Lexicon and Ontology Interplay in *Senso Comune*

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Abstract

Following a fashionable recent trend in the scientific community, computational lexicons are often said to incorporate or even correspond to linguistic ontologies, whose purpose is to describe semantic constructs of language (bound to grammatical units). Nevertheless there's a big debate on whether the categorial structures of computational lexicons could be acknowledged as ontologies or not. We think that the most effective approach is to keep those layers separated, as the philosophy underlying *Senso Comune* suggests. *Senso Comune* is a collaborative platform to build and maintain an open (hybrid) knowledge base of Italian language. As linguistic knowledge base here we mean a machine-readable dictionary that provides semantic information in a formal way. The knowledge base will be initially populated with a suitable formalization of basic Italian lexicon (2K lemmas, about 10K senses) (De Mauro, 1965), then it will be integrated with other existing linguistic resources, as well as user supplied information. The project is backed by an association of Italian scientists, under the supervision of Prof. Tullio De Mauro, which includes as emeritus member Padre Roberto Busa, and is being supported by Fondazione IBM Italia.

1. An introduction to Senso Comune

Senso Comune is a collaborative platform to build and maintain an open knowledge base of Italian language. As linguistic knowledge base here we mean a machine-readable dictionary that provides semantic information in a formal way. The knowledge base will be initially populated with a suitable formalization of basic Italian lexicon (2K lemmas, about 10K senses) (De Mauro, 1999), then it will be integrated with other existing linguistic resources, as well as user supplied information. The project is backed by an association of Italian scientists chaired by Prof. Tullio De Mauro, and is being supported by Fondazione IBM Italia.

The idea at the basis of Senso Comune is that natural languages consist in their concrete use. In the line of Saussure's linguistics (de Saussure, 1949), natural languages are seen as social products, based on users' consensus. At the same time, language users pursue specific goals, with respect to entities that belong to their world (be them physical or not), within social contexts where expressions are creatively produced and understood. This is the reason why physical and cultural realities can be regarded to as the dimension in which speakers' consensus takes shape. Ontologies, as conceptualizations of such realities, and languages, though clearly distinct, are therefore significantly related.

The interplay of linguistic expressions with that kind of abstractions of physic and social situations which we call 'concepts', is subject of a lasting philosophical debate that we won't introduce here. Nevertheless, Senso Comune aims at collecting lexicographic information and put it into relation with corresponding conceptualizations, which raises the non trivial question: how to model such a relationship?

2. The General Model

Ontologies represent an essential link between Knowledge Representation and Computational Lexical Semantics. The most relevant areas of interest in this context are represented by Semantic Web and Human-Language Technologies (HLT): they converge in the task of providing a semantic description of content, although concerning two different dimensions: the conceptual and lexical one. Implemented ontologies and computational lexicons aim at digging out the basic elements of a given semantic space (domain-dependent or general), characterizing the different relations holding among them. Nevertheless, they differ with respect to some relevant aspects:

- the polymorphic nature of lexical knowledge can't be straight off related to ontological categories;
- the widespread phenomenon of polysemy bears upon the lexicon but doesn't affect ontologies at all;
- the architectural features of computational lexicons are far from being easily coded in a logic-based language;
- considering foundational ontologies, a major distinction appears with respect to computational lexicons, the former focusing on high-level concepts (endurant, amount of matter, quality, perdurant) while the latter affect basic-level categories (dog, gold, red, walk).

Following a recent trend in the scientific community, computational lexicons are often said to incorporate or even correspond to linguistic ontologies, whose purpose is to describe semantic constructs of language (they are bound to grammatical units). Nevertheless, there's a big debate on whether categorial structures of computational lexica could be acknowledged as ontologies or not. We think that the most effective approach is to keep the two layers separated. Separating linguistic senses and relationships (e.g. synonymy, hyponymy, and antinomy) from their ontological counterparts (concept, inclusion, and disjointness) is therefore at the basis of our model. This separation prevents linguistic facts to be directly mapped to logic propositions, thus relieves linguistic meanings the burden of embodying ontological commitments. Still, of course, we want the

two layers to be somehow interlinked: in fact, interfacing implemented ontologies and computational lexicons is the key-goal for the new generation of knowledge systems. The model we describe here provides an account of this linkage. By separating linguistic information from conceptualization, we allow language users to manifest their knowledge in a free, incremental, natural, and collaborative way. Of course, this kind of knowledge elicitation is potentially conflicting. As Wikipedia demonstrates, collaborative projects produce huge amount of knowledge, which is continuously updated, amended and extended by wiki-editors. We think that this dynamic approach can be also adapted to Semantic Web frameworks, exploiting human common-sense and linguistic knowledge.
In the rest of this paper we will present in details the features of the ontological and the lexical model underlying Senso Comune, together with the survey of a tutoring methodology for interactive cooperative building of knowledge resources.

2.1. The Metamodel

The *metamodel* at the basis of Senso Comune is a description logics called DL-Lite (Calvanese et al., 2004). With respect to the typical applications of lexical ontologies, we analyzed that DL-Lite provides an appropriate computability and tractability trade-off. UML [1] (Class Diagrams, in particular) has been adopted ad concrete diagrammatic syntax to develop the model, based on a known correspondence with DL-Lite constructs (Table 1).
Basically, DL-Lite is a tractable description logics to specify ontologies and to query large knowledge bases with the same efficiency as relational DBMS. To obtain such efficiency, DL-Lite limits the use of constructs such as universal quantification, disjunction, and enumeration. In fact, the use of these constructs in data-intensive systems would lead to bad computational properties, as Calvanese et al. (Calvanese et al., 2007) have shown.
As any description logics, DL-Lite provides means to define *concepts* (i.e. classes) and *roles* (i.e. binary relations), inclusion dependencies, existential quantification on roles, and negation. Furthermore, syntactic restrictions are adopted to limit the language expressiveness. These are based on distinguishing:

AtomicConcept : atomic concepts (*A*)

BasicConcept : basic concepts (*B*)

GeneralConcept : general concepts (*C*)

AtomicRole : atomic roles (*P*)

BasicRole : basic roles (*Q*)

GeneralRole : general roles (*R*)

ValueDomain : attribute domain (*D*)

These elements are interlinked by the following rules:

- Concepts:

$$B \leftarrow A \mid \exists R$$
$$C \leftarrow B \mid \neg B$$

- Roles:

$$Q \leftarrow P \mid P^-$$
$$R \leftarrow R \mid \neg R$$

where the construct P^- is used to represent inverse roles (e.g. $love^- =$ loved-by). Moreover, roles can be marked as *functional*, that is, of range cardinality equals to 1.
DL-Lite allows *inclusion axioms* of the form:

$$B \sqsubseteq C \quad Q \sqsubseteq R$$

In practice, it is possible to set inclusion dependencies involving base concepts (roles) on the left-side, and general concepts (roles) on the right side. This limitation is crucial to improve tractability of ontology-based data access.
Membership axioms are specified as usual:

$$A(a) \quad D(a) \quad P(a, b)$$

Finally, DL-Lite formal semantics is given by a standard first-order interpretation structure like other description logics (Baader et al., 2003).

2.2. The Ontology

Linguistic resources like WordNet are generally built by lexicographers on the basis of analysis of language. The main taxonomic structure of these resources consists in a hierarchy of hyponyms derived from a comprehensive enquiry of the lexicon. In general, this approach does not deal with ontology-based distinctions, namely with the categorial structure of concepts (synsets). The ontological rearrangement of these resources is possibly made *a posteriori*, as in the case of OntoWordNet (Gangemi et al., 2003). *Senso Comune* starts from a different perspective. A small number of concepts is taken *a priori* as a reference ontological structure that constrains the other semantic constructs to be defined in the resource. This reference ontology has been designed according to DOLCE basic distinctions (Gangemi et al., 2002)[2]. In the following list we provide some informal descriptions of the main basic categories:

Entity (∈ Atomic Concept) : the most general category.

Concrete (⊑ Entity) : spatio-temporal entities (i.e., objects, events).

Abstract (⊑ Entity) : non spatio-temporal entities (i.e., propositions, numbers).

Object (⊑ Concrete) : spatial concrete entities with autonomous existence. Objects don't have temporal parts but their properties can change in time (i.e. a ship, a rock, a person).

Event (⊑ Atomic Concept) : temporal concrete entities. Events depend on suitable participants (those objects which take part to a particular event) and can have temporal parts (i.e. a race)[3]

[1] http://www.uml.org/

[2] The latest release of DOLCE consists in thirty concepts and twenty binary relations.

[3] Atomic events don't have, stricly speaking, temporal parts, since they are considered as instantaneous.

Table 1: UML and DL-Lite

UML	DL-Lite
Class	A
Association, Attribute ($\neq PrimitiveType$)	P,P^-
Attribute (PrimitiveType)	D
InstanceSpecification	$A(a)$
LiteralString	$D(d)$
Slot (definingFeature.type $\neq PrimitiveType$)	$P(a,b)$
Slot (definingFeature.type $= PrimitiveType$)	$D(a,b)$
Generalization	$B \sqsubseteq C$
cardinality = 1	$funtc(P)$

Quality ($\sqsubseteq$ Entitiy) : qualifying characteristics of entities; the existence of qualities is bound to the existence of the correspondent entities (i.e. the colour of a particular rose), although they are not parts of them.

In *Senso Comune*, the association between linguistic senses and the reference ontology is based on a genuinely naive assumption, namely that objects are commonly lexicalised by nouns, qualities by adjectives and kinds of events by verbs[4]. Nevertheless, the relation holding between the previous list of ontological categories and suitable parts of speech (nouns, verbs, adjectives and adverbs) is not as simple as it could appear: those correspondences are not stable across languages and case exceptions are frequent in linguistic practice.

2.3. The Lexicon

Lexical information in managed in Senso Comune by means of a suitable extension of the base ontology, which consists in a set of abstract concepts to represent linguistic notions. During the analysis phase, the need of representing and integrating classic lexicographic structures along with user-collected data emerged. This lead us to a representational model which is more complex than other state-of the art ones, e.g. the Lexical Markup Framework (Francopoulo et al., 2006). In any case, our model shares with LMF most of the basic structures, making it easy to map them if needed.
Besides representing morphological structures, Senso Comune lexical model provides classes and relations to represent meanings and semantic relationships.

2.3.1. Meanings

The class diagram in 1 shows how word meanings are modeled.

Meaning ($\sqsubseteq$ Abstract) : reified relation that represents the fundamental semantic structure (*sign*), independently from any description (**MeaningDescription**). The meaning relation brings together a word form (or multi-word) to the concept in an ontology and (possibly) the contexts (which, in turn, are concepts) where the meaning occurs.

[4]We avoid here to consider the ontological counterparts of adverbs, which however could be preliminarily conceived as "modes" of events, like in the example "John was running *fastly*".

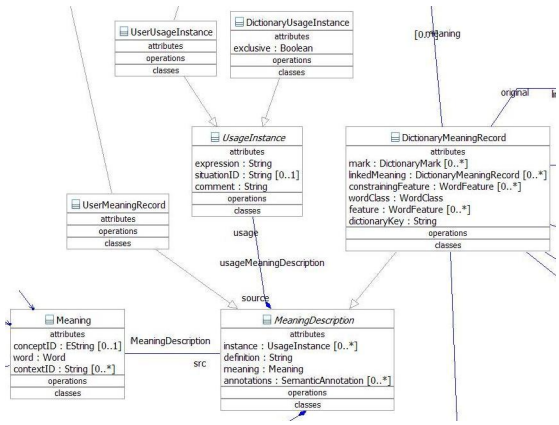

Figure 1: Linguistic Model: meanings

MeaningDescription ($\sqsubseteq$ Abstract) : descriptive structure associated to **Meaning**, including a phrase (glossa), a set of usage instances, and a set of semantic annotations.

UserMeaningRecord ($\sqsubseteq$ MeaningDescription) : **MeaningDescription** provided by users.

DictionaryMeaningRecord ($\sqsubseteq$ MeaningDescription) : **MeaningDescription** coming from to dictionary lexicographic structures.

UsageInstance ($\sqsubseteq$ Abstract) : usage instances which are part of **MeaningDescription**.

UserUsageInstance ($\sqsubseteq$ UsageInstance) : usage instances provided by users.

DictionaryUsageInstance ($\sqsubseteq$ UsageInstance) : usage instances coming from dictionary lexicographic structures.

Note that **Meaning** represents a linguistic acceptation in form of association between linguistic expressions and conceptual content. The latter consists in a `URI` pointer to a single concept, so that it is possible to define a function:

$$\sigma : Meaning \rightarrow Concept$$

In particular, σ is neither injective (different meanings could point to the same concept), nor surjective (not all concepts must be mapped with lexical counterparts). We just require each meaning to be mapped to a unique concept.

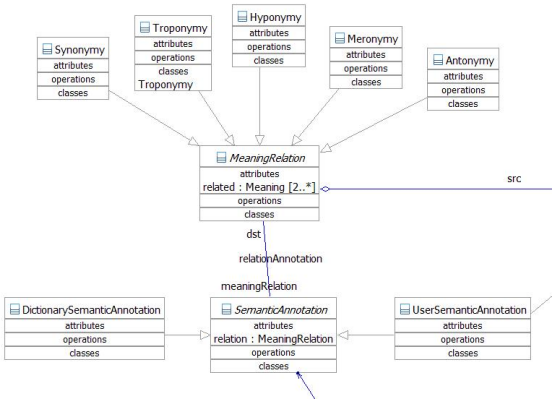

Figure 2: Linguistic Model: meaning relations

2.3.2. Lexical relations

The diagram in 2 shows binary relations involving meanings. In particular, relationships taken into account include: synonymy, troponymy, hyponymy, antonymy, and meronymy. Corresponding classes are:

MeaningRelation (⊑ Abstract) : reified relation that associates meanings pairwise.

Synonymy (⊑ MeaningRelation) : represents synonymy, i.e. meaning equivalence in all contexts. Differences in connotation (e.g. *child* vs. *kid*) may determine fuzziness in users' perception.

Troponymy (⊑ MeaningRelation) : represents troponymy, i.e. different ways for an action to take place (e.g. *walk* vs. *crawl*). It is in question whether troponymy can always maps to conceptual inclusion.

Hyponymy (⊑ MeaningRelation) : represents specialization (e.g. *dog* vs. *canine*). As for synonymy, hyponymy is subject to fuzzy perception by users.

Antonymy (⊑ MeaningRelation) : represents contrariety, typically for adjectives (e.g. *bad* vs. *good*). Whether antonymy implies conceptual disjointness should be evaluated case by case.

Meronymy (⊑ MeaningRelation) : represents part-whole relationships. Conceptually, this relation may be in correspondence to a number of different parthood notions.

In sum, semantic relationships elicited by users cannot be directly mapped in logic relationships within the framework of formal theories of linguistic meanings as lexical ontologies are. Instead, these theories must be constructed by carefully analyzing linguistic perceptions declared by users or condensed by dictionaries.

3. The Development Process

In the initial stage of the project, *Senso Comune* knowledge base will be populated with approximately 10000 senses associated to 2075 lemmas of De Mauro's core dictionary (De Mauro, 1965); for each of these senses a DOLCE-based conceptual counterpart (see 2.2.) will be provided.

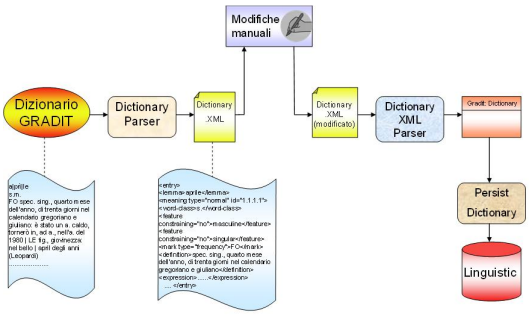

Figure 3: Acquiring the basic lexicon

Suitable conversions of ontological linguistic resources for Italian, such as EuroWordNet (Vossen, 1998), will enable an integration with *Senso Comune*[5]. Starting from a core set of fundamental senses, *Senso Comune* knowledge base is going to be developed by supervised contribute of speakers through a cooperative open platform.

3.1. Acquiring the Basic Lexicon

The acquisition of the basic lexicon is under completion. Starting from plain textual lemmas extracted from the dictionary, the main goal is to build the correspondent instances of the **LexicalEntry** class. The overall strategy of conversion depends on the exploitation of an intermediate format: an XML file is created with suitable identifiers for the lexical contents of the dictionary. The population of the knowledge base is then obtained through a compiling process.

Manual annotation of lemmas has been discarded on the basis of a feasibility study, estimating approximately 3-years working period for the complete annotation of De Mauro's core 2075 entries. Moreover, the analysis of the main structures of the dictionary revealed that textual formats in De Mauro's resource can be hardly tractable with a fully automatic methodology of extraction: this study prevented from developing an *ad-hoc* parser.

In this context, the employment of a semi-automatic approach emerged as the most adequate solution: first, a suitable parser is used to produce an approximation of an XML desired format, which is then adapted and amended by linguists, who are also responsible for solving uncertainties and deciding for the best candidate entry (see 3). In particular, the distinction between use cases and "nuances" of meaning cannot be regularly extracted from the syntactic structures of the textual formats of the dictionary.

3.2. The Cooperative Platform

After the acquisition of the basic terminology, *Senso Comune* computational lexicon will be extended through a cooperative platform mirroring the main characteristcs of the so-called 'wiki'. Wiki is a web-based software that allows visitors to edit the content of a given website. This open platform is particularly appropriate and easy-to-use for cooperative tasks related to texts and hypertexts. Currently,

[5]Currently, we are evaluating how part of proprietary resources like EuroWordNet could be made available as Open Source through *Senso Comune* model, interface and format.

a large number of wiki systems is available on the web; although wikis are usually task-oriented and designed according to specific user requirements, they share some common essential features:

- Editing through browser: contents are usually inserted through web-browsers with no need of specific software plug-ins.
- Rollback mechanism: versioning of saved changes is available, so that an incremental history of the same web page is mantained.
- Non restrictive access: in most cases, wikis are free access resources and visitors have the same 'privileges'[6] in the editing process.
- Collaborative editing: many wiki systems provide support for editing through discussion forums, change indexes, and so on and so forth.
- Emphasis on *linking*: wiki pages are usually strongly connected with other hypertexts.
- Search functions: in practice, every wiki system allows for search over internal contents.
- Upload of non-textual contents: many wikis allow visitors to upload multimedia data (images, audio files, videos).

There are mainly three critical aspects in wiki-systems:

1. Difficulty of keeping neutral perspective on information[7]. It's diffult to represent the neutral view on wiki contents, since total agreement on topics is almost impossibile to be reached. In general, the moderators of a wiki are responsible for monitoring contents and sensibilize visitors.
2. Quality of contents. This aspect share a similar scenario with the previous issue but focuses on 'bad' or low-level contents.
3. Exposure to 'malevolent attacks': Attacks aim at damaging contents or to introduce offensive (or out of scope) information.

On the basis of wiki philosophy and architecture, Wiktionary project has been initiated, aiming at building an open multilingual dictionary with meanings, etimologies, pronunciations. Although Wiktionary could be seen as the closest initiative to *Senso Comune*, the strong limitations of the resource[8] lead Senso Comune association to develop a brand new original system.

The current prototype version of *Senso Comune* computational lexicon is grounded on a relational database resulting from the linguistic model (see 2.3.). The database has been also integrated with a suitable DL-Lite reasoner, designed and implemented to operate on large ontologies. After visualising the information linked to a searched meaning, a user will be able to decide whether to insert a new lemma, a new sense, a new lexical relation or simply to leave a 'feedback' (i.e., her familiarity with available senses and lexical relations). On the contrary, the deep conceptual part of the lexicon (the ontology) won't be made accessible to users: when a new sense of a lemma is added, the system semi-automatically creates a corresponding specific concept to be positioned with respect to the ontological layer of the database. This semi-automatical procedure will be initially driven by an interactive Q/A system, by means of what we have called a **T**utoring **M**ethodology for the **E**nrichment of **O**ntologies (**TMEO**).

4. The TMEO Methodology...in a nutshell

Senso Comune depends on two core aspects: 1) a top-down direction, where top-level ontological categories and relations are introduced and maintained by ontologists to constrain lexicalised concepts; 2) a bottom-up direction, where non-expert users are asked to enrich the semantic resource with linguistic information through a wiki-like platform. In this building-up process, visitors are allowed only to access to the lexical level of the resource (therefore, explicit ontological choices are kept 'opaque' to ease users' task). These access-restrictions produce an *epistemological spread* between dimensions 1) and 2), a necessary requirement if we want to keep the deep technical aspects of the ontological layer aside from wiki-users. Conversely, to make dimension 2) plainly effective, those lexical concepts and relations which are introduced by users must fit the intended ontological choices underlying the system. For this reason, we are designing a tutoring methodology to support linguistic enrichment of ontologies, towards the creation of comprehensive hybrid semantic resources. **TMEO** is an interactive Q/A system based on general distinctions embedded in DOLCE. We present here some preliminary characteristics of the methodology[9].
First, a given lemma and the corresponding gloss is visualised by *Senso Comune* wiki-user interface: for instance, the word 'glass' defined as "a container for holding liquids while drinking"(sense 2 of WordNet). Afterwards, the system *asks* natural language questions to the user, aiming at

[6] using the Internet jargon

[7] One could object that 'neutrality' of information is an utopia. Although it's not our aim to deepen this issue in the present paper, we could say that, under a context-driven treshold, as far as multiple views and heterogeneity of information are mantained, the richness of a wiki can be assessed. On the other hand, it's trivial that when wiki contents reflect partial and distorted views on facts and knowledge, the danger for the overall Internet community is extremely high.

[8] The most important one concerns the model of the dictionary, which depends on the couple lemma-page, where different senses of a lemma are coded as free text without specific identifiers in the same page. This feature almost completely hides the conceptual information associated to lemmas.

[9] For the sake of simplicity and to make the example readable for non-Italian speakers, we exploits available mappings between *Senso Comune* lexical nodes for Italian and Princeton WordNet synsets, providing examples in English.

specializing the intended meaning of the submitted lemma. In the following we report some examples[10]:

1. Would you consider [glass] in the sense of ["a container for holding liquids while drinking"] as something concrete, namely which has a spatial and/or temporal nature?
2. Does [glass] refer to something tangible, namely that a human can sense?
3. Could you count [glass]-es[11]?
4. Is [glass] produced/built by hand/machines?

The typical answers to those questions would be: yes/no/yes/yes/yes; however, the method will optimize the way questions are posed to the user by navigating ontology inclusions and disjunctions. In particular, terms like *glass* would commonly be interpreted as referring to some concrete tangible object. The second-last question aims at helping the user to discriminate between unitary entities (artifacts like tables and coins, natural entities like trees and animals, etc.) from scattered and unbound entities like substances (liquids like water, materials like gold, etc.). The conclusive result is that in the macro-world of human senses - which is the actual domain of *Senso Comune* - the selected sense of the word *glass* can be modeled by the class 'Artifact', which is a specialization of DOLCE-based top-node 'Concrete'. Although this information might appear trivial, in case of a different sense of the term *glass*, namely "a brittle transparent solid with irregular atomic structure" (Wordnet sense 1), the final output would have been different: since here the lexicalised concept refers to the material and not to the object, the answer to question 3. should have been negative, cognitively 'evoking' the ontological category 'Substance'.

The internal algorithm of **TMEO** automatically selects the most adequate category of the reference ontology as the super-class of the given lexicalised concept: difference sequences of answers induce different mappings between the lexicon and the (hidden) ontological layer. In this context it's important to notice that **TMEO** list of questions does not have a flat organization: a conditional chain based on "if..then' clauses[12] rules the logical structure of the tutoring system. Moreover, the system makes automatic storage of each Q/A interaction, building a sort of dynamic reference manual to be exploited as help documentation by wiki-users[13]. Of course there may be cases where a user does not know how to answer to **TMEO** questions: we will adopt two solutions to overcome the stall. In the short-term, we are creating an open forum where expert modelers will periodically answer *vis-à-vis* to specific questions posited by users; in the long-term, we are going to include uncertainty in **TMEO** algorithm, allowing for a third optional answer ("I don't know") by the user. Although this enhancement is going to make the general heuristics of the tutoring system more complex, it will fasten the interactive process with respect to the forum solution.

[10]The form of **TMEO** questions is generally fixed: words in square brackets (lemma + gloss) change every time a new lemma is submitted to the wiki-user by the system.

[11]The plural syntactical form is automatically generated by the system.

[12]*IF answer = Yes THEN (term IS-A ontological categoryA) ELSE (term IS-A ontological categoryB).*

[13]For instance, a user that has to model sense 1 of glass might want to look up how sense 2 has been treated by previous visitors.

5. Conclusions

We have presented Senso Comune, an open, cooperative project to build a knowledge base for Italian language. Basing on a simple and yet powerful metamodel (the DL-Lite description logic), a minimal foundational ontology (DOLCE), a specific representation model for linguistic knowledge, and a core lexical resource (De Mauro's fundamental lexicon), Senso Comune will be built and continuously updated by collecting input from users. One of the major features of our approach is the way linguistic meanings and ontological concepts are put into relation. Meanings are not modeled as concepts, but rather as signs. Accordingly, lexical relationships such as synonymy or hyponymy are not mapped into formal relations such as equivalence or inclusion, but rather are taken as input for the construction of ontological theories.

Future research will include modeling situations by means of frame-like structures, consistently with the formal model developed so far. Lexical relationships to capture thematic roles will be therefore introduced. Another research direction is toward algorithms for automating the introduction ontology axioms (e.g. equivalence, inclusion, disjointness, participation) based on linguistic information, by taking both quantitative and qualitative aspects into account.

Finally, we think that Senso Comune as an open source of knowledge of Italian language can make a long way as key enabling factor for business, Web communities, and public services in Italy. The resource will be distributed under Creative Commons license and made available for any kind of use.

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