Procesamiento del Lenguaje Natural, núm. 43 (2009), pp. 265-273 recibido 1-05-2009; aceptado 5-06-2009

Bringing Role and Reference Grammar to natural language understanding

Aproximación de la Gramática del Papel y la Referencia a la comprensión del lenguaje natural

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Resumen: La Gramática del Papel y la Referencia es una teoría funcional del lenguaje que permite la representación de un texto de entrada en términos de su estructura lógica. Con el fin de ir más allá de la gramática nuclear, el Modelo Léxico-Construccional, el cual se fundamenta en el modelo teórico anterior, proporciona una descripción más detallada de todos los aspectos implicados en la construcción del significado. Este artículo explora la integración de FunGramKB, una base de conocimiento para el procesamiento del lenguaje natural, en el Modelo Léxico-Construccional, y cómo este enfoque abre una nueva vía hacia la implementación computacional de una teoría de la comprensión del lenguaje dentro del marco de la Gramática del Papel y la Referencia.
Palabras clave: Gramática del Papel y la Referencia, Modelo Léxico-Construccional, FunGramKB, comprensión del lenguaje natural, estructura lógica conceptual

Abstract: Role and Reference Grammar is a functional theory of language which allows an input text to be represented in terms of its logical structure. In order to go beyond the core grammar, the Lexical Constructional Model, which is grounded on the previous theoretical model, provides a fine-grained description of all aspects involved in meaning construction. This paper explores the integration of FunGramKB, a knowledge base for natural language processing, into the Lexical Constructional Model, and how this approach opens a new road to the computational implementation of a theory of language understanding within the Role and Reference Grammar framework.
Keywords: Role and Reference Grammar, Lexical Constructional Model, FunGramKB, natural language understanding, conceptual logical structure

1 *Introduction*

Complex natural language processing (NLP) systems should be grounded in some linguistic theory in order to capture syntactic-semantic generalizations which can manage and interpret data, that is, which are able to provide both explanations and predictions of language phenomena. Evidently, it is really much easier to build NLP systems when linguistic theories are neglected, but those systems will unavoidably fail (Raskin, 1987). NLP applications which can work perfectly with no foundation in any linguistic theory are deceptively intelligent (Halvorsen, 1988), since they don't allow natural language understanding. Therefore, robust NLP systems require a sound linguistic model. But which model turns out to be the most beneficial for NLP knowledge bases? This paper describes how Role and Reference Grammar (RRG) in the form of the Lexical Constructional Model (LCM) can be semantically enriched when

ISSN: 1135-5948

FunGramKB is integrated, particularly relevant to the deep comprehension of language input.

2 The Lexical Constructional Model

RRG (Van Valin and LaPolla, 1997; Van Valin, 2005), one of the most relevant functional models on the linguistic scene today, adopts a communication-and-cognition view of language, i.e. morphosyntactic structures and grammatical rules should be explained in relation to their semantic and communicative functions. RRG is a monostratal theory, since the semantic and the syntactic components are directly mapped without the intervention of abstract syntactic representations. Thus, the semantic and the syntactic components are directly mapped in terms of a linking algorithm, which includes a set of rules that account for the syntax-semantics interface.

There are three main levels of representation in RRG: (i) a representation that captures the meaning of linguistic expressions in terms of an inventory of logical structures, (ii) a representation of the syntactic structure of sentences based on universally valid distinctions, and (iii) a representation of the information structure of the utterance.

The LCM (Ruiz de Mendoza and Mairal, 2008; Mairal and Ruiz de Mendoza, 2009), which is grounded on the RRG framework, has been developed in the last few years as a model which accounts for all those aspects involved in meaning construction, including those that go beyond core grammar, i.e. pragmatic implicature, illocutionary force and discourse coherence. Unlike some other existing linguistic models, the LCM is meant to provide a comprehensive description of meaning, which will serve as input for the syntactic apparatus, the output of which will be mapped to phonological form. For the syntactic apparatus, the LCM follows the RRG linking algorithm in the sense that theoretical notions such as macroroles, privileged syntactic arguments etc are used for the description of the syntactic phase.

Both RRG and the LCM share two features which are essential for a computational model of language:

- A functional view of language allows us to capture syntactic-semantic generalizations which are fundamental to explain the semantic motivation of grammatical phenomena.
- A strong commitment is made towards typological adequacy, which signifies that universal distinctions are introduced as part of the linguistic framework. Typological adequacy is obviously a *conditio sine qua non* in multilingual models.

3 FunGramKB

The LCM Core Grammar is linked to FunGramKB (Periñán-Pascual and Arcas-Túnez, 2004, 2005, 2007), 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 (e.g. information retrieval and extraction, machine translation, dialogue-based systems, etc) and with many natural languages.[1]

On the other hand, our knowledge base is lexico-conceptual, because it comprises two general levels of information: a lexical level and a conceptual level. Each one of these two levels consists of several independent but interrelated modules:

Lexical level (i.e. linguistic knowledge):

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

Conceptual level (i.e. non-linguistic knowledge):

- The ontology is presented as a hierarchical catalogue of all 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 conceptual macrostructures, i.e. script-

[1] 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.

like schemata in which a sequence of stereotypical actions is organised on the basis of temporal continuity, and more particularly on Allen's temporal model (Allen, 1983; Allen and Ferguson, 1994).

- The onomasticon stores information about named entities and events—i.e. instances of these type of concepts, 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.

The main consequence of this two-level design is that every lexical module is language-dependent, while every conceptual module is shared by all languages involved in the knowledge base. Therefore, computational lexicographers must develop one lexicon and one morphicon for English, one lexicon and one morphicon for Spanish and so on, but knowledge engineers build just one ontology, one cognicon and one onomasticon to process any language input conceptually. Furthermore, the ontology becomes the pivot for the different lexica, which explains why we maintain that this model is conceptually rather than lexically-driven.

4 Exploiting FunGramKB within the Lexical Constructional Model framework

Four different types of scheme come on to the scene in the lexico-conceptual linkage between the LCM and FunGramKB: meaning postulate, thematic frame and conceptual logical structure (CLS). Whereas the first two are concept-oriented, the last one is lexically-driven.

4.1 Thematic frames and meaning postulates in FunGramKB

In the FunGramKB ontology, concepts are provided with semantic 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 semantic knowledge representations, formally stated in what has been called Conceptual Representation Language (COREL).

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 concept. To illustrate, (1) presents the thematic frame of concept +PULL_00, to which lexical units such as *pull, draw* [Eng] or *tirar, estirar* [Spa] are linked:

(1) (x1: +HUMAN_00 ^ +ANIMAL_00)Agent (x2: +CORPUSCULAR_00)Theme (x3)Location (x4)Origin (x5)Goal

Thematic frames can also include those selectional preferences typically involved in the cognitive situation.[2] Thus, the thematic frame (1) describes a prototypical cognitive scenario in which "entity$_1$ (Agent) moves entity$_2$ (Theme) from one place (Origin) to another (Goal), there also being a place (Location) along which entity$_2$ moves". It should not be forgotten that, although one or more subcategorization frames can be assigned to a single lexical unit, every concept is provided with just one thematic frame.

Furthermore, every ontological concept is provided with one and only one meaning postulate, which 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.[3] For example, (2) presents the meaning postulate of +PULL_00:

(2) +((e1: +MOVE_00 (x1)Agent (x2)Theme (x3)Location (x4)Origin (x5)Goal (f1: +HAND_00 ^ +MOUTH_00)Instrument (f2: (e2: +SEIZE_00 (x1)Theme (x2)Referent))Condition)(e3: +BE_00 (x1)Theme (x5)Referent))

If the semantic burden of this concept, and consequently of all its corresponding words, lay just on the 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

[2] Indeed, selectional preferences are stated when they can exert some predictive power on the participant.

[3] Periñán-Pascual and Arcas-Túnez (2004) describe the formal grammar of well-formed predications for meaning postulates in FunGramKB.

conceptual meaning in the ontology. Unlike some other approaches in NLP, FunGramKB adopts a deep semantic approach which strongly emphasizes the commitment to provide semantic knowledge via meaning postulates. For example, (3) presents the natural language equivalent of the meaning postulate (2):

(3) A person or animal moves something towards themselves with their hand or mouth, providing that they hold it firmly.

An intriguing issue that divides both linguists and language engineers is the granularity of descriptions, i.e. how fine-grained or coarse-grained the resulting representation should be. The granularity of meaning postulates in FunGramKB is not as fine as that in human-oriented lexicographical definitions. If NLP knowledge bases stored the same number of meanings that paper-based dictionaries have, it would be very difficult to differentiate formally the various senses in polysemous lexical units, not mentioning the dramatic increase of data to be stored and the consequent combinatory explosion that would occur when disambiguating lexically an input text. However, FunGramKB meaning postulates are fine-grained in comparison with the axioms in other formal ontologies.

Every participant in the thematic frame is referenced by co-indexation to some participant in the meaning postulate, so at first sight thematic frames could seem to be redundant because they are fully integrated into meaning postulates. However, the relevance of thematic frames becomes manifest, since they bring to the fore those participants which will be potentially involved in the mapping with the variables in the lexical templates. In fact, if thematic frames did not exist, this mapping could not be performed, and consequently the linkage would eventually be non-existent.

4.2 Lexical templates in the Lexical Constructional Model

The LCM Core Grammar contains those attributes whose values allow the system to build automatically the CLSs of lexical units.

4.2.1 *Aktionsart*

Each lexical unit is assigned one or more *Aktionsarten* from the inventory of the RRG verb classes, which is divided into *states, activities*, *achievements*, *semelfactives*, and *accomplishments*, together with their corresponding causatives. The verb class adscription system is mainly based on the distinctions proposed by Vendler (1967).

4.2.2 Lexical Template

4.2.2.1 Variables

One or more variables (i.e. *x*, *y* and *z*) represent the prototypical arguments of the lexical unit. The number of variables is determined from that *Aktionsart* with the highest number of arguments. For example, *dry* is assigned two variables, those coming from the causative accomplishment class. Following the RRG approach, lexical entries do not include subcategorization features of the arguments (e.g. syntactic function), but just the number of arguments.

4.2.2.2 Thematic-frame mapping

Each variable in the lexical template of the lexical unit is uniquely bound to one and only participant in the thematic frame of the concept that lexical unit is linked to. As can be seen with *pull* (4), not all participants in thematic frames must be mapped.

(4) TF Mapping: x = Agent, y = Theme
(x1: +HUMAN_00 ^ +ANIMAL_00)Agent (x2: +CORPUSCULAR_00)Theme (x3)Location (x4)Origin (x5)Goal

The reason of this lack of biunivocity—since an injective function takes place—lies in the fact that, whereas the thematic-frame mapping is grounded on linguistic criteria, ontology engineers are not concerned with the behaviour of lexical items but just with their semantic burden when thematic frames are constructed.

4.2.2.3 Idiosyncratic features

Apart from the thematic relations, RRG also recognizes another type of semantic function: macroroles. Macroroles are generalizations across different argument types that have significant grammatical consequences. The group of thematic relations that are subjects in transitive active sentences and prepositional complements in passive sentences will be termed *Actors*, and those that make up the group of thematic relations that behave as direct objects in active sentences and as subject in passives will be called *Undergoers*. One general way to describe these two macroroles is by regarding them as the "logical subject" and the "logical object" respectively. The assignment of macrorole functions to the arguments is conditioned by the argument positions in the logical structures, according to the Actor-Undergoer Hierarchy (Van Valin, 2005). According to this hierarchy, in the logical structure of a predicate with two arguments, the leftmost argument will be the Actor and the rightmost one will be the Undergoer. This is the default situation, but there is one marked option of the Undergoer assignment, and that is when the Undergoer is the first argument of a two-argument state predicate (third position in the scale) and not the second argument (fourth position in the hierarchy). Alternatively, if the verb in a one-place logical structure has an activity predicate, the macrorole is Actor, while if the verb has a non-activity predicate, the macrorole is Undergoer.

The presence of idiosyncratic features in the lexical entry implies that the above Default Macrorole Assignment Principle is overridden. Some exceptional macrorole assignments are expressed by means of the feature [MR=α], where α can be 0, 1 or 2. This is the case of *belong*, which is exceptional with regard to the Default Principle, since it allows the assignment of only one macrorole (i.e. Undergoer) although the verb is associated to two variables. Another kind of lexical idiosyncratic feature can also be specified in the FunGramKB lexical template. For example, it is necessary to specify that the *z* argument of *donate* is the only possible choice for Undergoer, i.e. [U=z], since *donate* does not allow the typical "dative alternation" of three-argument verbs:

(5) Peter donated his gallery to the museum.
*Peter donated the museum his gallery.

4.3 Conceptual logical structures

According to RRG, the semantic representation of the lexical unit *ask for* is stored as (6).

(6) [do' (x, [say' (x, y)])] PURP [do' (y, 0)] CAUSE [BECOME have' (x, z)] (U = y)

Alternatively, the CLS Constructor can build automatically the representation (7) from the information stored in the LCM Core Grammar together with conceptual knowledge stored in the FunGramKB ontology.[4]

(7) [do (x_{Theme}, [+REQUEST_01 (x_{Theme}, y_{Goal})])] PURP [do (y_{Goal}, 0)] CAUSE [BECOME +REQUEST_01 (x_{Theme}, $z_{Referent}$)] (U = y)

This shift from the standard RRG model of logical structure to the CLS approach can bring many benefits. Firstly, lexical representations in the form of CLSs now become real language-independent representations, since these are made of concepts and not words, as in the classical logical structure. One of the consequences of this interlingual approach is that redundancy is minimized while informativeness is maximized.

For example, consider the Spanish predicate *arreglar,* which has two potential meanings: (i) put into a proper or systematic order (e.g. *Mi madre arregló las flores del jarrón*) and (ii) restore by replacing a part or putting together what is torn or broken (e.g. *Mi padre arregló el televisor*). Each sense is linked to a different concept, +TIDY_00 and +REPAIR_00 respectively, whose meaning postulates are presented in (8-9).

(8) +(e1: +DO_00 (x1)Theme (x3)Referent (f1: (e2: +BE_01 (x2)Theme (x4: $TIDY_D_00)Attribute))Result)

(9) +(e1: +CHANGE_00 (x1)Theme (x2)Referent (f1: (e2: past +DAMAGE_00 (x3)Theme (x2)Referent))Reason (f2: (e3: pos +OPERATE_00 (x4)Theme (x2)Referent))Result)

But if these meaning postulates hadn't been integrated into the logical structures (10) and (11) through the concepts +TIDY_00 and +REPAIR_00 respectively, it would have been impossible to distinguish both senses because these logical structures turn out to be structurally identical.

(10) [do (x_{Theme}, 0)] CAUSE [BECOME +TIDY_00 ($y_{Referent}$)]

(11) [do (x_{Theme}, 0)] CAUSE [BECOME +REPAIR_00 ($y_{Referent}$)]

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[4] The CLS Constructor also requires the RRG linking algorithm together with a word-sense-disambiguation method to accomplish the task.

It might also be the case that two or more lexical units which are linked to the same concept can have different lexical templates. To illustrate, the CLSs of lexical units *see* and *look* are presented in (12) and (13) respectively.

(12) +SEE_00 (x_{Theme}, $y_{Referent}$)

(13) do (x_{Theme}, [+SEE_00 (x_{Theme}, $y_{Referent}$)])

Here the difference does not lie in the semantic meaning, since both CLSs take the concept +SEE_00 as a primitive—whose meaning postulate is presented in (14), but on the different view of the state of affairs, where the former takes a state and the latter an activity.

(14) +(e1: +PERCEIVE_00 (x1: +HUMAN_00 ^ +ANIMAL_00)Theme (x2)Referent (f1: +EYE_00)Instrument)

Secondly, the inferential power of the reasoning engine is more robust if predictions are based on conceptual expectations. For instance, the sentence (15) would have the CLS (16).

(15) Betty asked Bill for an apple.

(16) <$_{IF}$ DECL <$_{TNS}$ PAST <[do (%BETTY_00$_{Theme}$, [+REQUEST_01 (%BETTY_00$_{Theme}$, %BILL_00$_{Goal}$)])] PURP [do (%BILL_00$_{Goal}$, 0)] CAUSE [BECOME +REQUEST_01 (%BETTY_00$_{Theme}$, +APPLE_00$_{Referent}$)]>>>

In order to perform some reasoning with the input, the CLS (16) should be transduced into a COREL representation, so that it can be enriched by the semantic knowledge in meaning postulates. In this COREL mapping process, the grammatical operators, the FunGramKB concepts and their thematic roles are the only CLS elements taken into account. Thus, the CLS (16) is modelled into the predication (17).

(17) +(e1: past +REQUEST_01 (x1: %BETTY_00)Theme (x2: +APPLE_00)Referent (x3: %BILL_00)Goal)

The next step consists in obtaining relevant background knowledge. In FunGramKB, underlying semantic and common-sense knowledge is revealed through a process called Microconceptual-Knowledge Spreading (MicroKnowing),[5] which can be defined as a multi-level pre-reasoning process for the construction of the extended meaning postulate of a concept. On the one hand, 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. On the other hand, the MicroKnowing can be conceived as a pre-reasoner. We are currently developing an automated cognizer with human-like defeasible reasoning powers which will be able to draw conclusions from information about facts of the real world and knowledge from the repository of meaning postulates. Indeed, in the latter case, the cognizer will take extended meaning postulates as input, so the MicroKnowing will play a key role as a pre-reasoner. Therefore, the concepts in the predication (5) trigger the MicroKnowing in order to spread their meaning postulates.

Thus, the MicroKnowing repository acts as the conceptual space in which the Presupposition Builder identifies those predications which are salient for explaining contextual interaction of information. The Presupposition Builder is partly inspired on Rieger's model of conceptual memory processes, which "are abstract enough to be divorced from any particular meaning representation formalism" (Rieger, 1975: 10). The output of the Presupposition Builder makes up the working memory of the application, through which the system is able to construct the referential situation model of the input text.

[5] Periñán Pascual and Arcas Túnez (2005) give an accurate description of the MicroKnowing in FunGramKB.

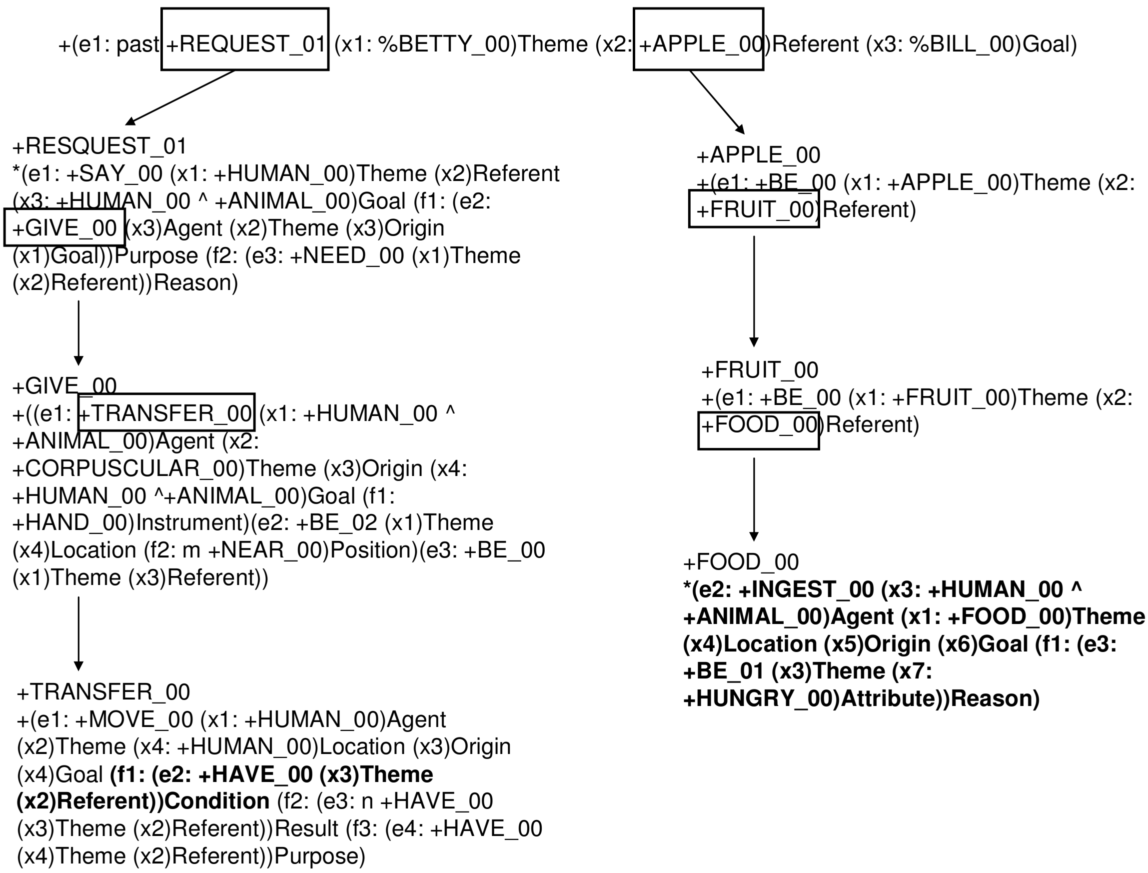

Figure 1: Building presuppositions from extended meaning postulates

In the case of (5), for example, the FunGramKB reasoner can infer, among many other presuppositions, that “Betty thought that Bill had an apple” and that “she probably ate it because she was hungry”,[6] as shown in Figure 1. Although this figure presents presuppositions obtained from meaning postulates, practical reasoning for real applications cannot be grounded just on semantic knowledge, but it requires comprehensive background knowledge, also including world knowledge, situational knowledge etc (Bos, 2005).

Therefore, automated reasoning for deep comprehension is performed by means of two computationally-implemented modules: the MicroKnowing (i.e. lower-level comprehension) and the Presupposition Builder (i.e. higher-level comprehension). However, this model of natural language understanding is feasible providing that two types of cross-lingual representations are interrelated:

- The CLS, which is able to account for a wide range of linguistic phenomena within the RRG framework (e.g. passivization), serves as the pivot language between the input text and the COREL representation.
- The COREL representation, which provides the background knowledge from the FunGramKB conceptual modules (i.e. ontology, cognicon and onomasticon), serves as the pivot language between the CLS and the automated reasoner.

Finally, it should not be forgotten that CLSs will serve as input for the rest of the three remaining layers of the LCM:

- *Level 2* or *implicational module,* which accounts for aspects of linguistic communication that have traditionally been handled in connection with implicature theory.
- *Level 3* or *illocutionary module,* dealing with traditional illocutionary force.

[6] The strength of the presupposition is determined by a weight assigned on the basis of the spreading level in which the presupposition occurs.

- *Level 4* or *discourse module,* which addresses the discourse aspects of the LCM, with particular emphasis on cohesion and coherence phenomena.

Each level is either subsumed into a higher-level constructional configuration or acts as a cue for the activation of the relevant conceptual structure that yields an implicit meaning derivation (cf. Mairal and Ruiz de Mendoza, 2009).

5 Conclusions

We have demonstrated that RRG can be semantically enriched by means of the CLSs, which construct a bridge between the more abstract conceptual level as represented in the FunGramKB ontology and the particular idiosyncrasies as coded in a given linguistic expression.

This approach is intended to be implemented in an ongoing project on the research field of cross-lingual question-answering systems. Here the CLS would become the pivot language of the application, where both the query and the document collection could be transduced into this interlingua. Moreover, the MicroKnowing and the Presupposition Builder would assist in the query analysis and the answer extraction processes. By fully integrating the semantic transducer, the reasoner and the knowledge base, the overall performance of this type of question-answering system is expected to be improved.

6 Acknowledgement

Financial support for this research has been provided by the DGI, Spanish Ministry of Education and Science, grant FFI2008-05035-C02-01/FILO. The research has been co-financed through FEDER funds.

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