

# Ontological commitments in FunGramKB

## *Criterios ontológicos en FunGramKB*

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**Resumen:** Cualquier trabajo en ingeniería ontológica debe estar fundamentado en un protocolo de directrices bien definidas que no sólo organicen la estructuración de la ontología sino que además ayuden a determinar sus unidades ontológicas y propiedades. Una sólida metodología para el desarrollo de ontologías exige la eliminación de muchos de los errores e inconsistencias que se suelen cometer en el modelado ontológico, facilitando así la interoperabilidad y el conocimiento compartido—especialmente útil cuando se diseña un recurso multipropósito. En el contexto del procesamiento del lenguaje natural, este artículo describe los compromisos ontológicos que la Ontología de FunGramKB debe cumplir.

**Palabras clave:** ontología, FunGramKB, herencia, postulado de significado

**Abstract:** Ontology engineering should be grounded on a protocol of well-founded guidelines concerning the structuring of the ontology as well as the elements to be included and their ontological properties. A sound methodology for ontology development involves a dramatic reduction of many common errors and inconsistencies in conceptual modelling, facilitating thus interoperability and knowledge sharing—particularly useful when a multipurpose resource is designed. In the natural language processing context, this paper describes the ontological commitments to which the FunGramKB Ontology is subject.

**Keywords:** ontology, FunGramKB, inheritance, meaning postulate

## **1 Introduction**

A key aspect in knowledge engineering is the design and construction of an ontology model under a series of well-founded guidelines, particularly when you want to reuse it in different natural language processing (NLP) applications, e.g. document retrieval, information extraction, text categorization, data mining, etc. Ontology structuring must be supported by some theory about the elements in the domain, their inherent properties and in which way these elements are related. Since knowledge engineers face numerous problems in the conceptual modelling of ontologies, it is necessary to work with some underlying ontological commitment. These guidelines should help us to make decisions on what to be

incorporated as a conceptual unit, where to place it, how to represent its meaning and how to organize the structure of the whole ontology (Mahesh, 1996).

## **2 FunGramKB**

FunGramKB (Perrián-Pascual and Arcas-Túnez, 2004, 2005) is a multipurpose lexico-conceptual knowledge base for NLP systems. On the one hand, FunGramKB is multipurpose in the sense that it is both multifunctional and multilingual. Thus, FunGramKB has been designed to be potentially reused in many NLP tasks and with many natural languages.<sup>1</sup>

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<sup>1</sup> English and Spanish are fully supported in the current version of FunGramKB, although we have just begun to work with other languages, i.e. German, French, Italian, Bulgarian and Catalan.

On the other hand, our knowledge base comprises three major knowledge levels, consisting of several independent but interrelated modules:

Lexical level:

- The Lexicon stores morphosyntactic, pragmatic and collocational information about lexical units.
- The Morphicon helps our system to handle cases of inflectional morphology.

Grammatical level:

- The Grammaticon is composed of several Constructicon modules whose constructional schemata help Role and Reference Grammar to build the semantics-syntax-semantics linkage (Van Valin and LaPolla, 1997; Van Valin, 2005).

Conceptual level:

- The Ontology is presented as a hierarchical catalogue of the concepts that a person has in mind when talking about everyday situations. Here is where semantic knowledge is stored in the form of meaning postulates.
- The Cognicon stores procedural knowledge (e.g. how to fry an egg, how to buy a product, etc) by means of scripts, i.e. conceptual schemata in which a sequence of stereotypical actions is organised on the basis of temporal continuity, and more particularly on the basis of Allen's temporal model (Allen, 1983; Allen and Ferguson, 1994).
- The Onomasticon stores information about instances of entities and events, such as Bill Gates, Taj Mahal, or 9/11. This module stores two different types of schemata (i.e. snapshots and stories), since instances can be portrayed synchronically or diachronically.

In the FunGramKB architecture, every lexical or grammatical module is language-dependent, whereas every conceptual module is shared by all languages. In other words, computational linguists must develop one Lexicon, one Morphicon and one Grammaticon for English, one Lexicon, one Morphicon and one Grammaticon for Spanish and so on, but knowledge engineers build just one Ontology, one Cognicon and one Onomasticon to process

any language input conceptually. In this scenario, the Ontology becomes the pivotal module for the whole architecture, which explains why this model is conceptually rather than lexically-driven.

### 3 *Ontological commitments*

Nowadays there is no single right methodology for ontology development. Ontology design tends to be a creative process, so it is probable that two ontologies designed by different people have a different structuring (Noy and McGuinness, 2001). To avoid this problem, the ontology model should be founded on a solid methodology. The remaining of this section describes seven methodological criteria applied to the FunGramKB Ontology, some of which are based on principles implemented in other NLP projects (Bouaud et al., 1995; Mahesh, 1996; Noy and McGuinness, 2001).

#### 3.1 **Commitment #1: universality and linguistic motivation**

FunGramKB is provided with a universal, linguistically-motivated and general-purpose ontology.

Firstly, the FunGramKB Ontology takes the form of a universal concept taxonomy, where “universal” means that every concept<sup>2</sup> we imagine has, or can have, an appropriate place in the Ontology. A universal approach is adopted on the relation between language and conceptualization, where cross-lingual differences in syntactic constructions do not necessarily involve conceptual differences (cf. Jackendoff, 1990). In our case, the relation between language structures and conceptual constructs is mediated by conceptual logical structures (CLS), where phenomena such as diathetic alternations are directly reflected. The role of a CLS is to serve as a bridge between the more abstract level as represented in the Ontology and the particular idiosyncrasies as coded in a given linguistic expression. Therefore, CLSs are used as the interface between the semantic structure and the syntactic representation of sentences. To illustrate, the

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<sup>2</sup> Terms such as “class”, “category” or “semantic type” are often used in ontology engineering to refer to elements such as FunGramKB “concepts”. However, we prefer the latter, since it better describes the domain of processing in the two-tier model of our NLP knowledge base, i.e. lexical level and conceptual level.

CLS of sentence (1) is presented in (2):<sup>3</sup>

- (1) Betty asked Bill for the aspirin.
- (2) <<sub>IF</sub> DEC <<sub>TNS</sub> PAST <[do (%BETTY\_00, [+REQUEST\_01 (%BETTY\_00, %BILL\_00)])] PURP [do (%BILL\_00, 0)] CAUSE [BECOME +REQUEST\_01 (%BETTY\_00, \$ASPIRIN\_00)]>>>

Secondly, the FunGramKB Ontology is linguistically motivated, but not language-dependent. In other words, the Ontology is involved with the semantics of lexical units, but the knowledge stored in the Ontology is not specific to any particular language. Thus, a new concept should be introduced in the Ontology whenever there is at least one lexical unit whose meaning does not match any of the meaning postulates stored in the knowledge base, provided that the values of the ontological properties of that new concept are shared by all lexical units which are linked to it. In this respect, it is commonly said that the model of the world portrayed in a particular ontology is generally biased by distinctions made in the knowledge engineers' languages (Hovy and Nirenburg, 1992). Consequently, an ontology can be closer to some language communities than to others, finally affecting the ontology design. However, this is not a real problem in FunGramKB, because the structuring of the Ontology is guided by a process of negotiation. More particularly, the basic conceptual level of the Ontology can be slightly re-modelled as knowledge from other languages is being incorporated.

Finally, the FunGramKB Ontology is general-purpose, because neither it is domain-specific nor contains terminological knowledge.<sup>4</sup>

### 3.2 Commitment #2: three-layered ontology model

The FunGramKB Ontology distinguishes three different conceptual levels, each one of them with concepts of a different type:

- (i) Metaconcepts, preceded by symbol #

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<sup>3</sup> CLSs are inspired on the logical structures in the Role and Reference Grammar (Van Valin and LaPolla, 1997; Van Valin, 2005). The main difference is that the former are rooted in the FunGramKB conceptual knowledge repository.

<sup>4</sup> In brief, we shall like to extend the FunGramKB Ontology to include terminological submodules.

(e.g. #ABSTRACT, #COLLECTION, #EMOTION, #POSSESSION, #TEMPORAL etc), constitute the upper level in the taxonomy. The analysis of the upper level in the main linguistic ontologies—DOLCE (Gangemi et al., 2002), Generalized Upper Model (Bateman, Henschel and Rinaldi, 1995), Mikrokosmos (Mahesh and Nirenburg, 1995), SIMPLE (Lenci et al., 2000), SUMO (Niles and Pease, 2001)—led to a metaconceptual model whose design contributes to the integration and exchange of information with other ontologies, providing thus standardization and uniformity. The result amounts to forty-two metaconcepts distributed in three subontologies: #ENTITY, #EVENT and #QUALITY.

(ii) Basic concepts, preceded by symbol + (e.g. +BOOK\_00, +DIRTY\_00, +FORGET\_00, +HAND\_00, +MOVE\_00 etc), are used in FunGramKB as defining units which enable the construction of meaning postulates for basic concepts and terminals, as well as taking part as selectional preferences in thematic frames. The starting point for the identification of basic concepts was the defining vocabulary in *Longman Dictionary of Contemporary English* (Procter, 1978), though deep revision was required in order to perform the cognitive mapping into a single inventory of about 1,300 basic concepts.<sup>5</sup>

(iii) Terminals (e.g. \$AUCTION\_00, \$CADAVEROUS\_00, \$METEORITE\_00, \$SKYSCRAPER\_00, \$VARNISH\_00 etc) are headed by symbol \$. The borderline between basic concepts and terminals is based on their definitory potential to take part in meaning postulates. Hierarchical structuring of the terminal level is practically non-existent.

Theoretically speaking, there are two basic strategies in ontology development. On the one hand, a top-down approach starts with the definition of the most general concepts in the domain and then they are further specialized. On the other hand, a bottom-up approach starts with the definition of the most specific concepts with subsequent grouping of these concepts into more general concepts. FunGramKB employs an “integrated top-down and bottom-up” development process split into three subsequent

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<sup>5</sup> This basic level has been tested for validation with the defining vocabulary in the dictionaries of other languages, e.g. *Diccionario para la Enseñanza de la Lengua Española* (VOX-Universidad de Alcalá de Henares, 1995).

phases. In a first stage, a shared view of the modelled world was sought to shape the upper level (i.e. metaconceptual level). In a second stage, the most descriptive concepts were hierarchically arranged in a middle level (i.e. basic level). In a third stage, the most specific concepts are incorporated as leaves of the ontology (i.e. terminal level). Thus, we started with metaconcepts until terminal concepts were reached (globally top-down), but each ontology level was developed in a locally bottom-up fashion. Although bottom-up approaches tend to lead to *ad hoc* ontologies, this problem is solved by postulating the high-level ontology beforehand. Currently, the third stage of the ontology modelling is still being developed. Indeed, the development of the FunGramKB Ontology is grounded on a spiral model, where conceptual promotion and demotion can occur between the basic and terminal levels. Thus, some terminal concepts can be “promoted” to basic concepts when the inclusion of a new language demands a slightly different view to the world model. On the contrary, some basic concepts can be “demoted” to terminal concepts when their expectations as meaning descriptors are not finally fulfilled. In any case, the metaconceptual level always remains stable. Figure 1 illustrates the design of the FunGramKB Ontology.

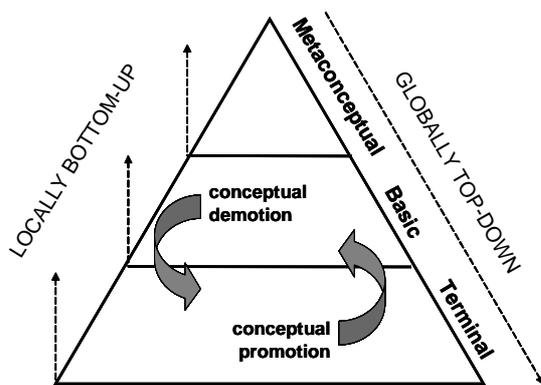


Figure 1: FunGramKB Ontology design.

The motivation of constructing such an ontology model responds to the need of a core level of knowledge (i.e. basic concepts) playing a pivotal role between those universal categories which can facilitate ontology interoperability (i.e. metaconcepts) and those particular concepts which can grant immediate applicability (i.e. terminals).

### 3.3 Commitment #3: non-atomic conceptual units

In FunGramKB, basic and terminal concepts are not stored as atomic symbols but are provided with conceptual properties such as the thematic frame and the meaning postulate. Both of them are conceptual schemata, since they employ concepts—and not words—as the building blocks for the formal description of meaning. Thus, thematic frames as well as meaning postulates become language-independent conceptual knowledge representations.

Every event and quality in the Ontology is assigned one single thematic frame, i.e. a conceptual construct which states the number and type of participants involved in the prototypical cognitive situation portrayed by the event. To illustrate, we present the thematic frame of +OPEN\_01 (3), to which lexical units such as *open* [Eng], *abrir* [Spa], *offnen* [Ger], *ouvrir* [Fre] and *aprire* [Ita] are linked:<sup>6</sup>

- (3) (x1)Agent (x2: +DOOR\_00 ^  
+WINDOW\_00)Theme (x3)Location  
(x4)Origin (x5)Goal

Thematic frames can also include those selectional preferences typically involved in the cognitive situation.<sup>7</sup> Thus, thematic frame (1) describes a prototypical cognitive scenario in which “entity<sub>1</sub> (Agent) moves entity<sub>2</sub> (Theme)—being typically a door or window—from one place (Origin) to another (Goal), there also being a place (Location) along which entity<sub>2</sub> moves”. Although one or more subcategorization frames can be assigned to a single lexical unit, every concept is provided with just one thematic frame.

A meaning postulate is a set of one or more logically connected predications ( $e_1, e_2... e_n$ ), i.e. conceptual constructs carrying the generic features of concepts.<sup>8</sup> Consider (4-5) as a representation of the thematic frame and

<sup>6</sup> Although FunGramKB knowledge is stored in XML, examples of thematic frames and meaning postulates shown in this paper are presented by means of those parenthetic string representations created by language engineers through FunGramKB Suite ([www.fungramkb.com](http://www.fungramkb.com)).

<sup>7</sup> Selectional preferences are stated when they can exert some predictive power on the participant.

<sup>8</sup> Perrián-Pascual and Arcas-Túnez (2004) describe the formal grammar of well-formed predications for meaning postulates in FunGramKB.

meaning postulate of +INGEST\_00, to which lexical units *drink* [Eng], *beber* [Spa], *trinken* [Ger], *boire* [Fre] and *bere* [Ita] are linked:

- (4) (x1: +HUMAN\_00 ^  
+ANIMAL\_00)Agent (x2:  
+LIQUID\_00)Theme (x3:  
+THROAT\_00)Location (x4)Origin (x5:  
+STOMACH\_00)Goal
- (5) +(e1: +ABSORB\_00 (x1)Agent  
(x2)Theme (x6)Location (x4)Origin (x7:  
+MOUTH\_00)Goal (f1: x6)Instrument  
(f2: (e2: +SWALLOW\_00 (x1)Agent  
(x2)Theme (x3)Location (x7)Origin  
(x5)Goal))Purpose)

The thematic frame of +INGEST\_00 depicts a situation in which five participants are typically involved: a person or animal (x1) makes a liquid (x2) move through their throat (x3) from one place (x4) to their stomach (x5). If the semantic burden of this concept, and consequently of their corresponding words, lay just on this thematic frame, then we would not be actually describing the conceptual content of those lexical units. This is the reason why meaning postulates were introduced as notational devices for the representation of conceptual meaning in the Ontology. Unlike some other approaches in NLP, FunGramKB adopts a deep semantic approach which strongly emphasizes the commitment to provide meaning definition via meaning postulates. For example, (6) presents the natural language equivalent of the meaning postulate of +INGEST\_00:

- (6) A person or animal absorbs a liquid through an instrument to the mouth with the purpose of swallowing it to the stomach.

### 3.4 Commitment #4: meaning postulates as ontology organizers

The structure of the FunGramKB Ontology complies with the similarity, specificity and opposition principles applied to the meaning postulates of concepts.

Firstly, all subordinate concepts must share the meaning postulate of their superordinate concept (i.e. similarity principle), though non-monotonicity is permitted.

Secondly, all subordinate concepts must have a meaning postulate which states a distinctive feature (or *differentiae*) not present in the meaning postulate of its superordinate

concept (i.e. specificity principle). Therefore, a new conceptual unit can be placed within the Ontology providing that there is some information which can be expressed about that concept and was not already stated about the superordinate concept. However, it is necessary to achieve a balance in the ontology design in order to avoid the creation of multiple subordinate concepts on the basis of minor specifications on superordinate concepts.

Finally, *differentiae* in the meaning postulates of sibling concepts must be incompatible one another (i.e. opposition principle). In this way, every subordinate concept has an exclusive value within the cognitive dimension established by the superordinate concept.

Strictly speaking, these principles are not directly applied to the meaning postulates stored in the knowledge base but to the output of the Microconceptual-Knowledge Spreading (MicroKnowing), a pre-reasoning process for the construction of the extended meaning postulate of a concept. The MicroKnowing takes place in a multi-level scenario, since it is performed by the iterative application of two types of reasoning mechanisms: inheritance and inference. Whereas inheritance strictly involves the transfer of one or more predications from a superordinate concept to a subordinate one in the Ontology, our inference mechanism is based on the constructs shared between predications linked to conceptual units which do not take part in the same subsumption relation within the Ontology. It might be the case that two hierarchically-linked concepts could not be distinguished by means of their meaning postulates; this is feasible providing that their extended meaning postulates are dissimilar, since different predications are inferred. Indeed, this approach is an advantage of the FunGramKB Ontology model, since meaning postulates are underspecified in order to avoid unnecessary duplication of information. Therefore, the MicroKnowing plays the role of a pre-reasoner running on the Ontology with the aim of minimizing redundancy as well as maximizing informativeness in the semantic and world knowledge repository of FunGramKB.<sup>9</sup>

<sup>9</sup> A more accurate account of the resolution of incompatibilities in the MicroKnowing is described in Perrián-Pascual and Arcas-Túnez (2005).

### 3.5 Commitment #5: IS-A taxonomic relation

At first sight, it can seem that the exclusive use of the IS-A relation can impoverish the ontology model. Indeed, a consequence of this restriction on the taxonomic relation is found in the modelling of the upper level into three subontologies, where metaconcepts #ENTITY, #EVENT and #QUALITY arrange nouns, verbs and adjectives respectively in cognitive dimensions. However, the fact that concepts linked to lexical units of different grammatical categories are not explicitly connected in the Ontology doesn't prevent FunGramKB to relate those lexical units in the conceptual level through their meaning postulates. Indeed, the Ontology establishes a high degree of connectivity among concepts by taking into account conceptual components which are shared by their meaning postulates. In order to incorporate human beings' commonsense, the Ontology must identify the relations which can be established among conceptual units, and hence among lexical units. However, displaying conceptual similarities and differences through taxonomic relations turns out to be more chaotic than through meaning postulates linked to conceptual units. For example, some ontologies present PART-OF as a taxonomic relation, so VEHICLE and WHEEL would be explicitly linked through the ontology structuring itself. However, problems arise when inheritance takes place, since the properties of the superordinate are inherited by the subordinate. On the contrary, FunGramKB can retrieve any kind of relation by means of their meaning postulates, as can be seen in (7), as well as maintaining the consistency of the Ontology.

- (7) +(e1: +BE\_00 (x1: +VEHICLE\_00)Theme (x2: +TRANSPORT\_00)Referent) \*(e2: +COMPRISE\_00 (x1)Theme (x3: +WHEEL\_00)Referent)

### 3.6 Commitment #6: multiple inheritance

The model of the FunGramKB Ontology allows multiple inheritance, where a conceptual unit can be subsumed by two or more concepts, creating complex hierarchies in the form of a mesh instead of a tree. In case of multiple inheritance, the first predication of the meaning postulate always includes all the superordinate concepts of the *definiendum*, together with one

and only one logical relation (&, | or ^) between the multiple parents. In other words, FunGramKB gives the possibility to state if a subordinate concept can refer simultaneously to the referents of all its superordinate concepts (8), or if the conceptual parents are disjuncts (9).

- (8) +((e1: +BE\_00 (x1: +HAIR\_01)Theme (x2: +BODY\_PART\_00 & +GROUPO\_00)Referent) (e2: +COMPRISE\_00 (x2)Theme (x3: +HAIR\_00)Referent))
- (9) +(e1: +BE\_00 (x1: +DRUG\_00)Theme (x2: +SOLID\_00 ^ +LIQUID\_00 ^ +GAS\_00)Referent) \*(e2: n +BE\_01 (x1)Theme (x3: +LEGAL\_00)Attribute) \*(e3: +INGEST\_00 (x4)Agent (x1)Theme (x5)Location (x6)Origin (x7)Goal (f1: (e4: +BE\_01 (x4)Theme (x8: +HAPPY\_00 | +NERVOUS\_00)Attribute))Result)

The meaning postulate of a concept can also help to determine the IS-A path to its root. For example, as can be seen in the meaning postulates of +DRUG\_00 (9) and +BALL\_00 (10), both of them are a kind of +SOLID\_00.

- (10) +(e1: +BE\_00 (x1: +BALL\_00)Theme (x2: +ARTIFICIAL\_OBJECT\_00 & +CORPUSCULAR\_00 & +SOLID\_00)Referent) \*(e2: +BE\_01 (x1)Theme (x3: +ROUND\_00)Attribute) \*(e3: +PLAY\_00 (x4: +HUMAN\_00)Theme (x5)Referent (f1: x1)Instrument (f2: (e4: +THROW\_00 (x4)Agent (x1)Theme (x4)Origin (x6)Goal))Manner ^ (f3: (e5: +HIT\_00 (x4)Agent (x1)Theme (x4)Origin (x6)Goal (f4: +FOOT\_00)Instrument))Manner)

In turn, +SOLID\_00 can be a subordinate of +CORPUSCULAR\_00 or +SUBSTANCE\_00, both of which can be subordinated to +ARTIFICIAL\_OBJECT\_00 or +NATURAL\_OBJECT\_00. The problem is that, unlike +DRUG\_00, +BALL\_00 does not share the conceptual path of its ontological ancestors, since it is neither +SUBSTANCE\_00 nor +NATURAL\_OBJECT\_00, as illustrated in Figure 2. FunGramKB solves this type of problems on multiple inheritance by explicitly stating in the first predication of the meaning postulates the conceptual route to be taken.

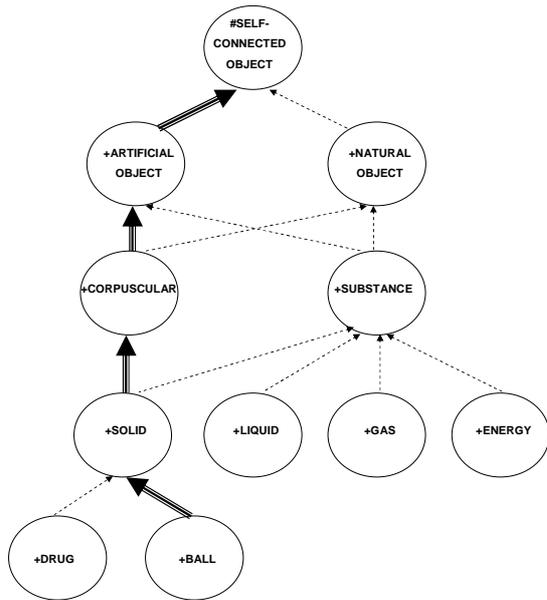


Figure 2. A sample of complex multiple inheritance.

### 3.7 Commitment #7: non-monotonic inheritance

Non-monotonicity is a key issue in human reasoning, because it permits the withdrawal of conclusions which are true just for the typical members of a particular class. On the contrary, monotonic inheritance is not able to deal with the intrinsic properties of middle-level concepts in the ontology, because this type of inheritance doesn't admit exceptions to inherited default values.

Non-monotonic logics is an umbrella term for a family of formalisms based on default reasoning, where the system can override previous beliefs in the light of further information. Although non-monotonic logics has been widely developed in the last thirty years, resulting in formalisms such as circumscription (McCarthy, 1980), default logic (Reiter, 1980) and autoepistemic logic (Moore, 1983), most of these models involve a high computational cost when being implemented in working applications which require knowledge representation. On the contrary, and despite its less-expressive power, the simplicity of defeasible logic makes it one of the most efficient non-monotonic reasoning model for NLP (Antoniou et al., 2000; Maher et al., 2001). Defeasible reasoning allows the possibility of working with incomplete

information, so a closed-world assumption cannot be applied.

There are usually three types of rules in a defeasible theory: strict rules, defeasible rules and defeaters. Strict rules are law-like rules, which have no exceptions: e.g. whales are mammals, circles are round. On the other hand, defeasible rules can be defeated by contrary evidence: e.g. birds typically fly. Finally, defeaters are used to block some defeasible rules in order to prevent some conclusions. For example, a rule such as "if an animal is heavy, then it may not be able to fly" may override the conclusion drawn from the defeasible rule "birds typically fly". The superiority relation, in which a superior rule may override an inferior one, can be expressed by means of rules (e.g.  $r_2 > r_1$ , in case rules can be labelled) or a superiority operator.

In FunGramKB, each predication taking part in a meaning postulate is preceded by a reasoning operator in order to state if the predication is strict (+) or defeasible (\*). The FunGramKB reasoning engine handles predications as rules, allowing monotonic reasoning with strict predications, and non-monotonic with defeasible predications. The superiority relation is not explicitly stated in the predications, but the priority principle is applied at the different levels of the MicroKnowing to resolve conflicts between predications.

## 4 Conclusions

The definition of these methodological criteria in the analysis and design phases of the FunGramKB Ontology and the strict application of these guidelines in the development phase contributed to avoid some common errors in conceptual modelling. Moreover, the conceptual acquisition process is much easier when ontology development takes place under a user-friendly interface. Finally, knowledge engineers emphasize the importance of performing an ontology analysis (Noy and McGuinness, 2001). In this respect, the FunGramKB Ontology is provided with some diagnosis tools for checking the most common errors and inconsistencies during the ontology development, and thus validating computationally the ontological commitments described in this paper.

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