The Role of Syntactic Dependencies in Semantic Interpretation

Pablo Gamallo

Departamento de Informática

Universidade Nova de Lisboa

2825–114 Caparica, Portugal

gamallo@di.fct.unl.pt

September 9, 2002

Abstract

This paper discuses in model-theoretic terms the semantic content of syntactic dependencies. It is assumed that syntactic dependencies play a central role in semantic composition. They are defined as binary predications that put the denotations of the dependent expressions together in the same semantic structure. Special attention will be paid to the main property of dependencies, namely their ability to drive co-compositionality.

1 Introduction

The main proposal of this paper is to sketch a model-theoretic description of the semantic content of syntactic dependencies. We will focus, in particular, on dependencies such as subject, direct objetc, prepositional complement and nominal modifier. We consider a syntactic dependency as a binary semantic function that takes as arguments the denotations of the two dependent expressions, and produces the denotation of the composite expression. Syntactic dependencies drive the semantic interpretation process of composite expressions. Let us take the composite expression "long construction". We argue that the intrepretation of this expression relies on, at least, three semantic objects: the denotation of the noun "construction", the denotation of the adjective "long", and the denotation of the syntactic dependency relating them: the nominal modifier. Note that the two combined expressions convey some kind of lexical underspecification. On the one hand, "construction" seems to refer to two different entities: either the process of building or the object resulting out of the process. On the other hand, adjective "long" may refer to either spatial or temporal dimensions. Yet, the interpretation of the composite expression "long construction" is no more ambiguous. It leads to activate one of the meanings of each polysemous expression. Whereas the adjective "long" activates the processual and temporal sense of the noun, this one selects for the temporal aspect of the adjective. Both expressions, "long" and "construction" co-operate together to restrict their underspecified lexical content. Such a co-operation is directly driven by the specific syntactic dependency –the nominal modifier– relating both expressions. This dependency is viewed here as a dynamic device searching within the lexical content of the two expressions those pieces of information that can be considered as semantically compatible. On this basis, it explores the content of "construction" in order to describe "long" as a temporal dimension, instead of as a spatial measure. At the same time, it explores the content of "long" in order to configure "construction" as a temporal process, instead of as the artefact taken as the result of the process.

Hence, in this article, we attempt at describing the role of the syntactic dependencies in the semantic interpretation of composite expressions. For this purpose, we will focus on three semantic properties of syntactic dependencies:

- A syntactic dependency is able to select and organise the semantic restrictions the two dependent expressions impose on each other. Such an ability is what we call "co-compositionality".

- The two dependent expressions related by a syntactic dependency have not the same behaviour. The one behaves as a participant, and the other behaves as the domain in which the participant is integrated. The participant is taken as a nominalised entity, while the integrating expression is viewed as a relational structure. These two modes of being syntactically dependent will lead us to distinguish two main basic categories: nominals and relationals.

- As syntactic dependencies are conceived here as semantic operations, we situate Syntax at the centre of the semantic interpretation process. Syntax is not more considered as an autonoumous level independent of Semantics. Rather, it is described as a particular semantic level.

These three properties of syntactic dependencies will be explained throughout the different sections of the article, which is organised as follows. First, in Section 2, we will outline informally the basic linguistic assumptions underlying the model-theoretic notions of our proposal. Then, Section 3 will introduce in more formal terms our categorial system. More precisely, we will sketch the model-theoretic interpretation of our three basic categories: nominals, relationals, and syntactic dependencies. Section 4 will be focused on the analysis of the different subtypes of syntactic dependencies. Finally, Section 5 will explore one of the main properties of dependencies, namely, co-compositionality.

2 Linguistic Assumptions

We will start by introducing two linguistic issues. First, we will characterise the semantic content of basic morphosyntactic categories such as nouns, verbs, adjectives, etc. This will be done in cognitive terms. Then, we will sketch the parameters involved in the construction of the meaning of composite expression. Special attention will be paid to the process of word disambiguation by co-compositionality.

2.1 Cognitive Characterisation of Nominals and Relationals

Linguistic expressions convey both lexical and morphosyntactic information. Lexical information provides us with notions, parameters and principles organising ontological classes such as artefacts, events, properties, substances, states, natural objects, etc. Morphosyntactic information, however, leads expressions to be grammatically codified by means of categories such as noun, adjective, finite verb, adverb, infinitive clause, participle, etc., regardless of their lexical content. Two expressions may be morphosyntactically codified in different ways while they carry the same lexical content. For instance, even though 'red' can be codified both as an adjective ('red table') and as a noun ('the red of the table'), it keeps the same lexical content; that is, it refers to a specific colour. Likewise, 'running' can be codified either as a verb or as a noun, but it refers in both cases to the same ontological event. It seems to be obvious that we cannot make a direct mapping from morphosyntactic categories like verbs, nouns or adjectives into ontological classes such as events, discrete objects or properties. According to cognitive linguistic frameworks (e.g., [Langacker, 1987, Hudson, 1990, Wierzibicka, 1988]), morphosyntactic categories must be considered as abstract conceptualisations, i.e., organising schemes on the basis of which ontological information is structured and configured.

Our aim here is to characterise the conceptualisations underlying the abstract meaning of two basic categories: both relationals, which are morphosyntactically codified in verbs, adjectives, adverbs, prepositions, etc., and nominals, which are codified in nouns, nominal phrases, that-sentences, infinitive clauses, etc. This characterisation was introduced in [Gamallo, pear]. The main notions was inspired by Langacker's Cogntive Grammar [Langacker, 1987, Langacker, 1991].

As most cognitive approaches, we assume that conceptualisations are abstract mechanisms related to specific abilities of perception. When a viewer perceives an object, he/she can focus, at least, on two different aspects: either its internal structure or the external relations it holds with the objects of its environment. In order to schematise and represent these two ways of perceiving the same entity, we must take into account, at least, three levels of organisation: the focal level in which the perceived entity is located, the level in which is situated the integrating domain, and the level of the internal constituents. Consider the event of someone reading something (see Figure 1). At the focal level, we locate the perceived event of *reading* (in bold). At this level, the event may hold various relations with other external entities, such as spatial and temporal landmarks, perceivers, humans giving opinions about different aspects of the event, etc. Horizontal lines represent the potential connections between the perceived event and the external entities, within a specific integrating domain. At the domain level, *reading* is an entity perceived as a part of some integrating activity or process, such as the fact of localising it in the space and time, the action of perceiving it, the act of giving a critical or an aesthetic opinion about it, etc. Finally, at the constituent level, the interconnected parts (i.e., the potential participants and thematic roles) of the focal event are integrated to build together its internal valence.

On the basis of this perceptual organisation, we will characterise two types of grammatical constructions: *relationals* and *nominals*. These two constructions are in accordance with the two ways of perceiving the focal entity.

A relational construction is obtained by focusing on the "whole-part" connections between the focal entity and its internal constituents. The event of reading is perceived as a relational if we are able to focus on its two internal participants: the individual who is reading (*reader*) and the symbolic object that is read (*read*). The integrating domain is situated beyond the scope of this construction. The relational construction of reading is illustrated in Figure 3. This construction (or conceptualisation) is used to describe the argument structure of verb "read". Downward arrows symbolise the semantic conditions the constituents are required to fill in order to be integrated in the event. Expressions like "Mary" and "the book" may become internal constituents, since they fill the semantic requirements. Relationals are semantic constructions denoted, not only by verbs, but also by adjectives, prepositions and adverbs. For instance, the adjective 'blue' also denotes a relational with two interconnected internal constituents: a material object and a specific kind of colour. On this basis, we argue that relational constructions organise as standard subcategorisation frames the lexical content evoked by verbs, adjectives, and further relational expressions.

A nominal construction is the result of focusing on the "part-whole" con-

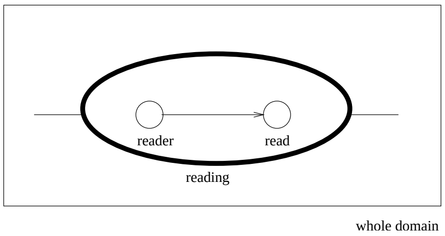

Figure 1: event of reading

nections between the focal entity and the domains that may integrate it. The event of reading is viewed as a nominal if we focus on how it is integrated as an internal participant of larger activities, states, or more complex events: for instance, localising the event of reading in the space and time, perceiving it, imagining it, giving a critical or an aesthetic opinion about it, etc. As a constituent part of an integrating domain, the event of reading may be in contact with other entities: a spatio-temporal landmark, a perceiver, etc. The result of such a conceptualisation is the nominal construction represented in Figure 2. The upward arrow illustrates the semantic conditions the domain must fit in order to let *reading* be one of its internal participants. For example, the specific states denoted by "Mary enjoys *doing something*" and "*something* is fun" can be considered as possible domains of the event of *reading*, provided that the latter is perceived as an internal participant: "Mary enjoys *reading*" and "*reading* is fun". Both states fit the semantic restrictions required by *reading*. Hence, we also need subcategorisation restrictions to organise the ontological content evoked by nouns, infinitive clause, nominal phrases, etc.

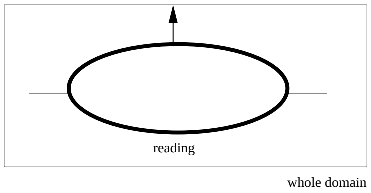

Figure 2: nominal construction

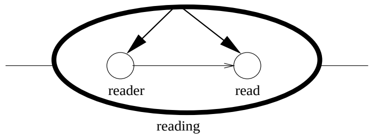

Figure 3: relational construction

It follows that not only relationals impose semantic conditions on their participants, but also nominals impose semantic restrictions on the domains into which they may be integrated. This is called *co-composition* [Pustejovsky, 1995]. In the next section, we will describe how co-composition and word disambiguation will be explained by taking into account both modes of imposing semantic preferences.

2.2 Meaning of Composite Expressions

We will focus here on two aspects of the interpretation of composite expressions: co-composition and parallel processing of syntactic and lexical information.

2.2.1 Interpretation by Co-Composition

Traditionally, a binary syntactic dependency is constituted by both the word that imposes linguistic constraints (the predicate) and the word that must fill such constraints (its argument). In a syntactic dependency, each word plays a fixed role. The argument is perceived as the word specifying or modifying the syntactic-semantic constraints imposed by the predicate, while the latter is viewed as the word specified or modified by the former. However, recent linguistic research assumes that the two words related by a syntactic dependency impose semantic restrictions on each other [Pustejovsky, 1995, Gamallo et al., 2002]. Not only verbs or adjectives are taken as predicates selecting different types of nouns, but also nouns should be considered as predicates requiring different types of verbs and adjectives.

Consider the polysemic verb "to drive", which may refer to, at least, to different events: *running by leading a vehicle*, and *making/digging a hole*. The nouns with which it combines in the direct object position are able to select one of its particular meanings. For instance, while noun "bus" requires the verb to take the running meaning ("to drive the bus"), the noun "tunnel" selects for the digging sense ("to drive a tunnel").

Two syntactically dependent expressions are no longer interpreted as a standard pair "predicate-argument", where the predicate is the active function imposing the semantic preferences on a passive argument, which matches such preferences. On the contrary, each dependent word is perceived simultaneously as a predicate and an argument. That is, each word both imposes semantic restrictions and matches semantic requirements. When one word is interpreted as an active functor, the other is perceived as a passive argument, and conversely. Both dependent expressions are simultaneously active and passive compositional terms. The process of mutual restriction between two related words is called by Pustejovsky "co-specification" or "co-composition" [Pustejovsky, 1995]. Co-composition is one of the main notions we will use to model the intepretation process. Such a modelisation will be outlined in sections 3 and 4. Unlike

Pustejovsky, we put the notion of syntactic dependency at the centre of the co-compositional mechanism.

2.2.2 The Role of Syntactic and Lexical Information in the Interpretation Process

The more standard approaches to semantic interpretation are based on the assumption that considers syntax as an autonomous linguistic level [Frazier, 1989]. Inspired by chomskian generativism, such approaches assume that the semantic interpretation process can be activated only if the syntactic analysis has been achieved in a previous stage. This way, further semantic information (lexical, pragmatic,...) is not available unless the syntactic structure of the sentence has been built.

On the contrary, semantic-oriented approaches consider syntax as the more abstract facet of semantics [Langacker, 1991, Wierzibicka, 1988]. They aim at modelling semantic interpretation by taking into account different types of linguistic information, more precisely, those lexical and morphosyntactic cues that are available during the interpretation process. Hence, morphosyntactic structures are no longer conceived of as the input of semantic interpretation, but rather as conceptual constraints, which cooperate with other linguistic constraints, to achieve a particular semantic interpretation of the sentence.

These ideas are close to some psycholinguistic approaches to language understanding [Tanenhaus and Carlson, 1989, Truswell et al., 1994, McRae et al., 1997]. They describe syntactic processing and sentence understanding as a mechanism giving access simultaneously to morphosyntactic and lexico-semantic information. According to this assumption, both information sources must be available in parallel. They argue that the listener reaches a particular interpretation by grasping at the same time morphosyntactic and lexico-semantic information. In opposition to the more standard approaches in which words are interpreted only once the syntactic structure is built, here the construction of this structure and the interpretation mechanism merge into one and the same process. In other words, building the syntactic structure of a sentence and interpretating it are not two different processes any more: they are involved in the same semantic procedure.

Parallel processing of syntactic and lexical information will also be considered one of the main aspects of the interpretation model we will describe in the next sections. Spetial attention will be paid to the notion of syntactic dependency.

3 Model-Theoretic Interpretation of Basic Syntactic Categories

We propose here a model-theoretic defintion of syntactic dependency. This defintion will lead us to characterise two basic semantic categories: nominals and relationals. Such a characterisation is not far from the notions of "nominalisation" and "functionalisation", respectively, which have been defined in Property Theory [Chierchia and Turner, 1988]. However, unlike Property Theory, our two basic categories will be defined by using a situation-based model.

3.1 Situation-Based Model for Semantic Interpretation

I will consider a situation-based system of model-theoretic interpretation, mainly inspired by work by G.N. Carlson [Carlson, 1984], as well as by some aspects of situation semantics [Barwise, 1987] and the algebra of events [Bach, 1990]. The main idea is that situations (or eventualities) like events, states, processes, and so on, are viewed as the basic entities of the model. Let us call S the set of token situations. A verb like "kick"cannot be defined as denoting any specific token situatiation of S, given that this same verb can refer to different token situations in different sentences. Rather, such a verb seems to denote the set of all possible situations where some is kicking. This characteristic set of situations is noted $kick$. As verbs denote sets of situations, we know that $kick$ is a subset of S. This does not provide a rich structure of the verb denotation, but it will be shown later how the denotation of verbs and adjectives may be associated to more elaborate argument structures, involving nominal participants and thematic roles. At present, only set-theoretic relationships between denotations can be defined. For instance, $Mary\_kick\_Bill$ will be a subset of $kick\_Bill$, which will be a subset of $kick$. This means that arguments and other nominal expressions combine with verbs to form more complex expressions also denoting sets of situations.

Under a situation-based analysis, nominals can also be defined as sets of situations. In particular, a nominal like "Bill" may be analysed as the set of situations which Bill participates in. Such a nominal denotes itself a subset of S. Both relational and nominal denotations defines an algebra of situations.

However, since nominal denotations could be a hetereogenous mixture of events, processes, and states, its internal structure should be neatly different from verb denotations. As has been pointed out in the previous section, in order to distinguish nominal from relational denotations, we need to define in a more accurate way the notion "participant of". At present, this notion is left undefined. Consider the example analysed by Carlson in [Carlson, 1984]. Suppose $kick \subseteq S$, and $Bill \subseteq S$. The set of situations denoted by the tenseless VP "kick Bill" is the result of intersecting $kick$ with $Bill$: $kick\_Bill = kick \cap Bill$. Likewise, we can build an interpretation for "Mary kick Bill" by intersecting the subset denoted by "Mary", $Mary \subseteq S$, with $kick\_Bill$. Thus, "Mary kick Bill" denotes the set of situations resulting from $Mary \cap kick \cap Bill$.

However, since the notion of "participant of" remains underspecified, this set of situations may include situations that are inadequate to describe the meaning of the sentence. Suppose that the meaning of $Mary$ includes situations where Mary gets kicked. Likewise, suppose that $Bill$ includes situations where Bill is the kicker. Hence, the intersection $Mary \cap kick \cap Bill$ should also be true with respect to those situations where Bill kicks Mary. Yet, these situations should not be used to describe the meaning of "Mary kick Bill".

As Carlson claims, these difficulties can be dealt with if we are able to distinguish among different ways of "participating" in a situation. For this purpose, he defined thematic roles as functions from nominal denotations to subsets of those denotations. For example, let us consider $\mathbf{agent}(Mary)$ be that subset of $Mary$ in which Mary participates as an agent, and $\mathbf{theme}(Bill)$

be the subset of $Bill$ in which Bill is viewed as theme. The interpretation of "Mary kick Bill" is represented by the sets of situations resulting from 1:

$$\mathbf{agent}(Mary) \cap kick \cap \mathbf{theme}(Bill) \tag{1}$$

This interpretation does not account for those situations in which Mary acts as theme (e.g. when she gets kicked), nor those in which Bill is the agent (e.g., when he is the kicker). Hence, "Mary kick Bill" and "Bill kick Mary" give rise to different interpretations.

The notion of thematic role proposed by Carlson relies on a traditional conception of semantic interpretation. Inspired by chomskian generativism, this conception assumes that interpretation can be activated only once a syntactic structure and its associated logical form have been built in a previous stage. This way, thematic roles like **agent** and **theme** are not elaborated by semantic interpretation. They underlie the logical form that has been built by applying specific lexical rules to the sentence's syntactic structure [Levin and Rappaport, 1996]. Mapping thematic roles onto nominal arguments is, then, considered, as a lexical process involved in syntactic analysis, and not in semantic interpretion. This is against what we claimed in Section **??**, where it was assumed that both syntactic analysis and semantic interpretation must be viewed as the same process (or, at least, as two procedures that should be processed in parallel).

Instead of thematic roles, we propose here a model-theoretic definition of syntactic dependencies. Let us define a set of functions δ, such that for any member **dep**, **dep** is a binary function from nominal and relational denotations to intersections of those denotations. For example, consider **subject** $\in \delta$; **subject**$(kick, Mary)$ will be that set of situations in which $Mary$ appears in the subject position of $kick$. As will be shown later, the thematic role "agent" will be obtained by considering lexical information of both the nominal "Mary" and the relational "kick". The specific thematic role is not a pre-condition for interpreting the sentence, but part of the outcome of interpretation.

This notion of syntactic dependency let us to integrate into the same process both syntactic analysis and semantic interpretation. This will be appear more evident in sections 4 and 5. For the moment, I will use the internal structure of syntactic dependecies to distinguish between nominal and relational denotations.

3.2 Model-Theoretic Interpretation for Nominals and Relationals

Syntactic dependency relations, such as subject, direct object, nominal modifier, or verbal modifier, may be viewed in the semantic space as binary operations that combine nominal with relational denotations. They result in either nominal or relational denotations. Let us take the binary function **dep**, member of δ, and two linguistic denotations $d1$ and $d2$, subsets of S (see 2 below). Two conditions are necessary to **dep**$(d1, d2)$ be a correct denotation. First, one of the denotations must be contained into the other, in particular the relational denotation must be a subset of the nominal one. Second, the intersection of both denotations must be contained into the relational denotation. So, if $d1$ is a relational and $d2$ a nominal, $\mathbf{dep}(d1, d2)$ entails the postulates depicted in 2.

$$d1 \subseteq d2$$
$$(d1 \cap d2) \subseteq d1 \tag{2}$$

The two arguments of **dep** have two different semantic behaviour within the dependency. Consider again $\mathbf{subject}(kick, Mary)$. This is a correct denotation if, at least, $kick$ is a subset of $Mary$, and the intersection of both denotations is also a subset of $kick$. Intuitively, that means that $Mary$ must be a potential participant of $kick$, and $Mary \cap kick$ must represent a set of situations contained in $kick$. Note that these two conditions are not specific enough to characterise all significant aspects of $\mathbf{subject}(kick, Mary)$. Yet, they allows us to distinguish two different logical positions (or internal roles) within the dependency: the position occupied by the relational denotations and the position occupied by the nominal ones.

In order to distinguish the relational position from the nominal one, we define a syntactic dependency as a binary predicate with two internal roles: the role that will be filled by relationals (noted "$\downarrow$"), and the role that will be filled by nominals (noted "$\uparrow$"). Hence, the denotation of "Mary kick" will be $\mathbf{subject}(kick^{\downarrow}, Mary^{\uparrow})$, where $kick$ and $Mary$ have respectively the logical properties of $d1$ and $d2$ in 2. That is, $kick$ is a subset of $Mary$, and the intersection of both denotations is a subset of $kick$. Regarding the subject syntactic dependency, $kick$ represents a relational denotation, while $Mary$ represents a nominal one. Hence, the internal structure of syntactic dependencies, in particular the two internal roles, may be used to define in a more accurate way the denotation of relationals and nominals. For instance, $Mary$ and $kick$ could be defined to a certain extent by means of the following meaning postulates:

$$
\begin{array}{ll}
Mary & \forall \mathbf{dep} \exists d [d \subseteq Mary \rightarrow \mathbf{dep}(d^{\downarrow}, Mary^{\uparrow})] \\
kill & \forall \mathbf{dep} \exists d [kick \subseteq d \rightarrow \mathbf{dep}(kill^{\downarrow}, d^{\uparrow})]
\end{array}
\tag{3}
$$

where d is a subset of S representing a linguistic denotation. In sum, nominals are denotations that appear in "$\uparrow$-positions", while relationals appear in "$\downarrow$-positions" of syntactic dependencies.

The two postulates depicted in 3 provide us with a straightforward way for distinguishing the denotation of "kick" from that of "kicking". The former denotes the relational $kick$, and the latter the nominal $kicking$. Relational $kick$ represents the set of situations characterised by the nominals with which it can be syntactically dependent. This definition is in accordance with the representation of verb "to read" in Figure 3 (Section 2.1). On the other hand, nominal $kicking$ embraces the set of situations characterised by those relationals with which it can be dependent. This reminds the cognitive representation of noun "reading" in Figure 2 (Section 2.1). Furthermore, although they represent different denotations, we also need to put them in relation. This can be done provided that we posit the existence of an ontological concept resulting from unifying $kick$ and $kicking$. Hence, $kick \cup kicking$ is a concept referring to situations like *Mary kick Bill, kicking is fun*, etc. Even if it is a subset of S, it cannot be considered as a denotation, since it does not represent the meaning of any linguistic expression. It merely represents a conceptual unit, which could be analogous to the ontological base of the event of reading illustrated in Figure 1 (Section 2.1).

Traditional morphosyntactic categories may be analysed as polymorphic objects behaving as both relationals and nominals. Verbs are relationals with regard to functions like subject, direct object or indirect object, which introduce internal participants. However, they are viewed as nominals with regard to modifiers (adverbs and external prepositional phrases). Consider equation 4, taken as the denotation of "Mary kick Bill violently":

$$\textbf{modifier}(violently^{\downarrow}, Mary\_kick\_Bill^{\uparrow}) \tag{4}$$

The adverbial relational *violently* represents the set of violent situations, which is contained in $Mary\_kick\_Bill$. Indeed, when $Mary\_kick\_Bill$, *kick_Bill*, or *kick* appear in modifying dependencies, they embraces those verbal properties (temporal reference, spatial sites, modality, and so on) that can be used to modify the action of someone kicking someone.

A verb denotation is then the reunion of two sets of situations: those situations defining it as a relational with a particular argument structure, and those adverbial situations characterising it as a nominal.[1] In case of ambiguity,

[1] We keep the term "nominal" for this verb functionality, even if it is obvious that such a term is not here the more adequate.

we will note $verb^{\downarrow}$ and $verb^{\uparrow}$ the relational and nominal uses of $verb$, respectively. The denotation of verb "kick", for instance, will be $kick^{\downarrow} \cup kick^{\uparrow}$, where $Mary\_kick\_Bill \subseteq kick^{\downarrow}$ and $violently \subseteq kick^{\uparrow}$.

3.3 Modifiers

Adjectives and adverbs are usually defined as functions from noun and verb denotations to noun and verb denotations. Given denotation d, an adjective or an adverb would be defined as the modifier function $\mathbf{M}$, such that $\mathbf{M}(d)$ is a denotation of the same semantic type than d. Such a definition of modifiers consider that the meaning construction of "adjective-noun" and "verb-adverb" combinations is mainly driven by adjectives and adverbs, respectively. They play the active role in the interpretation process of modifying expressions. Yet, this is not in accordance with co-composition and word disambiguation (see Section 2.2.1). For instance, consider that adjective "green" may convey two different meanings: both the *colour* and the *ecological* meanings. In order to interpret "green activities" in ecological terms, we need to consider the noun as the main active operation enabling to desambiguate adjective "green". It seems that it is the noun that selects for some aspects of the meaning of the adjective. For these cases, function $\mathbf{M}$ is not adequate since it only enables to specify and desambiguate the modified noun. The reverse is not allowed. For this reason, we separate adjective and adverb denotations from modifier dependencies. Adjectives and adverbs denote relationals that combine with nominals by means of modifier dependencies. The active role in sense disambiguation is assigned to modifiers, which are interpreted as dependencies. So, a modifier denotes a binary function operating on its two arguments (a relational and a nominal) in order to build a compatible set of situations, which represents the meaning of the composite expression.

Two logic types of modifiers are generally distinguished: those that restrict the extension of their arguments (extensional modifiers), and those that do not restrict their extension (intensional modifiers). It is generally assumed that "halfway" and "fake" should be interpreted as intensional modifiers in expressions (1a) and (1b):

(1a) "Mary filled the tank halfway"

(1b) "fake gun"

An intensional interpretation would consider that denotation 5, which is the interpretation of sentence (1a), should not entail $Mary\_fill\_tank$. This is motivated by the fact that such an intensional interpretation of adverb "halfway" cut off the access to some necessary information inherent to the interpretation of "Mary filled the tank". More precisely, it cut off the access to property *the tank is full.* From the same intensional viewpoint, denotation 6, which is the interpretation of expression (1b), does not entail gun. Indeed, adjective "fake" seems to remove some necessary information underlying the meaning of "gun". In particular, it is claimed that the interpretation of (1b) does not contain the property *the gun is a firearm.*

$$\mathbf{modifier}(halfway^{\downarrow}, Mary\_fill\_tank^{\uparrow}) \tag{5}$$

$$\mathbf{modifier}(fake^{\downarrow}, gun^{\uparrow}) \tag{6}$$

According to the intensional interpretation of "halfway", the set of situations characterising denotation 5 is not contained in $Mary\_fill\_tank$. Note that this is confronted with the interpretative conditions pointed out by the postulate introduced in 2 (Section 3.1). The same problem arises with the fact that denotation 6 is not contained in gun.

By contrast, we consider that those intensional interpretations are the consequence of a naive assumption on lexical meaning. Both underlying information, *the tank is full* and *the gun is a firearm*, does not represent necessary properties of the meaning of respectively "Mary filled the tank" and "gun". They merely represents some possible situations that could be inferred from these expressions if no further information is available. Concerning modifying dependencies, $Mary\_fill\_tank$ represents a nominal denotation that embraces situations concerning the state of the container. Properties like *the container is full, the container is half-full*, and so on, are possible situations in which $Mary\_fill\_tank$ may participate in. According to the two postulates depicted above in 2, we can state the two following conditions :

$$halfway \subseteq Mary\_fill\_tank$$
$$\mathbf{modifier}(halfway^{\downarrow} Mary\_fill\_tank^{\uparrow}) \subseteq halfway \tag{7}$$

As 7 states, a half-full situation is part of the meaning of both verb "fill" and verb phrase "Mary filled the tank".[2] In similar terms, *gun* contains, among others, two possible situations: *the gun works with fire bullets*, and *the gun does not work with fire bullets.* The latter could be considered a particular fake situation somehow involved in the meaning of "fake". So, the alleged intensionality of this adjective is not confronted with the postulates pointed out by 2. In accordance with 2, we state the following:

$$\begin{gathered} fake \subseteq gun \\ \mathbf{modifier}(fake^{\downarrow} gun^{\uparrow}) \subseteq fake \end{gathered} \tag{8}$$

According to 8, a fake situation is one of the properties contained in the lexical meaning of "gun".

In our framework, intensional adjectives and adverbs are not semantically different from the extensional ones. Both intensional and extensional modifiers have the same logical behaviour: they are relationals that combine with nominals following the interpretative postulate illustrated in 2.

[2]The specific situation denoted by the closed sentence "Mary filled the tank." entails that the tank is full. Yet in (1a), this expression is no more a sentence denoting a particular situation. Rather, it is conceived as denoting a nominal, which can participate in many adverbial situations.

3.4 Quantification over Situations

Even though noun and verb quantification is beyond the scope of the present study, let us give some intuitive ideas on how our model-theoretic notions could be used to deal with it.

A subset of situations representing either a nominal or a relational denotation could be defined as a characteristic function from S to thrue values. Hence, both types of denotations represent unary situation predicates. Given $sit \in S$, sit is a true element of run (i.e., $sit \in run$) if sit represents a running situation. Such a characterisation reminds the davidsonnien event predicates used as denotations of verbs. However, we also define nominal denotations in similar terms: $sit \in man$ if sit represents a situation in which man is participating. The role of determiners in NPs and aspectual morphems in tensed VPs may be defined using quantification over situations. For instance, the nominal denotation associated to the NP "all men" could be restricted by the particular meaning postulate illustred in 9:

$$\forall sit[sit \in man \rightarrow \exists \mathbf{dep} \exists d(sit \in \mathbf{dep}(d, man))] \tag{9}$$

Postulate 9 means that for all situations in which a man is a participant, then something is happening to him. Intuitively, $\mathbf{dep}(d, man)$ represents any property of a man, that is any situation in which a man may participate. More precisely, it represents the relationals with which man can combine in linguistic composition. Note that if we are able to define determiners as relations beteween nominal denotations and the relationals with which it can combine, we are not far from the ideas underlying the generalised quantifiers theory[Barwise and Cooper, 1981].

Aspectual and tensed morphems in VPs should also be defined as quantifiers on situations.

As NPs and tensed verbs quantify over situations, they merge into only one quantification procedure. Consider that 10 represents the denotation of the tensed clause “Mary is kicking all men”.

$$\forall sit[(man(sit)\ \&\ sit{=}Now\ \&\ sit{\in}\mathbf{subject}(kick^{\downarrow},Mary^{\uparrow}))\ \rightarrow\ sit{\in}\mathbf{dobj}(kick^{\downarrow},man^{\uparrow})] \tag{10}$$

That means that for every current action in which a man is participating and Mary plays the subject role, it is the man who is kicked by Mary. Both determiners and tensed morphems operate together on the set of situations in order to build a quantified interpretation of the linguistic expression. We do not need to separate quantification over individuals from quantification over situations. The fact of keeping only one type of quantification is in accordance with the strong semantic dependence between the meaning of determiners and aspectual issues of verb phrases. The best way of dealing with this interpretative depedence is to consider quantification as a general procedure over only one type of objects.

3.5 Categorial System and Related Work

The categorial system we have introduced above was inspired by Cognitive Grammar. This system leads us to consider expressions like “car”, “the car” “that the car runs” as belonging to the same basic semantic type: nominals. Likewise, expressions like “kick”, “run”, “blue”, “be blue”, “kick Bill”, “Mary kick”, “the car run”, “the car is running”, have also in common significant properties: they posses a relational structure.

Nevertheless, most model-theoretic approaches does not take into account such a categorial distinction. Semantic types are motivated by different assumptions. For instance, it is generally assumed that common nouns (“car”) and intransitive verbs (“run”) are taken as denoting entities of the same semantic type: unary predicates. Whereas noun “car” and verb “run” are associated to the the same logical type, “the car” and “car”, which are both nominals in cognitive terms, denote entities having significantly different types. This is not in accordance with the basic intuitions of linguistic theories such as Cognitive Grammar. It is also broadly assumed in model-theoretic approaches that common nouns and intransitive verbs are logically more related than intransitive and transitive verbs. This is motivated by the fact that “car” has been usually interpreted as if it were considered the intransitive verbal expression “be a car”. Again, such a categorisation is not in accordance with current linguistic theories. These grammatical incosistencies have been inherited by many formal semantics frameworks: e.g., Montague’s Grammar, Dynamic Semantics, Situation Semantics, and Discourse Representation Theory.[3]

Our categorial system attempts at overriding these inconsistencies by keeping the basic ideas of Cognitive Grammar.

4 Model-Theoretic Interpretation of Syntactic Dependecies

4.1 Two Logic Types of Dependencies

Syntactic dependencies, such as subject, direct object, or nominal modifier, denote objects of type $\langle\langle e, e\rangle, e\rangle$, given that $\langle e\rangle$ is taken here as the type of both nominal and relational denotations. An expression of type $\langle e\rangle$ is then a subset of situations. However, we may make more precise the type characterisation of dependencies, provided the known differences between nominal and relational denotations. Consider $\langle r\rangle$ and $\langle n\rangle$ the types for relational and nominal denotations, respectively. A expression of type $\langle r\rangle$ denotes a relational, and as such, it can only be assigned to the "$\downarrow$-position" of dependencies. In similar terms, an expression of type $\langle n\rangle$ denotes a nominal, and as such, it can merely appear in the "$^u parrow$-position" of dependencies. On this basis, we distinguish two types of dependencies: $\langle\langle r, n\rangle, r\rangle$ and $\langle\langle r, n\rangle, n\rangle$. The former are verbal dependencies such as subject and direct object; they take as input both a relational and nominal, and produces a more specific relational. The latter are modifiers

[3]Boolean Semantics [Keenan and Faltz, 1985], however, try to override such a puzzle by providing intransitive verbs and common nouns with different logical types.

and nominal complements; they take a relational and a nominal as input, and give rise to a more elaborate nominal. This distinction is directly related to the syntactic notion of "head". When the head of the dependency is the relational, the compound expression must denote a relational. On the contrary, if the head is a nominal, the compound also denotes a nominal. According to the Langacker's terminology, it is the head expression that imposes its profile (i.e., its denotation) to the composite.

Note that our model-theoretical definition of dependency takes into account two different internal patterns: the relational-nominal pattern, on the one hand, and the head-complement structure, on the other. As the head can be either the relational or the nominal within a dependency, we assume that both linguistic patterns are conceptually independent.

4.2 Dependencies as Compositional Operations

A syntactic dependency *denotes* a compositional operation. This operation leads the semantic entities denoted by the two syntactically related expressions to be merging into a composite entity. The resulting composite represents a more specific semantic entity. Syntactic dependencies are then perceived as dynamic objects activating and driving the semantic composition process. They are not merely passive syntactic cues related in a particular way (linking rules, syntactic-semantic mappings, syntactic assignments, etc.) to thematic roles or lexical entailments of verbs [Dowty, 1989]. They are conceived of as compositional operations taking part in the process of meaning interpretation.

On this basis, we associate compositional functions, not to relational expressions (verbs, adjectives, ...), but to dependencies. In functional terms, a dependency can be considered as a binary λ-expression:

$$[\lambda x \lambda y \mathbf{dep}(x^{\downarrow}, y^{\uparrow})] \tag{11}$$

where x is a denotation of type $\langle r \rangle$, and y of type $\langle n \rangle$. The result of applying function 11 to both a relation and a nominal is a more specific denotation, which can be either a relation or a nominal. Take the expression "Mary kick". This is constituted by three linguistic units: nominal $Mary$ denoted by "Mary", relational $kick$ denoted bythe verb "kick", and the binary function $[\lambda x \lambda y \mathbf{subj_r}(x^{\downarrow}, y^{\uparrow})]$, denoted by the subject syntactic dependency. The term $\mathbf{subj_r}$ represents the fact that the subject function gives rise to a composite denotation of type $\langle r \rangle$. That is, a subject dependency haa a relational "head", and as such, produces a specific relational. Hence, the result of applying this function to two adequate arguments yields the relational denotation in which Mary participates as subject of kicking: $\mathbf{subj_r}(kick^{\downarrow}, Mary^{\uparrow})]$. As we will show later, only lexical information from the two related expressions ("kick" and "Mary") is able to specify the subject relation as a particular thematic role. In this case, such an information could be used to consider the abstract **subject** relation as the **agent** role.

This semantic definition of a dependency presupposes two possible intermediate levels of semantic composition. On the one hand, we can posit the function $[\lambda x \mathbf{subj_r}(x^{\downarrow}, Mary^{\uparrow})]$, which is a semantic object of type $\langle r, r \rangle$. This function takes as argument relationals in which Mary may participate as subject, and results in a specific relational where Mary is actually participating as subject. Such as semantic function may be used in some case-style languages as the denotation of "Mary+Nominative", where "Nominative" represents some morphological marker inducing "Mary" to be the subject of the clause. On the other hand, function $[\lambda y \mathbf{subj_r}(kick^{\downarrow}, y^{\uparrow})]$, of type $\langle n, r \rangle$, takes as argument those nominals that can be integrated as subjects into the relational of kicking. The result is the same relational with a specific nominal playing the subject role.

Consider now the expression "blue car", constituted by three linguistic units: nominal *car* denoted by noun "car", relational *be-blue* denoted by adjective "blue", and the binary function $[\lambda x \lambda y \mathbf{modifier_n}(x^{\downarrow}, y^{\uparrow})]$, denoted by the modifier dependency. As the composite denotation is a specific nominal, and not a relational, the compositional function is an object of type $\langle\langle r, n\rangle, n\rangle$. The result of applying the modifier function to two arguments produces a specific nominal, which appears to be modified by a specific colour attribute: $\mathbf{modifier_n}(\textit{be-blue}^{\downarrow}, car^{\uparrow})$. This colour attribution should be the same than in $\mathbf{subject_r}(\textit{be-blue}^{\downarrow}, car^{\uparrow})$, which is the denotation of the verbal expression "the car be blue". However, whereas the latter attribution represents the specific relational *be-blue_car*, such that $\textit{be-blue\_car} \subseteq \textit{be-blue}$, the former represents the specific nominal *car_be-blue*, such that $\textit{car\_be-blue} \subseteq car$. Note that, in the first expression, nominal *car* represents the head of the composite, whereas, in the second one, the head is *be-blue*. This allow us to differenciate in a straightforward way the denotation of the adjective "blue" from the denotation of the verbal expression "to be blue".

We will identify only one kind of $\langle\langle r, n\rangle, n\rangle$ dependency, which will be called **modifier**. Concerning those of type $\langle\langle r, n\rangle, r\rangle$, we will identify three subtypes: **subject** for subject functions, **dobj** for direct objects, and **name_preposition** for prepositional objects of verbs.

4.3 The Role of Verbs in Compositional Interpretation

Most formal approaches to semantics consider that the lexical meaning of verbs drives the composition interpretation of sentences. Let us analyse the following expressions:

(2a) Bill run in the stade

(2b) Bill run to the supermarket

The interpretation of both (2a) and (2b) relies on two different functional terms: $[\lambda x \mathbf{run}(x)]$ and $[\lambda x \lambda y \mathbf{run\_to}(x, y)]$. The former is associated to the intransitive sense of "run", while the latter is related to its directional meaning. Yet, this is not in accordance with how we defined the process of meaning construction. It considers verbs as the only active functor in composition. The semantic preferences imposed by verbs select for specific arguments. Only verbs disambiguate the meaning of their dependent expressions (i.e., of their arguments). The reverse is not true. Nominals are viewed in the interpretation procedure as passive objects that merely fit the preferences imposed by verbs. They are not used to disambiguate verb meaning. However, as has been said before, nominal arguments should be considered as active functors imposing semantic preferences on the verbs with which they combine.

In many linguistic approaches to grammatical semantics, the meaning of verbs is disambiguated by giving access to some aspects of the lexical meaning of verbs and their arguments before semantic interpretation. Lexical information is used as a way of constraining the linking rules from nominal phrases to syntactic functions. It is this information that makes it possible to achieve a not ambiguous syntactic analysis by selecting the correct verb meaning (with the correct type of arguments) before starting semantic interpretation. Lexical information on verbs is then used to reach a non ambiguous syntactic structure. However, some not trivial questions arise: how could one distinguish the lexical information used to constraint syntactic analysis from that used to reach a specific interpretation? Is the main objective of Natural Language Understanding to describe the semantic constraints involved in syntactic analysis, or rather to study the semantic interpretation process? Such questions would not arise if we consider that syntactic analysis and meaning interpretation are one and the same semantic procedure.

In our approach, the active objects driving compositional interpretation are not verbs but syntactic dependencies. Syntactic dependencies are viewed as expert devices that use morphosyntactic and lexical information available from the conbined expressions, in order to built a possible semantic interpretation. From this viewpoint, semantic information is not used as a constraint on syntactic analysis. On the contrary, syntactic information is considered as a kind of linguistic constraint on the semantic interpration process.

Consider the following syntactic analyses:

(3a) $[_{VP}$ $[_{VP}$ to run] in the stadium]

(3b) $[_{VP}$ to run to the supermarket]

In a standard approach, the semantic interpretation of analysis (3a) will be driven by the functional operation $[\lambda x \mathbf{run}(x)]$, associated to the intransitive sense of verb "run". The intrepretation of analysis (3b), on the other hand, will rely on the binary function $[\lambda x \lambda y \mathbf{run}(x, y)]$, associated to the *go_to* sense of this verb. Nevertheless, these syntactic analyses are strongly dependent from semantics. In order to achieve those structures, it should be necessary to extract and use specific semantic information from verb "run" and its arguments: both "in the stadium" and "to the supermarket".

Interpretation process and syntactic analysis are merged into one process in our approach. Suppose that preposition "in" introduces an indirect object dependency, denoting function $[\lambda x \lambda y \mathbf{in}(x^{\downarrow}, y^{\uparrow})]$, which intends to combine relational $run^{\downarrow}$ with nominal *stadium*. This combination is possible if only if $\mathbf{in}(run^{\downarrow}, stadium^{\uparrow}) \neq \emptyset$. In this case, however, given that *park* cannot be a "in-participant" of $run^{\downarrow}$, dependency **in** is not able to build a not empty intersection between them. The interpretation process fails. We must find, then, an alternative way of driving interpretation. This is done by taking into account function $[\lambda x \lambda y \mathbf{modifier}(x^{\downarrow}, y^{\uparrow})]$. Within a modifier dependency, verb "run" is coerced to denote nominal $run^{\uparrow}$, while expression “in the stadium” is taken as denoting relational $in\_stadium$. Note that $in\_stadium$ is a composite that has been built by combining in a previous step preposition “in” with “the stadium”. The combination of the two expressions, “run” and “in the stadium”, is now possible because $in\_stadium$ is one of the kinds of situations in which nominal $run^{\uparrow}$ can participate. That is, as the event of running is likely to be located in a particular site, it may be viewed as the internal participant playing the role of *located* in location situations like $in\_stadium$. So, $in\_stadium$ is included in $run^{\uparrow}$. Analysis (3a) underlies such an interpretation.

Consider now the combination between relational $run^{\downarrow}$ and nominal *supermarket*, by means of function $[\lambda x \lambda y \mathbf{to}(x^{\downarrow}, y^{\uparrow})]$. As $\mathbf{to}(run^{\downarrow}, supermarket^{\uparrow})$ is not a empty set of situations, the interpretation process succeeds. Syntactic analysis (3b) is naturally inferred from such an interpretation.

4.4 Dependencies and Incremental Interpretation

One of the basic assumptions on meaning interpretation in formal frameworks such as Dynamic Logic [Groenendijk and Stokhof, 1991], Discourse Representation Theory [Kamp and Reyle, 1993], and Semantic Situations [Barwise, 1987], is that the meaning of a sentence both is dependent of the meaning of the previous sentence in the discourse, and modifies itself the meaning of the following sentence. Sentence meaning does not exist out of discursive unfolding. Meaning is incrementally constructed at the same time than discourse information is processed.

We assume that it is true not only at the inter-sentence level but also at the inter-phrase level, i.e., within sentences. Consider, for instance, this sentence:

(4) the government lost the journal.

Let's take NP "the journal" as a polysemic expression denoting either a printed paper or an organisation. We argue that the interpretation of this polysemic NP in (4) is dependent, not merely on the meaning of verb "lose", but on the interpretation concerning the entire previous expression: "the gouvernment lose". The NP is viewed here as an organisation because the denotation of "the gouvernment lose" -i.e., $\mathbf{subject}(lose^{\downarrow}, government^{\uparrow})$- represents those situations in which the government does not have control anymore over an activity or organisation. The journal cannot be viewed here as a printed paper, since the meaning of "government" seems to rule out those lose-situations in which someone has no more the ability to be in physical contact with something. So, the meaning of the composite expression "the government lose" has a direct influence on the polysemic meaning of the NP "the journal".

In sum, the interpretation of (4) should be conceived as an incremental process driven by the syntactic dependencies underlying the internal structure of the sentence. First, dependency **subject** gives rise to the composite denotation showed in 12, and then, **dobject** operates on the previous composite to elaborate 13. The set of situations resulting from 13 should be equivalent to 14.

$$\mathbf{subject}(lose^{\downarrow}, government^{\uparrow}) \tag{12}$$

$$\textbf{dobject}(\textbf{subject}(lose^{\downarrow}, government^{\uparrow})^{\downarrow}, journal^{\uparrow}) \tag{13}$$

$$\textbf{subject}(lose^{\downarrow}, government^{\uparrow}) \cap \textbf{dobject}(lose^{\downarrow}, journal^{\uparrow}) \tag{14}$$

In an incremental approach to meaning understanding, the sense resulting from the previous processed expressions constrains the sense of the expressions to be processed. Unlike many work on formal semantics, we do not situate incremental interpretation at the level of discourse, but at the level of phrases constituting sentences. Consequently, not only the meaning of discourse (as a sequence of sentences) is built in a dynamic and incremental way, but also the meaning of sentences (as a sequence of dependent phrases) is conceived as a dynamic and incremental process.

5 Word Disambiguation

Our main goal here is to deal with the process of co-composition. For this purpose, we postulate the existence of a dynamic entity, the dependency itself, responsible for the projection of subcategorisation restrictions to both dependent entities. During the process of compositional interpretation, the dependency builds a 2-place subcategorisation frame. One place is used to project the semantic restrictions the relational imposes on its potential nominals in that particular syntactic dependency. The other place is used to project the semantic requirements the nominal imposes on the potential relationals in which it can be an internal participant.

In standard work on formal semantics, only the relational is viewed as the dynamic entity selecting for its specific arguments. So, while the relational is able to disambiguate the meaning of its arguments, the reverse is not true. The arguments are considered as passive entities that does not select nor modify any aspect of the relational meaning. This is running counter to the thesis of co-composition.

5.1 Describing How Nominals are Disambiguated

Let us take a composite expression, "blue book", where it is the adjective that disambiguates the noun. Consider that noun "book" denotes, at least, three different nominals: i) a physical support, noted *book_phy*, such that physical relationals like *take*, *put*, *print*, *blue*, *small*, ... are contained in it; ii) an informative content , noted *book_inf*, such that symbolic relationals like *criticize*, *interessant*, *memorise*, *naive*,... are subsets of it; iii) a physic-informative sense, noted *book_phy-inf*, such that it contains relationals like *read* and *write*. This description is inspired by Generative Lexicon [Pustejovsky, 1995]. Provided such a description, the interpretation of the composite "blue book" must involve the disambiguation process of "book". This will be driven by the modifier dependency in conjunction with the lexical information conveyed by adjective "blue".

$$[\lambda x \lambda y \mathbf{modifier}(x^{\downarrow}, y^{\uparrow})](blue^{\downarrow}) \tag{15}$$

$$[\lambda y \mathbf{modifier}(blue^{\downarrow}, y^{\uparrow})](book\_phy^{\uparrow}) \tag{16}$$

In 15, the binary dependency is applied to relational *blue*. It results in the unary function illustred by 16. This function represents the set of nominals with which *blue* can be combined in the modifier position. In other words, this function must be perceived as the semantic preferences imposed by relational *blue*. In a standard framework, such a function would correspond to a second order predicate, $[\lambda N \mathbf{blue}(N)]$, from nominal denotations N to nominal denotations. However, in our framework, this predicate is not the lexical denotation directly associated to adjective "blue", but the result of combining the sense of the modifier syntactic function with the sense of the adjective.

Relational *blue* and nominal *book_phy* may be combined because they fit the two compositional postulates depicted above in 2, and now rewritten in 17:

$$blue \subseteq book\_phy$$
$$(blue \cap book\_phy) \subseteq blue \tag{17}$$

This is not true for neither $book\_inf$ nor $book\_phy\text{-}inf$. As the unary function 16 is only applied to the physical sense of "book", the result should be the specific nominal $\mathbf{modifier}(blue^{\downarrow}, book\_phy^{\uparrow})$. Later, this nominal could be combined with a further relational by means of a new syntactic dependency.

5.2 Describing How Relationals are Disambiguated

Following the same schema, we can define in a straithforward way the less standard process of relational disambiguation. Let us take a composite expression, "load the hay", where it is the nominal complement that disambiguates the verb. Let us consider that the verb denotes, at least, two different sets of load-situations: on the one hand, those situations, noted *load_bring*, describing someone bringing something to a place (e.g., "Ann loaded the hay onto the truck"). On the other hand, those situations, noted *load_mod*, describing someone changing the state of a place (e.g., "Ann loaded the truck with the hay").

In order to represent the polysemic meaning of "load" in the direct object position, we may opt for describing two meaning postulates, as those illustrated in 18 and 19.

$$\forall d[\mathbf{dobject}(load\_bring^{\downarrow}, d^{\uparrow}) \rightarrow \mathbf{theme}(load\_bring^{\downarrow}, d^{\uparrow})] \tag{18}$$

$$\forall d[\mathbf{dobject}(load\_mod^{\downarrow}, d^{\uparrow}) \rightarrow \mathbf{patient}(load\_mod^{\downarrow}, d^{\uparrow})] \tag{19}$$

These postulates account for the fact that verb "load" in the direct object dependency can produce two thematic roles, either **theme** or **patient**. Postulate 18 should be elaborated by linking the **into** dependency to the **destination** role for the *load_bring* sense of the verb. Indeed, the lexical meaning *load_bring* could be described as a particular case of the frame "Agent-Theme-Destination". Likewise, postulate 19 might be elaborated by associating the **with** dependency to the **instrument** role, for the *load_mod* sense. That means that the lexical meaning *load_mod* could be described as a particular case of the frame "Agent-Patient-Instrument". Note that both postulates cannot be considered as linking rules [Levin and Rappaport, 1996, Davis, 1996]. Linking rules are bridges from semantic frames to syntax constructions. They are used, in particular, to associate thematic roles to syntactic dependencies. From the standpoint of linking rules, syntactic dependencies are not dynamic semantic objects but passive morphosyntactic cues involved in the syntactic analysis of sentences. Meaning postulates 18 and 19, however, describes an entirely semantic process. They describe how the polysemic meaning conveyed by the direct object dependency is elaborated by two specific values, values which correspond to two thematic roles.

The disambiguation process of verb "load" is driven by the direct object dependency in conjunction with the lexical information conveyed by noun "hay".

$$[\lambda x \lambda y \mathbf{dobject}(x^{\downarrow}, y^{\uparrow})](hay^{\uparrow}) \tag{20}$$

$$[\lambda x \mathbf{dobject}(x^{\downarrow}, hay^{\uparrow})](load\_bring^{\downarrow}) \tag{21}$$

In 20, the binary dependency is applied to nominal *hay*. It results in the unary function 21. This function represents the set of relationals with which *hay* can be combined in the direct object position. In other words, this function must be perceived as the semantic preferences imposed by nominal *hay* to relationals in this specific syntactic position. The ability to build this type of functions could be considered as one of the major properties of our model.

Given that *hay* cannot be viewed as a spatial container in the patient role, the application of function $[\lambda x \mathbf{dobject}(x^{\downarrow}, hay^{\uparrow})]$ to *load_mod* must be ruled out. By contrast, the application of this function to $load\_bring$ is allowed, since *hay* is able to participate as a mobile theme in bringing events. That is, relational $load\_bring$ belongs to the set of semantic constraints imposed by *hay* in the direct object position.

Finally, by taking into account postulate 18, the functional application results in the specific relational $\mathbf{theme}(load\_bring^{\downarrow}, hay^{\uparrow})$, which is the denotation of "load the hay". As has been said above, syntactic analysis and semantic interpretation are running at the same time. It is during such a complex process that word disambiguation is achieved.

6 Perspectives in Natural Language Processing

In terms of Natural Languague Processing (NLP) strategies, our proposal may be considered as a semantic interpreter capable of building a semantic representation out of a very partial morphosyntactic analysis. Some NLP techniques for semantic interpretation that use less and less syntax are described in [Allen, 1995]. We do not need to process any kind of text in a robust fashion before starting the interpretation. Our method takes as input merely some basic morphosyntactic cues.

Consider the expression "to see the man with a coat". Before interpreting it, we need to identify the possible dependencies between the different canonical forms of words:

$$\mathbf{dobj}(see^{\downarrow}, man^{\uparrow})$$

$$\mathbf{with}(see^{\downarrow}, coat^{\uparrow})$$

$$\mathbf{with}(man^{\downarrow}, coat^{\uparrow}) \tag{22}$$

The dependencies illustred in 22 can be either correct or incorrect syntactic attachments. The correct attachments are not selected before starting the interpretation process, rather they are taken as the result of this process. A correct syntactic attachment means that the two dependent words are semantically compatible with regard to the specific dependency relating them. If this is not the case, like in the "with-dependency" between "see" and "coat", the attachment is not considered. Solving attachments is, then, a semantic task mainly driven by syntactic dependencies.

In order to implement this strategy, it would be necessary to organise the lexical information of words according to the co-compositional requirements of the dependency-driven interpretation. This is not a trivial task that arises several questions. How does the "with-dependency" uses the lexical information of "coat" so as to make it compatible with the "man" lexical information? What is the information we should have about coats that is likely to be involved in whatever co-compositional process? Even though this paper does not make any proposal for dealing with this kind of questions, we hope that it let make, at least, more pertinent questions about issues on lexical semantics.

References

[Allen, 1995] Allen, J. (1995). *Natural Language Understanding.* 2nd ed. The Benjamin / Cummings Publishing Company.

[Bach, 1990] Bach, E. (1990). The algebra of events. *Linguistics and Philosophy*, 9:5–16.

[Barwise, 1987] Barwise, J. (1987). *Recent Developments in Situation Semantics.* Language and Artificial Intelligence. Springer-Verlag, Berlin.

[Barwise and Cooper, 1981] Barwise, J. and Cooper, R. (1981). Generalized quantifiers and natural language. *Linguistics and Philosophy*, 4:159–201.

[Carlson, 1984] Carlson, G. (1984). Thematic roles and their role in semantic interpretation. *Linguistics*, 22:259–279.

[Chierchia and Turner, 1988] Chierchia, G. and Turner, R. (1988). Semantics and property theory. *Linguistics and Philosophy*, 11(3):261–302.

[Davis, 1996] Davis, T. (1996). *Lexical semantics and linking in the hierarchical lexicon.* PhD thesis, Standford University.

[Dowty, 1989] Dowty, D. (1989). On the semantic content of the notion of thematic role. In *Properties, Types, and Meaning, vol. 2*, pages 69–130. Kluwer Academic Publisher.

[Frazier, 1989] Frazier, L. (1989). Against lexical generation of syntax. In Marsllen-Wilson, W., editor, *Lexical Representation and Process*, pages 505–528.

[Gamallo, pear] Gamallo, P. (to appear). Cognitive characterisation of basic grammatical structures. *Pragmatic and Cognition*.

[Gamallo et al., 2002] Gamallo, P., Agustini, A., and Lopes, G. P. (2002). Using co-composition for acquiring syntactic and semantic subcategorisation. In *ACL-SIGLEX'02*, Philadelphy, USA.

[Groenendijk and Stokhof, 1991] Groenendijk, J. and Stokhof, M. (1991). Dynamic predicate logic. *LInguistics and Philosophy*, 14:39–100.

[Hudson, 1990] Hudson, R. (1990). *English Word Grammar*. Basil Blackell.

[Kamp and Reyle, 1993] Kamp, H. and Reyle, U. (1993). *From Discourse to Logic: Introduction to Model-theoretic Semantics of Natural Languge. Formal Logic and Discourse Representation Theory*. Kluwer Academic Publisher.

[Keenan and Faltz, 1985] Keenan, E. and Faltz, L. (1985). *Boolean Semantics for Natural Language*. Reidel, Dordrecht.

[Langacker, 1987] Langacker, R. W. (1987). *Foundations of Cognitive Grammar: Theoretical Prerequisites*, volume 1. Stanford University Press, Stanford.

[Langacker, 1991] Langacker, R. W. (1991). *Foundations of Cognitive Grammar: Descriptive Applications*, volume 2. Stanford University Press, Stanford.

[Levin and Rappaport, 1996] Levin, B. and Rappaport, M. (1996). Lexical semantic and syntactic structure. In Lappin, S., editor, *Contemporary Semantics*, pages 487–508. Blackwell Publishers.

[McRae et al., 1997] McRae, K., Ferreti, T., and Amoyte, L. (1997). Thematic roles as verb-specific concpets. In MacDonald, M., editor, *Lexical Representations and Sentence Processing*, pages 137–176.

[Pustejovsky, 1995] Pustejovsky, J. (1995). *The Generative Lexicon*. MIT Press, Cambridge.

[Tanenhaus and Carlson, 1989] Tanenhaus, M. and Carlson, G. (1989). Lexical structure and language comprehension. In Marsllen-Wilson, W., editor, *Lexical Representation and Process*, pages 530–561.

[Truswell et al., 1994] Truswell, J., Tanenhaus, M., and Garnsey, S. (1994). Semantic influences on parsing: Use of thematic role information in syntactic ambiguity resolution. *Journal of Memory and Language*, 33:285–318.

[Wierzibicka, 1988] Wierzibicka, A. (1988). *The Semantics of Grammar*. John Benjamins, Amsterdam.