the verb selecting them (PARTICIPATION relation).

Endurants and the Object/Stuff distinction

- DOLCE *Physical Endurant* corresponds to PHYSICAL ENTITY in T-PAS; the internal organization of the two nodes, however, differs.
- *Amount of Matter* is a sister node of *Physical Endurant* in DOLCE, while in T-PAS its closest equivalent STUFF is a type of PHYSICAL ENTITY (INANIMATE PHYSICAL ENTITY).
- It seems reasonable to move STUFF (and its subtypes) higher in the T-PAS taxonomy.
- The solution in DOLCE appears more adequate, as the animate/inanimate distinction apparently applies only to objects with Unity.

Endurants and the Object/Stuff distinction

- In T-PAS, Body and Part of body are child nodes of Physical Entity, and sister nodes of Animate and Inanimate.
- The CONSTITUTON relation, used in DOLCE for co-located entities, as in the case of a person (agent) and its organism (not agent), and the PARTHOOD relation, which defines the relation between a body and its parts, are not represented in T-PAS.
- The only relation between the semantic types is the IS_A relation.
- In the future it would be convenient to expand the relations in T-PAS to include CONSTITUTION and PARTHOOD.

Abstracts and the tangible/intangible distinction

- ABSTRACT ENTITY in T-PAS defines all intangible entities.
- DOLCE distinguishes among *Abstract* (entity without temporal qualities, such as mathematical objects) and *Non Physical Endurant* (entity with temporal properties such as *Mental* and *Social Object*;
- These two categories appear in different nesting levels.

Abstracts and the tangible/intangible distinction

- There is no possible one-to-one alignment in this case.
- From an applied perspective, the two DOLCE's category can be conflated into T-PAS ABSTRACT ENTITY as the latter does not draw a distinction between intangible entities with or without temporal qualities.
- Such a modeling decision, however, is far from being without consequences.

Agency and the Animate/Inanimate Distinction

- The *Agent* label is used in DOLCE for a potential agent, that is, a living being endowed with intentions, beliefs, and desires.
- In T-PAS, agent is not present, as it is considered a role assumed by a human in an eventuality rather than a type - a thematic role in linguistic terms, which, according to Guarino 2017, corresponds to the processual role theorized by Loebe.
- Therefore, the DOLCE *Agentive* / *NonAgentive PhysicalObject* distinction does not have a direct equivalent in T-PAS.

Agency and the Animate/Inanimate Distinction

- The closest type to which DOLCE's *AgentivePhysicalObject* can be associated in T-PAS is ANIMATE.
- In T-PAS animate subsumes, among others, HUMAN and HUMAN GROUP (*squadra*); it does not include PLANT but it includes the taxonomy of the animal kingdom (ANIMAL and ANIMAL GROUP).

Agency and the Animate/Inanimate Distinction

- The animal kingdom differs from the scientific taxonomy of Linnaeus.
- T-PAS includes semantic types for animals for whom there exists a verb that selects the class or species as argument.
- Typically these are verbs of sound emission such as *to bark* (DOG), or verbs of motion such as *to gallop* (HORSE).
- Linnaeus categories such as MAMMAL are not present, as no verb has been identified yet that selects for it.

Feature and Parasitic Entities

- DOLCE assumes the category *Feature* for parasitic entities that are constantly dependent on physical objects (their so-called *Hosts*).
- *Feature* subsumes *Place* (holes in a cheese) and *Relevant part* (bumps or edges).
- T-PAS does not have a type that matches *Relevant Part* but has APERTURE as a type of LOCATION, which can be aligned to DOLCE's *Place* category.

Locations

- In T-PAS we find the semantic type LOCATION, which is used for both natural places and artifactual ones (an island, a parking lot).
- DOLCE has the category *Place*, which, however, does not correspond to T-PAS LOCATION.
- In DOLCE, the spatial dimension is considered a *Quality* of an entity (specifically *Spatial Location* $>$ *Spatial Region*).

Locations

- There is therefore no direct mapping between the two systems as regards the type LOCATION.
- From a linguistic point of view, the solution in T-PAS appears more apt to account for the geographical entities denoted by words that qualify as independent entities: *mountains*, *lakes*, *islands*, and so forth.

Natural kinds vs. Artifactual Types distinction

- Neither DOLCE nor T-PAS draw a distinction between manufactured objects and natural, mind-independent entities.
- T-PAS has ARTIFACT as a type of INANIMATE but does not have its counterpart natural kind.
- DOLCE has neither one nor the other.
- In the ENTITY branch of T-PAS and the *Endurant* branch of DOLCE the prevailing distinction is that between concrete and abstract, and between individuated (i.e. with Unity) and mass (without Unity).

Natural kinds vs. Artifactual Types distinction

- The distinction between natural kind and artifactual type is orthogonal to the other categories: for example, STUFF in T-PAS subsumes both natural entities (metal) and artifacts (cloth), LOCATION subsumes both natural entities (hill) and artifactual ones (route), and so forth.
- From a linguistic perspective, the distinction between individuated and mass appears to be the most represented formally in the world's languages.
- The grammatical behavior of nouns appears to be primarily determined by their encoding as individuals or masses (Jezek 2016, 135).

Types vs. Roles

- T-PAS has FOOD and BEVERAGE as types of artifact.
- In (Guarino and Welty 2009, 218] it is observed that "nothing is necessarily food, and just about anything is possibly food".
- Food is considered a role that an entity can play in a food event (roles being anti-rigid properties that characterize the way something participates to a contingent event).

Types vs. Roles

- While sharing this theoretical stance, in T-PAS it is believed that there being a large numbers of verbs selecting for the two types (currently 78 for FOOD and 11 for BEVERAGE) it is pragmatically useful to keep the two labels in the repertoire of semantic types.
- This is also motivated also by the presence of artifactual food, that is, man-made entities which purpose is to be consumed as food.

Systematic Polysemies

- Systematic polysemy is the phenomenon whereby a word or expression exhibits an alternation of meanings that is also exhibited by other words in the lexicon, so that this alternation can be considered regular (in Apresjan's terms: cf. Jezek 2016 for an overview),
- Examples are content/container in the case of *glass*, *dish*, *bottle* ('break a glass' vs. 'drink a glass'), and physical object/information in the case of *book*, *letter*, *novel* ('The book is heavy to carry around' vs.' The book examines the life of Dante').
- In Jezek and Vieu 2014 we identified corpus evidence supporting the view that the second example is an instantiation of a particular kind of of systematic polysemy called inherent polysemy.

Systematic Polysemies

- Systematic polysemies are currently treated in T-PAS through multiple inheritance, that is, a semantic type inherits from more than one type, and each subsumption relation implicitly represents one of the types that are conflated in the ambiguous class.
- For example, the DOCUMENT type (instantiated by nouns such as *libro* 'book' and *lettera* 'letter') inherits from the artifact type and the information source type.
- This is a case of cross domain multiple inheritance, as the two types are situated in different branches of the type system (PHYSICAL ENTITY and ABSTRACT ENTITY respectively).

Systematic Polysemies

- Systematic polysemy is to my knowledge currently not represented in DOLCE.
- Aparinis and Vieu 2015 propose to formally represent complex categories that overlap with disjoint domains of entities using the ontological relationship of CONSTITUTION and the notion of coincidence.

Systematic Polysemies

- Although it is used in other lexical ontologies such as WordNet, multiple inheritance is normally avoided in formal ontologies.
- It introduces incoherence and inconsistency from an ontological perspective and it creates problems for calculating inferences.
- However, for the purposes of natural language processing task such as sense disambiguation we believe that multiple inheritance constitutes a valid ad interim solution to the problem of systematic polysemy, until a formal characterization is standardized.

Leaf Categories

- DOLCE is an upper level ontology, and for this reason it does not comprise fine-grained child categories.
- T-PAS comprises just as many child categories as they are required by verb selectional behaviour: the set of categories is not finite and may increase as long as new the analysis of new verbs requires new semantic types.

Leaf Categories

- At present the deepest type in the system is the type wine (stuff > fluid > liquid > beverage > alcoholic drink > wine), motivated by a specific sense of the verbs *invecchiare* 'to grow old' and *maturare* 'to ripen'.
- The largest node is Artifact, with 35 subtypes.

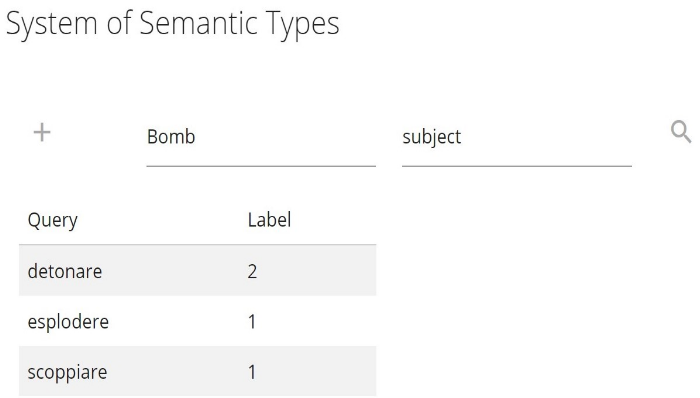
Leaf Categories

- Child categories in T-PAS disclose the anthropocentric character of the type system, that does not reflect the state of the art in scientific knowledge but rather how how everyday speakers communicate with each other and talk about the world (what they use when they do it).

Leaf Categories and Motivating Verbs

- As an example, the Artifact node includes: WEAPON (*puntare* 'point at') and its subtype BOMB (*denonare* 'detonate'); three subtypes of VEHICLES (ROAD, FLYING and WATER), FOOD, BEVERAGE, BUILDING, GARMENT (*indossare* 'wear'), FURNITURE (*arredare* 'furnish'), and peculiar types such as FLAG (*sventolare*) and STRING (*slegare* 'untie', *stringere* 'tighten').

Search Verbs through Semantic Types in T-PAS



System of Semantic Types

Bomb

subject

Query	Label
detonare	2
esplodere	1
scoppiare	1

Concluding Observations

- The exercise shows that the analysis based on linguistic evidence induces semantic types that can be linked to the upper level of a top-down ontology like DOLCE quite successfully, at least as far as the Endurant domain is concerned.

Concluding Observations

- One substantial issue emerge:
- The category abstract in T-PAS maps to two disjoint classes in DOLCE (*Abstract* and *NonPhysicalEndurant*) and there is no straightforward one-to-one alignment in this case;

Concluding Observations

- Insights on the language/cognition interface.
- The data-driven inventory of types in T-PAS is populated by semantic types that point to cognitive categories that are relevant to human communication, which do not necessarily match scientific classifications: hence the anthropic character of the T-PAS system.

Future work

- Completion of the alignment with DOLCE.
- Implementation of a distinct treatment for systematic polysemy and inherent polysemy?

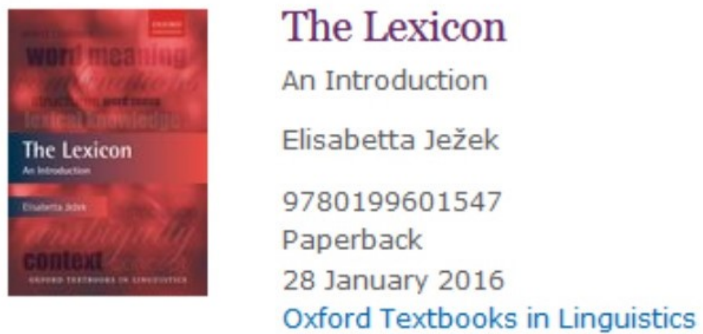
Ongoing work

- Validation of corpus-derived semantic types against automatically obtained clusters of argument fillers in a distributional semantic framework.
- Jezek Ponti Magnini 2019 *Evalating Distributional Representations of Verb Semantic Selection*, IWCS Gothenburg.

Open Question

- Open question: are selectional preferences as identified through manual clustering of corpus evidence truthmakers of ontological categories?

Thank you for listening!



The Lexicon

An Introduction

Elisabetta Ježek

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