LEXICAL REPRESENTATION BASED ON A UNIVERSAL SEMANTIC METALANGUAGE[1]

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ABSTRACT: *This paper presents a new model for lexical representation within the framework of Role and Reference Grammar. After revising the major challenges in lexical representation for linguistic theory, we move on to discuss a new proposal based on a universal metalanguage. We claim that the metalanguage should consist of a number of primes and a set of intervals (a mathematical notion), which will allow us to combine each of the primes to produce other non-atomic predicates. Furthermore, the new formalism is computationally interpreted in terms of two ontologies: the predicate and the object ontology. We discuss each of the modules and the way the two work together.*

KEYWORDS: *Semantics, syntax, ontologies, primitives, intervals, algorithm.*

RESUMEN: *Este trabajo presenta un nuevo modelo de descripción léxica en el marco de la Gramática del Papel y la Referencia. En una primer parte, revisamos los grandes objetivos que debe reunir una teoría sobre el léxico para centrarnos en el desarrollo de una propuesta que tiene su base teórica en un metalenguaje universal. Este metalenguaje consiste en una serie de primitivos y un inventario de intérvalos (una noción matemática), que nos permitirán combinar los primitivos para generar otros predicados no atómicos. Además, esta propuesta se articula computacionalmente en dos ontologías: (i) la ontología de predicados y la ontología de objetos. Finalmente, analizamos cómo estas dos ontologías interactúan.*

PALABRAS CLAVE: *Semántica, sintaxis, ontologías, primitivos, intervalos, algoritmo.*

INTRODUCTION

This paper outlines the methodological pillars that define a new system of lexical representation based on a universal metalanguage. This enterprise has been and still is one of the most challenging and fertile areas of research within linguistic theory since most linguistic models aspire to provide representations that are cross linguistically valid. However, the one million dollar question is still hovering: do we have a finite, systematic inventory of semantic primitives that we can use to provide typologically valid lexical representations? We are afraid that instead what we have is an endless ad hoc list of semantic primitives to be used every time the need arises and this includes practically all linguistic models (cf. section 1).

With this in mind, a new paradigm based on previous research (Mairal Usón and Faber, 2005) has been posited. What is perhaps more interesting is that we have had to look at some other disciplines (e.g. mathematics) to find out a possible answer to the above question. So, the resulting framework feeds upon notions that are not purely linguistic, e.g. the mathematical notion of interval as shall be shown below.

Initially, this new paradigm has been applied within the framework of Role and Reference Grammar (hereafter, RRG) (Van Valin, 2005) and has a twofold dimension: (i) to propose the use of a core set of semantic primitives as the basis for a semantic metalanguage or controlled vocabulary for the conceptual description of predicates, which would enrich RRG logical structures by making them more systematic; (ii) to provide the basis for a computational implementation of the resulting lexicon as well as the linking algorithm associated to the model.

Then, the organization of this paper goes as follows: Section 1 outlines some of the problems most lexical representations still have. Section 2 provides a general description of the new framework, while Sections 3 and 4 concentrate on a detailed description of the two major modules; the predicate ontology and the object ontology. Next, Section 5 shows the way the two ontologies work together.

1. PROBLEMS AND CHALLENGES IN LEXICAL REPRESENTATION THEORY

Although most lexical representations in linguistic theory, regardless of their functional or formal nature, aspire to cross-linguistic validity, they lack an enhanced semantic component capable of encoding the set of semantic and pragmatic parameters that underlie the meaning of each predicate. This theoretical gap raises the following problems which are applicable to all representations, although we will be using RRG for exemplification:

A) The specification of criteria upon which to base the selection of semantic primitives.

We understand that the existence of a set of undefinables has the advantage of permitting the systematic description of predicate meaning within a unified framework. However, this is presently not the case in RRG because no standardized procedure for this type of semantic codification has so far been specified. Consider the following examples from RRG:

(1) Activity predicates

sing	**do’** (x, [**sing’** (x)])
walk	**do’** (x, [**walk’** (x)])

(2) State predicates

melt: BECOME **melted’** (x)

shatter: INGR **shattered´** (x)

break: **do’** (x, Φ)] CAUSE [BECOME **broken’** (y)]

Example (1) shows that certain activity predicates defined by logical structures suffer from circularity since their definiens coincide with the definiendum. In (2) the central part of the definition of a predicate is the past participle of the same term being defined. This occurs in state predicates that encode the end result of the accomplishment /activity event. The examples in (2) contrast with those in (3) which point to a more fine-grained semantic decompositional system:

(3) Full semantic decompositional system:

learn: BECOME **know’** (x, y)

receive: BECOME **have’** (x, y)

kill: [**do’** (x, Φ)] CAUSE [BECOME [**dead’** (y)]

show: [**do’** (x, Φ)] CAUSE [BECOME [**see’** (y,z)]

cook: [**do’** (x, Φ)] CAUSE [BECOME **baked’** (y)]

The preceding examples in (3) are evidently based on the presupposition that certain predicates are more basic than others. From the semantic side of the fence, we might well ask whether *sing, walk, drink, melt* and *shatter* can truly be regarded as primitives, or if their meaning is not open to further decomposition. These predicates appear to differ substantially from others such as *have* and *know*, which seem to be better candidates for universal entities.

Nonetheless, there have been serious attempts to provide richer semantic representations in terms of lexical templates, as can be seen in the examples below (cf. Van Valin and Wilkins, 1993, Van Valin and LaPolla, 1997, Mairal Usón, 2003, Mairal Usón, 2004):

(4) Speech act verbs and the entry for *promise* (Van Valin and LaPolla, 1997:117)

a. **do’** (x, [**express**(α).**to**(β).**in.language**.(γ)’ (x,y)])

b. **do’** (x, [**express**(α).**to(**β**).in.language**.(γ)’ (x, y)]) CAUSE [BECOME **obligated’** (x, w)

α = w

β = y

(5) The predicate *remember* (Van Valin and Wilkins, 1993: 511)

BECOME think.again (x) about something.be.in.mind.from.before (y)

(6) The lexical class of *contact-by-impact* verbs (Mairal Usón, 2003)

[[**do´** (w, [**use.tool.**(α)**.in.**(β)**.manner.for.**(δ)´ (w, x)] CAUSE [**do´** (x, [**move.toward´** (x, y) & INGR **be.in.contact.with´** (y, x)], α = x.

The problem in (4), (5) and (6) resides in the fact that *express, obligated, think, move* are regarded as primitives. There seems to be no reason or explicit criteria for such a decision. It is as though *express,* for example, had been plucked out of the air without the use of any heuristic procedure for designating a set of primitives or, for that matter, an inventory of semantic fields, not to mention a description of their internal organization.

In this sense it is doubtful that **obligated'**, which is posited as the primitive predicate for the lexical entry for *promise* in (4), can even be remotely called a primitive. Furthermore, in (5) and (6), although *think* and *move* are putative universals, nothing is said of how these predicates have been arrived at or where they have come from. Although couched in more elaborate semantic decompositions, Mairal's (Mairal Usón, 2003) lexical templates are still not systematic enough in their use of activity and state primitives. Primitives such as *manner*, *tool*, and *use* appear in these representations, but no explanation is given of how they have been obtained.

B) The search of a neutral, language independent notational system which is easily applicable to all languages.

The use of a language-free notational system avoids the problem of using English words or predicates to describe, say, Tagalog predicates as has been standard practice in RRG[2]. Instead, (Mairal Usón and Faber, 2005) use lexical functions from Meaning Text Theory (Melcuk, 2000) and manage to provide universal representations.

(7) **fathom**: [MAGNOBSTR & CULM$_{12[\text{INTENT}]}$] **know'** (x, y)

The entry in (7) has two parts: (i) the semantic component in brackets; (ii) the representation of the logical structure. In this case, this predicate is represented by a state logical structure which takes **know'** as a primitive and has two arguments. Furthermore, this logical structure is in turn modified by a lexical function (or operator) MAGNOBSTR, which refers to the difficulty involved in carrying out an action, and in the case of *fathom*, there is great difficulty. As can be deduced from (7), lexical inheritance allows the packaging of enriched lexical information into one unified format given that hyponyms inherit the properties of their superordinate terms. Consider the lexical entry for *clarify*:

(8) **clarify**: [CAUS$_{123}$INSTR(BONCAUS(see))$_{123}$ & CULM$_{12[\text{INTENT}]}$]

do’ (x, Ø) CAUSE [BECOME **know’** (x, y)]

x = 1; y = 2; z = 3

In the same way as in the previous example, the lexical entry has two components; a causative accomplishment logical structure with three arguments and a semantic component which provides the distinguishing semantic specifications characteristic of this predicate: CAUS$_{123}$INSTR(BONCAUS(see))$_{123}$ [understand]. In *clarify*, an agent (arg1) causes (CAUS) a mental percept (arg2) to be understood better by a receiver-beneficiary (arg3).The means (INSTR) by which this is achieved is by causing (CAUS) somebody (arg3) to see(VISION) it (arg2) better (BON). As shall be observed, all the units in the lexical entry are part of the universal inventory of primitives (e.g. *see*) or operators.

The problem is that the resulting notational device is still too complex and not very transparent, which made the derivations very difficult to understand So, this explains why the new framework uses the mathematical notion of ‘interval’ (cf. Section 3.1).

C) **The codification of pragmatic and contextual information has been absent in most lexical representations**.

Linguists have often argued that pragmatic (or contextual) information has no grammatical impact and therefore it should not be included. Obviously, this is not entirely correct since the speaker's lexical competence obviously includes this sort of knowledge and besides it has been shown that some syntactic constructions are motivated by pragmatic information. Moreover, semantic representations to date are based either on 1st order predicate logic or on a form of semantic or conceptual network. These representations are equivalent in that it is possible to convert between them (Gómez-Gauchía et al., 2004), but they cannot easily handle complex concepts such as, for example, "punish". "Punish" means that A has done something that B or society thinks is bad and B does something to cause A to be unhappy. A similar case is the predicate 'peep'; the semantic structure of this predicate encodes that X deliberately performed an action of seeing because (REASON) X wanted to see Y, and this action is negatively evaluated by society, that is, society thinks that what X did is bad.

This kind of information is difficult to capture in a simple logical structure and is not easy to represent as a graph that is easy to use. Natural Semantic Metalanguage (Goddard and Wierzbeicka, 2002) and the earlier lexical templates formulated in RRG (cf. (Mairal Usón, 2003, Mairal Usón and Faber, 2002)) do have methodologies for capturing this kind of complexity but it involves a description in the language under consideration. This does not allow the possibility of translation between languages. In addition, there is no attempt to capture the range of meanings of any given word – and the range of meaning of each primitive is also not captured. More examples will be given in the following sections[3].

D) The specification of the exact semantic nature of the arguments in a predicate argument structure.

Very often linguistic models have made use of features of the type + / - animate, + /- human, which force languages to adopt the linguistic model rather than describing the language. Instead, we maintain that ontologies based on fuzzy sets and logic can throw light to this particular problem (cf. Section **¡Error! No se encuentra el origen de la referencia.**). In traditional set theory, an element is either in a set or not in a set. But in fuzzy set theory, it is possible to assign values denoting how well an item belongs to a set. For instance, if we consider the verb “drink” then all liquids that we (in our culture) normally drink would definitely be in the set of items that can take the place of the `y´ argument in **drink**´(x,y). Other items that other cultures drink may feature less strongly in the set, and poisons even less strongly. In fact, you could argue that all “things” that are liquid at room temperature (another fuzzy concept) could take the place of the `y´ argument, but we would not want them all to be linked strongly to the verb “drink”. Fuzzy set theory will allow us to do this[4]. Also, consider the verbs “persuade”, “coerce” and “force”. All of these contain the basic ideas that at first y did not want to do z, but x did something that caused y to do z. The difference in meaning between these verbs is in how nice the action by x is, but many of these actions can be applied to more than one verb, so the meanings of the verbs overlap. Again, this problem can neatly be solved using fuzzy set theory: the “extent of membership” for different actions that can apply to these verbs can be assigned different values in each set attached to each verb. Alternatively, we could order the actions according to the “strength” of the persuasion and use a continuous interval as in fuzzy logic.

E) **Meaning disambiguation and the problem of co-compositionality**.

We have no trouble in disambiguating meanings and in understanding each other. However, this cannot be done from the meanings of each word taken by itself. In many cases, the meaning of a sentence is given by its syntactic structure as well as the meanings of individual words. In addition, the meaning of the predicate can be dependent on its arguments. For example the phrases “cut string”, “cut bread”, and “cut finger” result in different forms of cutting: cutting bread means cutting the bread into slices; cutting string results in two (or more) pieces of string; but cutting a finger does not mean that a part is cut off, but that a wound is produced, which will heal in time. No representation to date handles this case.

F) Computational insights

It would be nice to build a computational lexicon with an active role in the linking algorithm. As things stand, most representations assume that syntax and semantics are separable. That is, that we can parse the sentence to produce a syntactic tree and then work out the semantics. For example MTT (Meaning Text Theory) has 7 discrete levels between the sentence and the deepest semantic representation and RRG posits an algorithm to convert syntax to semantics and back, where the lexicon is not involved in the parsing aspect.

Furthermore, in building a lexicon based on an ontology we resort to the use of conceptual maps, which allow us to represent complex information in the form of a network[5]. An example of this procedure is the representation of both the predicate and the object ontologies (cf. Sections **¡Error! No se encuentra el origen de la referencia.** and **¡Error! No se encuentra el origen de la referencia.**).

G) **Predicting morphosyntactic patterns from semantic representations**

Certainly, a lot has been done on identifying the set of linking regularities that account for the relationships between the meaning of a predicate and its potential morphosyntactic structures. However, we claim that with the use of a new semantic metalanguage more precise predictions can be obtained. This signifies the development of a set of semantic redundancy rules that account for the actual morphosyntactic expression of a given semantic value (cf. Mairal Usón and Guest, fc). For reasons of space, we will not deal with this issue here.

Now, let us move on to discuss the architecture of the new paradigm.

2. THE ARCHITECTURE OF A UNIVERSAL FRAMEWORK FOR MEANING REPRESENTATION

We outline a new semantic representation that attempts to address all the issues discussed above. Our semantic representation is actually a schema consisting of several interlinking parts. This schema is based around two separate ontologies: one for predicates (generally verbs) and one for objects, which are arguments of predicates (generally nouns). Each predicate and each object is defined using a universal semantic metalanguage. This metalanguage consists of universal primitives and functions that will enable a full description of any language, and a mapping between languages.

The ontologies are linked to each other so that, for example it is possible to work out which prepositional phrases are arguments or argument adjuncts of the predicates, and which give other information such as time and place. Predicates and objects are linked together so that predicates are directly attached to their possible arguments and objects are attached to predicates that are applicable. These latter links can help to pin down the meaning of the predicate when applied to this particular object. This also builds in a framework for knowledge representation as it would be fairly easy to deduce from such a network what objects are used for. In addition we propose to link objects together into some kind of fuzzy conceptual ontology so that, for example, the word “meal” can be attached to “table”, “cutlery”, “food”, “drink”, “human” etc, so that a whole context can be derived (as each object is also attached to appropriate predicates).

Modifying words (such as adjectives, adverbs, and auxiliaries) are included in our schema, and operate on objects or predicates. A schematic diagram of this schema is given in Figure 2. We outline each part and how they link together below.

In relation to the definitional apparatus, each prime will be at the top of its own hierarchy defined by a set of hyponyms derived from these semantic primes using universal functions applied to the intervals and a formal definitional language. These hierarchies each define a separate domain and provide a disconnected but well defined set of domains, based on universal primitives. Each derived word will inherit some or all of the intervals from the relevant prime and these intervals will describe the range of meaning of this word. These derived words are language specific because the primes are language specific. However, the metalanguage with which they are described is universal.

Words that contain ideas from more that one domain will sit between these domains Each word derived in this way will also be language specific. However, it will be possible to map concepts between languages by looking up common sets of intervals used and common definitions of words.

A schematic diagram of the predicate ontology is given in Figure 1 and a more detailed view of how this would work in practise is given for English verbs in Figure 3**.**

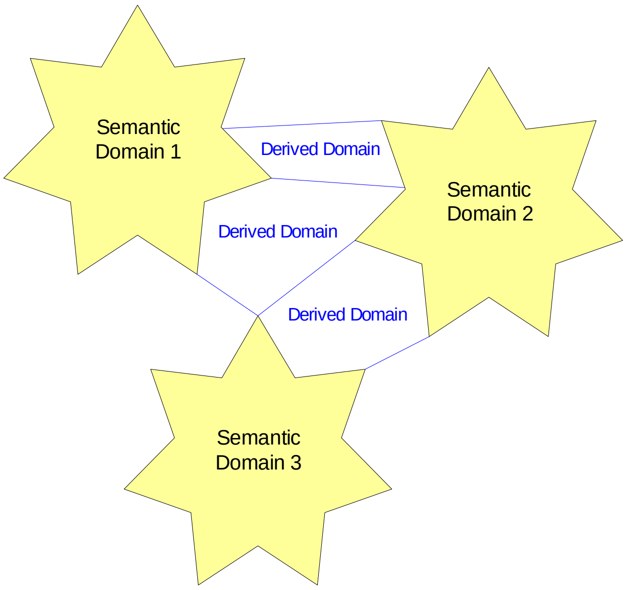

Figure 1: A schematic diagram of the predicate semantic domain.

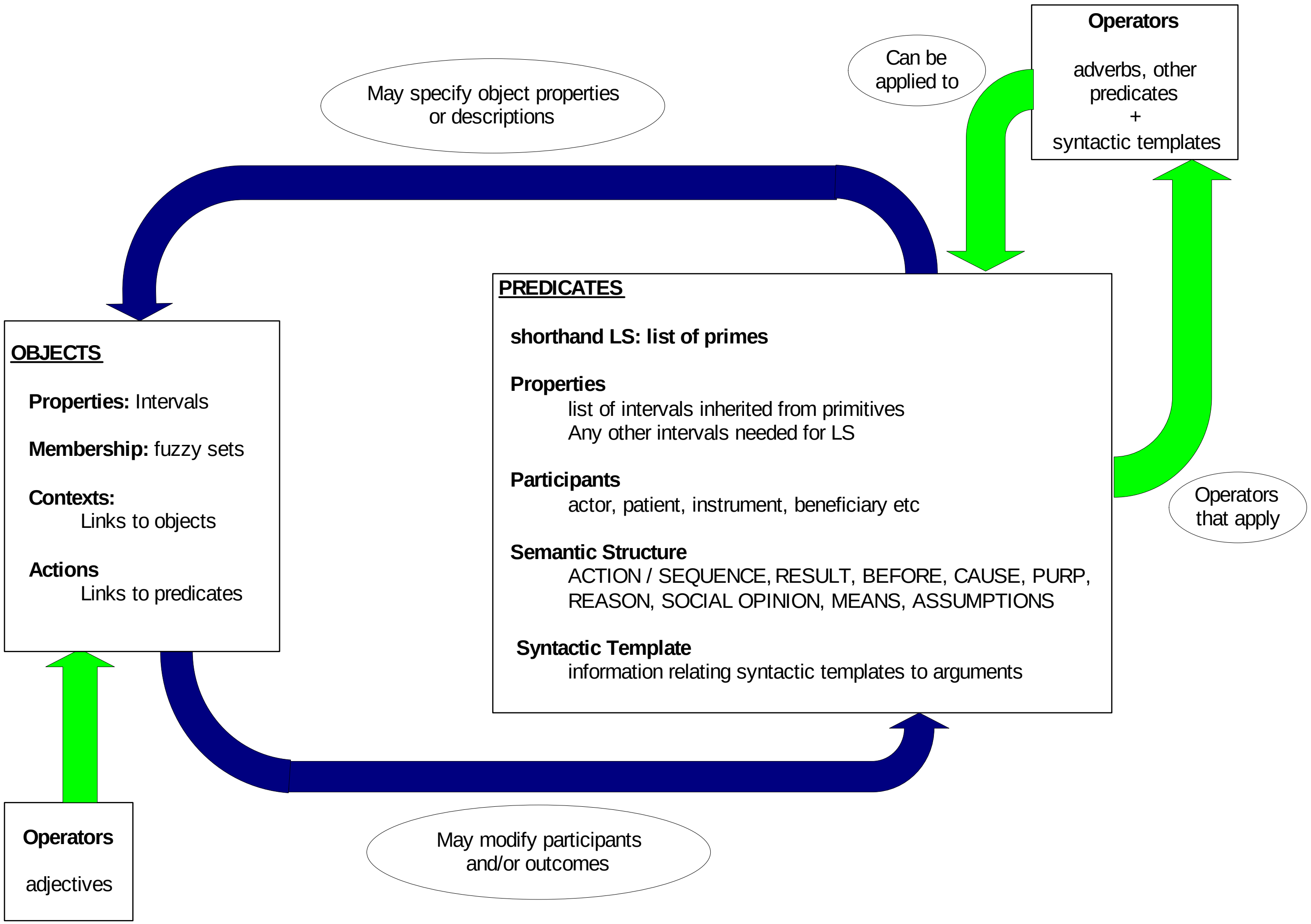

Figure 2: Overview of the new semantic framework

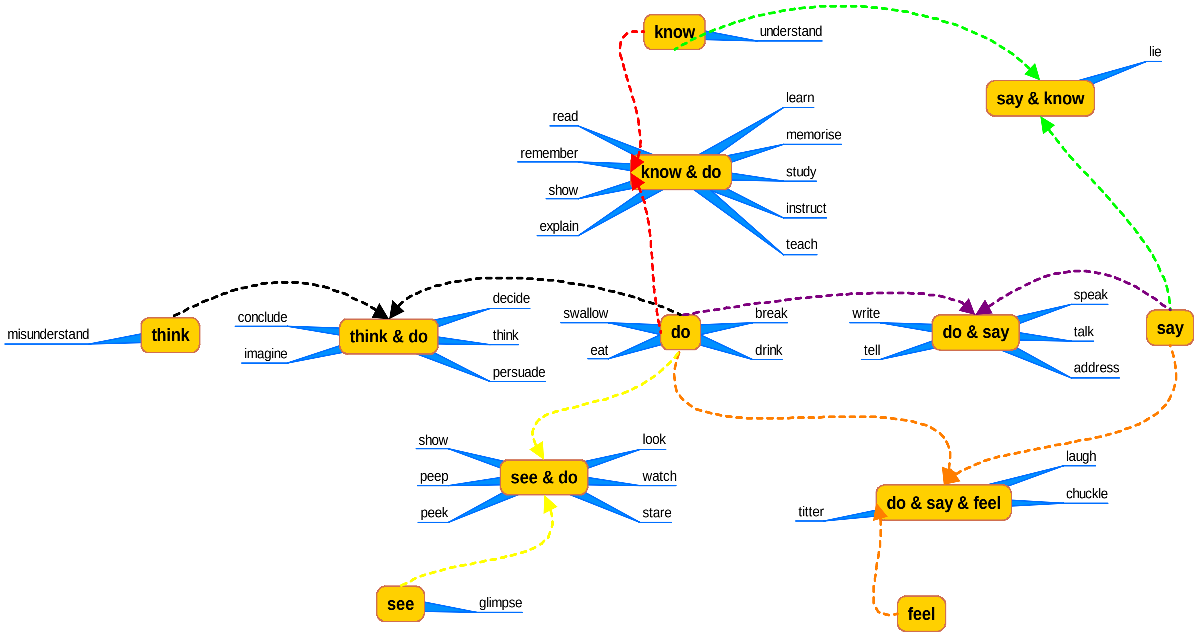

Figure 3: A partial ontology of English verbs. The arrows show that words that are derived from more than one prime inherit the intervals from all relevant primes.

3. THE PREDICATE ONTOLOGY

The most recent work done by (Mairal Usón and Faber, 2005) constitutes the initial stage of the new proposal. These linguists maintain that it is necessary and desirable to arrive at an inventory of semantic primes so that the resulting lexical representations are typologically adequate. In this regard, they use Wierzbicka's primitives (Goddard and Wierzbeicka, 2002) and Melchuk's Lexical Functions (Melcuk, 2000) to derive hyponyms from their corresponding primitives. However, the notation of this proposal should be improved as it is confusing and not very systematic.

Following the major proposals of this work, the predicate ontology consists of the following modules:

- A shorthand notation of the logical structure of a predicate together with the primitives used to derive its meaning. The shorthand logical structure consists of the predicate and a list of obligatory arguments. Consider the following examples: **think**(X), **eat**(X,Y), **decide**(X,Y,Z). Note that we are not restricted to one or two place predicates. The list of primes is needed to show which primes this word derives from and thus from which primes intervals are inherited (cf. lexical representations below).

- A list of intervals is attached to each prime and used to define the range of meanings associated with the prime. For example, an interval denoting a range of subjective modality, called SubTruth, could be attached to the prime **think.** Then we could derive **believe** from **think** by specifying a subinterval of the interval SubTruth. This use of intervals means that the prime is then language specific because although the intervals should have cross linguistic validity, the intervals required for each prime will vary because the meanings of the NSM semantic primes do not correspond exactly across languages. It is just the "core" meaning of each prime that corresponds. (cf. Section 3.1).

- A list of participants which contains a description of the semantic roles associated with each of the arguments. Fuzzy sets denoting possible participants are attached to these labels. Participants may be labelled as optional or lexical; the default is that they should be expressed (obligatory). Lexical means that they are understood in the meaning of the predicate.

- The semantic structure which defines the meaning of the predicate using a formal, neutral language (cf. section 3.2.).

- Semantic redundancy rules which link the semantics with the corresponding syntactic templates.

Let us now concentrate on the notion of interval and the internal design of the semantic structure module, which is in fact the actual semantic representation of the predicate.

3.1. *The notion of interval*

Each semantic prime can have intervals attached to it. These intervals are a way of describing the range of meaning of each prime. Predicates that are derived from more than one prime can inherit all the intervals from all of its parent primes. Note that not all intervals have to be inherited.

The intervals are continuous fuzzy sets. Various operators can be defined on them:

SUP: top end
MID: middle
INF: bottom end

PLUS: move up the interval
MINUS: move down the interval

The first three operators can be combined to form (for example)

INF SUP:	bottom of top end
SUP MID	top of middle
INF MID	bottom of middle
INF INF	bottom of bottom end

A diagram of the subintervals defined by these operators is in Figure 4.

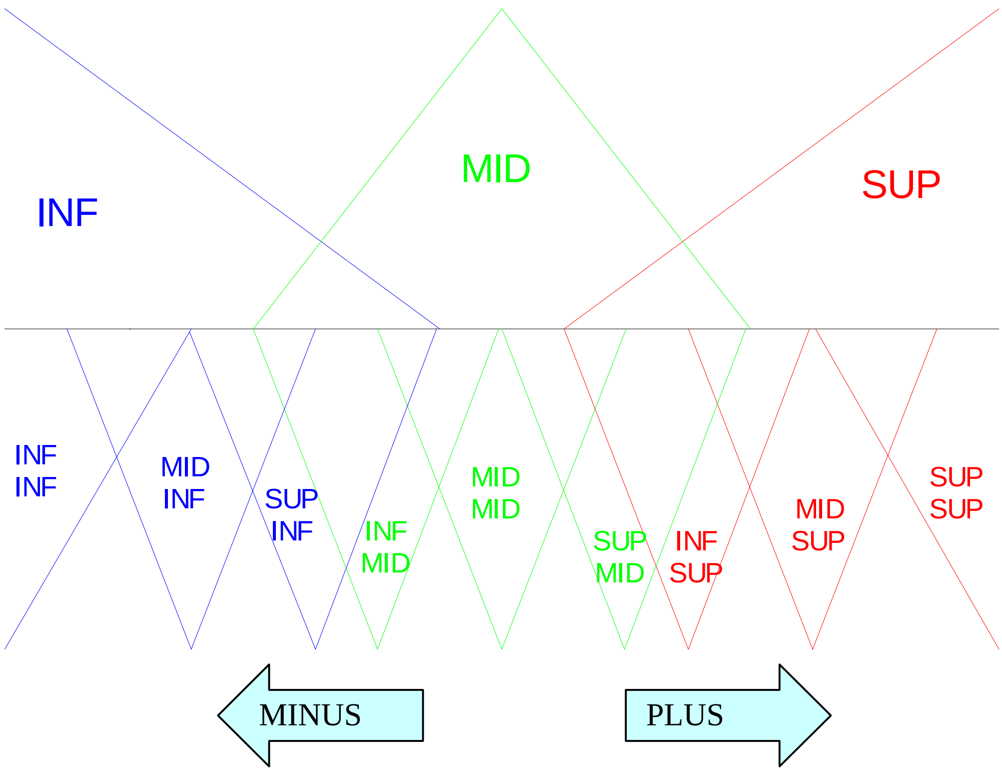

Figure 4: The operators applied to an interval.

A further operation is the &, which we will use to denote union of intervals. So MID&SUP(Interval) means the parts of the interval covered by MID or by SUP. In order to define a new predicate from a prime, we just need to specify the subinterval of the interval(s) that has been modified. So, for example, **understand** can be defined as **know**, but where the depth of knowledge of X about Y is at the upper end of the Depth interval. As none of the other intervals change, we can write this as

SUP(Depth) **know**(X,Y).

The full semantic representation for **understand** is given in **Figure 5**.

Forget involves a deterioration in all aspects of knowing about Y, so this can be written as

MINUS(Quantity, Depth, Application) **know**(X,Y).

Note that the idea of intervals maps onto work done in fuzzy logic (which is based on intervals). Fuzzy logic includes reasoning with intervals and allows for non-linear functions defined on these intervals. So for example, if we wanted to we could define a non-linear function on an interval so we could have smoother curves than triangles. The only restriction is that any such function should be one-to-one on the interval

understand(X,Y)**: know**

Intervals: Quantity, Depth, Application

Participants
Actor X: {animate}
Patient Y: {knowledge, animate}

Semantic Representation
SUP(Depth) **know**(X,Y)

Syntactic Template:
Y ≠ FACT: normal
Y = FACT: clausal subordination [=SUP(SubTruth) **know**(X,Y)]

Figure 5: Semantic representation for **understand**.

3.1.1. Intervals for each semantic prime

(Mairal Usón and Faber, 2005) use Wierzbicka's primes, which happen to coincide to a great extent with the superordinates that define their lexical domains. Here is a list of the most relevant verbal primes:

Think, know, want, feel, see, hear, say, do, happen, move, touch.

Next, the following chart is a tentative description of the list of intervals for each prime. In this regard, we are aware that this list is by no means exhaustive and needs further work:

do	Process	[start finish]	
	Length		How long it takes to do action
	Effort	[none all]	The amount of effort exerted by X to do Y
happen	Process	[start finish]	
	Length		How long it takes to do action
Think	SubTruth	[false posible true]	Subjective modality
	TimeLine	[past now future]	When thought took place
Know	Quantity	[nothing all]	How much X knows about Y
	Depth	[degrad magn]	How much X understands Y
	Application	[ANTI do do]	The extent to which X and do/apply Y
Want	WantIntens		How much X wants Y
Feel	EmotionIntens		How intensely X feels emotion Y
See	SeeTime		Duration of time that X saw Y
Hear			
Say	Formal	[informal formal]	Formality of communication
Move	Speed		Speed of movement
	Time		Length of time spent moving
Touch	TouchIntens		Intensity with which X touches Y

Let us briefly comment on the intervals that are proposed for each of these primes:

- *know*

Some intervals that might be included with the prime **know** are:

Quantity:	[nothing	all]	How much X knows about Y
Depth:	[degrade	magn]	How much X understands Y
Application	[ANTI do	do]	The extent to which X can do/apply Y

The interval Quantity describes how much X knows about Y, Depth describes the depth, or level of understanding of the knowledge that X has about Y, and Application describes whether or not X can apply their knowledge. For example if X can differentiate a mathematical function, but does not understand what this is about, then their knowledge of this aspect of maths would be at the lower end of Depth, but at the upper end of Application (since they can apply their knowledge). Conversely, if I know and understand all about Latin grammar, but am not good at translating something (because of a lack of vocabulary for example) then this knowledge is at the lower end of Quantity, the higher end of Depth, and the middle of Application. The full semantic representation for this prime is given in Figure 6.

know(X,Y)			
Intervals:			
Quantity:	[nothing	all]	How much X knows about Y
Depth:	[degrad	magn]	How much X understands Y
Application:	[Anti do	do]	The extent to which X can do/apply Y
Participants:			
Actor X: {animate, computer}			
Patient Y: {knowledge, human, dog, cat, horse}			
Syntactic Template:			
Y ≠ FACT: normal			
Y = FACT: clausal subordination [=SUP(SubTruth) **think**(X,Y)]			

Figure 6: Semantic Representation for the prime **know**. Note that there is no Semantic Representation section because primes cannot be defined in terms of other predicates.

- *Think*

The proposed intervals for **think** are:

SubTruth	[false	possible	true]	subjective modality
TimeLine	[past	now	future]	

SubTruth is a subjective measure of the truth value of what X is thinking about. For example if X believes in God then the subjective truth value of this proposition is at the upper end of the interval. If X is imagining something, and knows it isn't really happening, then we would use the lower end of the SubTruth interval. The interval TimeLine is included so that you can think about something that happened or you can plan for something to happen in the future. Note that the meanings of **think** and **know** overlap in English when the distinction between fact and opinion becomes blurred.

- *Want*

The only emotion for **want** identified so far is WantIntens. This ranges from zero intensity to an all-consuming and irresistible desire for something.

- *Feel*

The only interval proposed so far for **feel** is EmotionIntens. This interval is very similar to WantIntens described above. However, we can feel a range of feelings. We could specify this range as a set of intervals, one for each of the 6 basic emotions (Happiness, Sadness, Anger, Surprise, Fear, Disgust) established by Ekman (Ekman and Friesen, 1975) or we could say that we feel a feeling (making feel a 2 place predicate) and then define an object "feeling" with intervals for each of the 6 basic emotions. The latter is preferred for English because nouns for various feelings exist. In a language which uses predicates to describe feelings then the former option would be preferred.

- *See*

There is only one interval defined so far for **see**: SeeTime. This is the duration of time that X saw Y and can vary from a very short time (glimpse) to a long time (several hours). If we were describe this interval in terms of time, a logarithmic scale would be appropriate.

- *Hear*

No intervals for hear have yet been identified, though there are intervals that can be identified for sound:

Loudness (measured in decibels?)

Pitch

Variability [monotone ……….varied]

Variability may have several dimensions (eg variations in both pitch and sound) to it, and could be worked out by analysing a sound sequence if necessary.

- *Say*

Say is a difficult primitive to handle. The problem is due to its range of meaning. In English, say does not just mean communication via speaking, but can be applied to any form of communication, such as “it says, in this book that …”. Another problem is that speaking is not just a derivative of say, but also one of sound. This may be a case where the primitives of Wierzbeika are not so appropriate.

However, so far we have one interval for this primitive: Formal, which describes the formality of the act of communication. This interval ranges from informal to formal.

- *Do*

do basically contains all actions, that is happenings where there is an actor. The intervals are

Process	[start	finish]
Length	How long it takes to do an action.	
Effort	[none	max]

The Process interval allows the process of the action to be described so that it has a beginning, middle and end. For example, when reading a novel you generally start at the beginning of the book and work your way to the end. You can use the interval Length to describe how long it took you to read the book. This is an interval that may be modified by information from the object being acted on. The Effort interval simply describes how much effort the activity required from the actor. So for example, hitting a lamppost with your car generally requires little effort, but hitting a distant target using a bow and arrow will generally require more effort.

- *Happen*

happen is the predicate that can be used to do describe events where there is a change of state, but no actor. An examples is the concept of melting snow, where there is no specific actor, but a change of state of water from a form of solid to liquid. The intervals associated with happen are the same as for **do** except that the interval Effort is not included:

Process	[start	finish]
Length	How long the event takes	

- *Move*

The intervals associated with move are

Speed	speed of the movement
Time	how long the object (actor or patient) was moving for
Manner (swing, walk, run, slide)	

- *Touch*

The only intervals defined for **touch** is TouchIntens, which describes how strongly two objects are pressed.

The list of intervals and the list of participants, given in the semantic representation are needed for easy reference as they are referred to in the semantic structure section. In general, the list of intervals will contain those inherited from primes, but in some instances other intervals will be required. For example, the result of break verbs can vary from a crack to lots of pieces for concrete objects and thus it makes sense to include an appropriate interval to denote this. The participants are included because they will be referred to in the semantic structure, but also because sometimes the only way of differentiating between two predicates is on the arguments they take. Spanish “saber” and “conocer” are an example of this.

3.2. *The semantic structure module*

Independently of the complex semantic parameters that are characteristic of a predicate, one of the methodological prerequisites that cannot be violated is that all the units involved in the semantic representation must be drawn from the inventory of primitives and functions; hence, universally valid analytical units must be used

There are two ways of deriving predicates from primes. One way is to specify subintervals within one of more of the intervals in the list; the other is to define the meaning of the predicate using a formal language. Both of these occur in the semantic structure part of the semantic representation, and both may occur together. The semantic structure is broken into sections with various logical headings in order to enable a richer definition. This is similar to the approach taken by Weizbeicka, the main difference being that we have formalised the language.

The semantic structure is the part where the meaning of the predicate is expressed. Semantic primitives do not have this part because they cannot be further decomposed. The semantic structure may be in several sections headed by the key words

ACTION	Describes any actions involved in the verb.
SEQUENCE	Describes a sequence of actions that occur consecutively
RESULT	Describes the results of an action or sequence
BEFORE	Describes the situation before the start of the ACTION or SEQUENCE
CAUSE	Anything directly caused by an ACTION or SEQUENCE. May also occur within other headings.
PURP	The purpose of an ACTION or SEQUENCE
REASON	The reason why an ACTION or SEQUENCE is carried out
SOCIAL	Describes any social/cultural background that is key to the meaning.
OPINION	
MEANS	Gives a list of predicates that could describe how the RESULT is achieved
ASSUMPTIONS	List of assumptions behind the predicate

This list is not complete and is open to discussion. Below we provide a discussion of several case studies which show how intervals, primes and this formal metalanguage can be combined and posit a complete lexical representation.

3.2.1. Some case studies

In order to have a better understanding of how the theory actually works, we have made a selection of those predicates which are more representative and we have presented them in terms of the lexical domain they belong to. In so doing, we want the reader to be aware that a lexical domain is a repository of a large number of regularities, which means that a lot of information can be inherited and predicted.

A) Lexical domain of CHANGE: *break* and *shatter*

An example semantic representation is given in Figure 7 for the English verb **break.** This is a two argument predicate meaning that X breaks Y. The only prime involved is **do** which denotes a deliberate action. The intervals inherited from **do** are Process (the process of the action: start to finish), Length (how long the action took), and Effort (the amount of effort required on the part of the actor to carry out the action). In the case of accidental breakage, the amount of effort is zero (bottom end of interval) but if it required lots of blows with a sledgehammer then the effort is at the top end of the interval. Note that this interval allows a meeting, if not an overlap with the single argument version of **break**, which differs from the two place predicate by the lack of the Effort interval and the lack of an actor (and the semantics associated with the actor). The final interval is an extra interval called Pieces, which is not inherited and which is used to describe the result of **break**.

break(X, Y)**:do**

Intervals: Process, Length, Effort
Pieces [lots of pieces few pieces crack whole]

Participants:
Actor X: {thing}
Patient Y: {thing}
Instrument Z: {thing} (optional)

Semantic Structure
ACTION
do(X, Φ)

CAUSE
MINUS(Pieces) thing

Syntactic template: normal, with Z

Figure 7: Semantic Representation for the English verb **break**.

The two place version of **break** has two obligatory participants: an actor and a patient, and an optional participant: the instrument. So we can say X broke Y with Z. The (fuzzy) sets given with the participants define the kinds of objects that the participants can be: here any concrete object will do for all participants. Notice that the Semantic Structure has two sections: ACTION and CAUSE. This means that X does something which causes something else to happen. In this case, the something else that happens is that Y moves down the Pieces interval and is thus no longer whole. In standard semantic notation, we could write this as

do(X, Φ) CAUSE MINUS(`Pieces) thing

The reason why we break this up is because complex logical structures quickly become very difficult to read and because breaking things up allows a richer definition. One of the hyponyms of *break* is *shatter*. The predicate **shatter** (Figure 8) simply uses the keyword RESULT. There is no action because this predicate just inherits from **happen**, which does not involve an action. The result in this case is that X is broken into lots of pieces and thus its status moves to the bottom end (INF) of the Pieces interval.

Pred shatter(X)**:happen**

Intervals: Process, Length
Pieces [lots of pieces   few pieces   crack   whole]

Participants:
Patient X: {thing}

Semantic Structure

RESULT
INF(Pieces) X

Syntactic template: normal

Figure 8: Semantic Representation for the English verb **shatter**.

B) Lexical domain of VISION: *watch, stare* and *peep.*

If we move on to the domain of visual perception, let us analyze the predicates *watch, stare* and *peep*. First, the predicate *watch* uses the keyword ACTION. In this case the action is that X does something for a while and this something is to look at Y for a while. Notice that subintervals are specified both for the duration of the actions and the duration of the seeing (which should be the same). The reason why **watch** (Figure 9) inherits from **do** is that watching is an activity that requires the actor to consciously do something.

The predicate **stare** (Figure 10) introduces the keyword REASON. This is used to explain why X did the action. In this case there are two possible reasons for staring: because X is surprised at what X is seeing or because X is staring at Y because X wants to make Y feel fear (or in other words to intimidate Y). The modifications of the intervals says that X puts some effort into this action and that it takes some time.

watch(X,Y)**: see, do**

Intervals: SeeTime, Process, Length, Effort

Participants:
    Actor X: {animate}
    Patient Y: {thing, scene}

Semantic Structure

    ACTION
        MID&SUP(Length) **do**(X, MID&SUP(SeeTime) **see**(X,Y))

Syntactic Template: normal

Figure 9: Semantic representation for the English verb **watch**.

stare(X,Y)**: see, do**

Intervals: SeeTime, Process, Length, Effort

Participants:
Actor X: {animate}
Patient Y: {thing, scene}

Semantic Structure

ACTION
MID(Length) MID&SUP(Effort) **do**(X, MID(SeeTime) **see**(X,Y))

REASON
feel(X, surprise)
OR
want(Y, **feel**(fear)) (Y = animate)

Syntactic Template: stare at

Figure 10: Semantic representation for the English verb **stare**.

An example where pragmatic information plays a vital role is **peep** shown in Figure 11. In this example the Semantic structure means that X deliberately performed an action of seeing because (REASON) X wanted to see Y. The SOCIAL OPINION part means that society thinks that what X did is bad. In this example, there is also more use of the intervals. In this case, X took some time(MID(length)) and expended a fair amount to a lot of effort (MID&SUP(Effort)) to achieve the action of seeing Y. He wanted to see Y moderately to very badly (MID&SUP(WantIntens)) and achieved his aim for a while (MID(SeeTime)).

peep(X,Y)**: see, do, want**

Intervals: SeeTime, Process, Length, Effort, WantIntens

Participants:
Actor X: {human}
Patient Y: {thing, scene}

Semantic Structure

ACTION
MID(Length) MID&SUP(Effort) **do**(X, MID(SeeTime) **see**(X,Y))

REASON
MID&SUP(WantIntens) **want**(X, **see**(X,Y))

SOCIAL OPINION
be(X,bad)

Syntactic Template: peep at

Figure 11: Semantic representation for the English verb **peep**.

show(X,Y,Z)**: do, know**

Intervals: Process, Length, Effort, Quantity, Depth, Application

Participants:
Actor X: {animate}
Theme Y: {action}
Recipient Z: {animate}

Semantic Structure

ACTION
do(X,Y)

PURP
PLUS(Application) **know**(Z, **do**(Z,Y))

Syntactic Template: normal

Figure 12: Semantic representation for the English verb **show**.

C) Lexical domain of COGNITION: ***show, persuade, remember***

Continuing with this domain, let us consider the predicate *show*, which illustrates a double field membership between visual perception and cognition. So, one meaning of this predicate is to show someone how to do something with the intention that they can then do it. The other is to do something to enable some one to see something. Semantic representations for both these meanings are given below. Note that the first meaning inherits from **know** (Figure 12) and the second from **see (**

Figure 13). In both these semantic representations, there is an action followed by a PURP. The PURP indicates the intention behind the action. Note that the intention in the first semantic representation is to increase Z´s ability to do Y.

Now, within the domain of cognition there are two predicates that merit a comment: persuade and remember. The predicate **persuade** (Figure 14) shows how the keyword CAUSE is used. This semantic structure is saying that X communicates Z to Y and that X expends some effort (MID&SUP(Effort)) in doing this. This aspect allows for various kinds of persuading from simple verbal telling to more forceful action. If Z is an action then communicating this to Z causes Z to do it. If it is an idea or a fact, then communicating this causes Y to believe that Z is true.

SUP(SubTruth) **think**(Y,Z) means that Y believes Z is true. It says nothing about whether Z is actually true or not.

Finally, **remember** (Figure 15) introduces the keyword BEFORE. Something is assumed to have happened before this event: in this case X forgot some of his knowledge about Y and his knowledge decreased over all intervals. The action of remembering says that X does something that is unspecified and the result of this is that the knowledge about Y increases again across all intervals. Note that this says nothing about whether or not he remembered everything, but just that he remembered something. Again we use RESULT rather than CAUSE because there may be no direct cause and effect between the action and the result.

show(X,Y,Z)**: do, see**

Intervals: Process, Length, Effort, SeeTime

Participants:

Actor X: {animate}
Theme Y: {thing}
Recipient Z: {animate}

Semantic Structure

ACTION
do(X,Φ)

PURP
see(Z, Y)

Syntactic Template: normal

Figure 13: Semantic representation for the second version of the English verb **show**.

persuade(X,Y,Z)**: do, think**

Intervals: Process, Length, Effort, SubTruth, TimeLine

Participants:
Actor X: {human}
Patient Y: {human}
Theme Z: {action, {fact, idea}}

Semantic Structure

ACTION
MID&SUP(Effort) **do**(X, **say**(X,Z))

CAUSE
Z = action: **do**(Y,Z)
Z= {fact, idea}: SUP(SubTruth) **think**(Y,Z)

Syntactic Template:
Z = action: co-cosubordination
Z = {fact, idea}: clausal subordination

Figure 14: Semantic representation for persuade.

remember(X,Y)**: know, do**

Intervals: Quantity, Depth, Application, Process, Length, Effort

Participants:
Actor X: {human}
Patient Y: {knowledge}

Semantic Structure

BEFORE
MINUS(Quantity, Depth, Application) **know**(X,Y)

ACTION
do(X, Φ)

RESULT
PLUS(Quantity, Depth, Application) **know**(X,Y)

Syntactic Template:
Y ≠ FACT: normal
Y = FACT: clausal subordination

Figure 15: Semantic representation for remember.

eat(X,Y)**:do**

Intervals: Process, Length, Effort

Participants:
Actor X: {animate}
Patient Y: {food, meal}

Semantic Structure

SEQUENCE
do(X, **move**(X,Y)) CAUSE **loc**(Y, mouth Є X)
do(X, **swallow**(X,Y))

RESULT
NOT **exist**(Y)

Syntactic template: normal

Figure 16: Semantic representation for **eat**.

swallow(X,Y)**:do**

Intervals: Process, Length, Effort

Participants:
Actor X: {animate}
Patient Y: {food, drink}

Semantic Structure
ASSUMPTION
loc(Y, mouth Є X)

ACTION
do(X, **move**(X,Y)) CAUSE **loc**(Y, stomach Є X)

RESULT
NOT **exist**(Y)

Syntactic template: normal

Figure 17: Semantic representation for **swallow**.

D) Lexical domain of ACTION: *eat, swallow*.

Within the vast lexical domain of ACTION we are going to focus on two cases which are examples of verbs of ingesting: *eat* and *swallow*.

The predicate **eat** (Figure 16) inherits from **do** and is thus an action. There are no changes in the intervals in this example, but just a definition in the semantic structure. In this case, we have SEQUENCE and RESULT. SEQUENCE defines a sequential set of actions. In this case the actions are (1) X moves something to X´s mouth (mouth Є X) and then swallows it (swallow is defined below). The result of this action is that Y ceases to exist. We cannot use CAUSE here instead of result because it is not the sequence of actions that causes the result, but some other process, that is digestion. Note the use of CAUSE within the sequence of actions. This is simply a quick way of embedding a semantic structure. The longwinded way would have been to embed and ACTION and CAUSE semantic structure.

In the semantic representation for **swallow** (Figure 17), we have the keyword ASSUMPTION. This means that there are preconditions before this action can happen. In this case, the assumption is that the patient Y is in X´s mouth. The action causes Y to move to X´s stomach and the result is that Y ceases to exist.

4. THE OBJECT ONTOLOGY

The object ontology in our semantic schema is also based on primes and these primes will have intervals attached to them. There are two kinds of object: concrete nouns and abstract nouns and each will have to be dealt with separately.

4.1. *Concrete Nouns*

The best way to represent concrete nouns cross-linguistically is to link the words to pictures of concrete objects. Language is related to the physical and cultural worlds around us and translation is possible because we share much of the same physical world (although explanation is needed for cultural concepts that are not shared). Giving our semantic schema access to pictures, gives it a limited kind of "sight".

If nouns are linked to pictures, then physical properties of the objects depicted can be attached to these pictures and used to aid understanding. After all, such knowledge is assumed when we communicate with each other. Such properties could include the following:

- Physical size (or range of sizes) either as a bounding box, or as a set of values representing max and min width, height and depth.
- Whether the object is hard or soft (perhaps in interval defined by how much the object deforms by the application of a mass of some proportion of its weight)
- The sound (if any) made by the object
- Whether the object is liquid or solid, or viscous (interval)
- Weight (range of weights)

Objects that are less clear from a picture can be defined by their intervals, and by their uses, denoted by which predicates they link to (see below). We can construct an ontology from these objects by grouping them together into fuzzy sets. So for example, we could have a fuzzy set "animate", which would include human beings with maximum membership value. Most people would agree that an ant is animate, but not really as animate as a human, so we can give this a lower membership value. Any object may belong to many fuzzy sets and may have different memberships in each. Note that this approach handles the case where one language has one word where another language has many words. This is the case with the Spanish word "gusano" which stands for the English words "caterpillar", "worm", and “grub”. Spanish can group these items together, and English can keep them separate – and we have a cross-linguistic representation.

The above describes an ISA (is a kind of) relationship. We also need PART-OF relationships to show that an object is part of another. For example a finger is part of the hand. These kinds of relationships will be less fuzzy than the ISA kind, but some fuzziness is still needed to denote distance. For example the finger is part of the hand, but is it part of the arm? In some cases (such as amputation), the answer would be yes, while in other cases (such as touching on the arm), it would be negative.

4.2. *Abstract Nouns*

Nouns that do not denote concrete objects have to be dealt with differently. Some, such as “sound”, “thought” and “feeling” can be derived by defining them as the second argument of the appropriate primitive (hear, think, feel). Others could be defined by a set of intervals. For example, kinds of “meal” can be described by a time interval denoting the time eaten and fuzzy sets denoting the kinds of food eaten.

Nouns such as “sound” should have properties associated with them such as [loud …. Soft] (measured in decibels); “Feeling” should have an interval associated with intensity attached to it. These properties are similar to those that can be attached to verbs and derivation of new nouns by specifying subintervals can happen in the same way. So for example, if “feeling” has the intervals (from (Ekman and Friesen, 1975)):

Happiness [intensity]

Sadness [intensity]

Fear [intensity]

Anger [intensity]

Surprise [intensity]

Disgust [intensity]

Then we can define “happiness” by specifying zero intensity for all the intervals except the Happiness one. Or we could define “frustration” as a mixture of the intervals Sadness and Anger (with zero values for the other intervals).

4.3. *Object Semantic Structure*

A template for the object semantic structure can be seen in figures 2 and 18. It consists of the following sections:

1) **Properties**: These are the intervals associated with the object and may consist of the union of intervals from objects lower down the hierarchy in the case of concrete objects, or subintervals inherited from objects higher up the hierarchy, in the case of abstract nouns.

2) **Membership**: This is a list of ontologies (or fuzzy sets) that the object belongs to along with its membership value. An object may belong to many fuzzy sets making up part of an ontology. Note that the fuzzy set theory is well developed and union and intersection of these sets is well understood. (Amit, 2005).

3) **Contexts**: This is a list of links to other objects to provide some kind of context information. For example when faced with trying to translate the Spanish word

"gusano" into English, we have to make a choice between "caterpillar", "grub" and "worm". The correct term is normally clear from context and the aim is that these context links will provide the necessary context with which to compare words in the text. These contexts links also provide a form of knowledge representation. The links can be weighted to turn this aspect into a "fuzzy conceptual map" (Carlsson and Fullér, 1996, Nikravesh et al., 2004, Amit, 2005).

4) **Actions**: A list of links to predicates. These links can have information attached to narrow the choice of participants or to specify a narrower set of outcomes and can be weighted.

The final section is the most important for linking the objects and the predicates. Its function is to specify the meaning of the predicate when applied to this particular object.

5. THE INTERACTION OF THE TWO COMPONENTS

The two ontologies we have discussed both consist of complex semantic structures. We now show in detail how they are linked. A schematic diagram showing which parts of the object semantic representation link to which parts of the predicate representation and vice versa is shown in Figure 18.

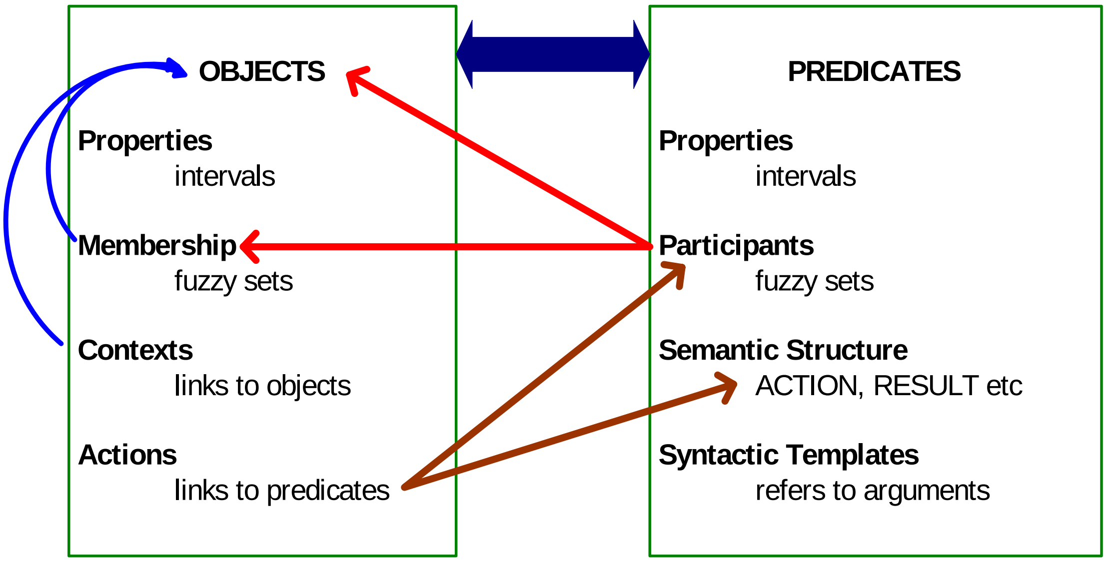

Figure 18: Diagram showing how the predicates and Objects are connected and related to each other.

This figure shows that the arguments of the predicate provide a link into the object ontology, both to specific objects and the fuzzy sets. In general, the arguments of the predicates will specify fuzzy sets rather than specific arguments, but a specific object will often be given in the sentence. This kind of linking provides some immediate context for the arguments of the predicate and enables the relevant representations to be found more quickly.

Each object is linked back to all the verbs which apply to it. However, these links provide useful information about how the verb applies to this particular object. For example, if the predicate is "cut" and the patient is "finger", then the "finger" object can tell the predicate that the result of the action is a wound (rather than lots of pieces, for example) and that the instrument could have been one of the following (fuzzy) set: {knife, saw, secateurs, paper, grass}. This set is fuzzy because for normal applications the most common cause would be a knife, so this would have a high membership value, whereas grass would have a low membership value because it is possible, but not likely. Membership values could be determined from corpus data.

Linking between objects and predicates in this way is a very important part of the semantic schema because

- it allows a narrower range of possible outcomes to be specified and thus allows a more complete understanding of a text to be built up.
- if optional arguments are present, knowing the obligatory arguments will help disambiguate optional arguments from non argument phrases.

A concrete example is shown in

Figure 19. This figure is incomplete in its links because otherwise the diagram would be too complicated. An incomplete ontology is given by the yellow boxes and items within this link to the predicate ontology (pink boxes). The blue lines linking words in the hierarchy denote ISA (is a kind of) relationships; the red lines denote PART-OF relationships.

The black dotted lines show the Action links from the object ontology. Some of these links have information attached to them regarding participants and the result of the action. For example, “bread” has a link to the predicate “cut” with the information that the implement used to cut bread is a knife and that the result is that the bread (the patient) is cut into slices. “Butter” links to spread with information about the kinds of things it is generally spread onto, the implement used to spread it, and the information that butter is the patient of this action. Arrows are at both ends of these lines to indicate that the predicates do have links to the ontology. The green dotted lines show the Context links and give an indication of how we might link words together in order to provide some context information. So, for example, although “meal” does not have a direct relationship with “food” (meal is an abstract concept, whereas food is concrete), there is a strong connection between the two. There are many more links than shown. For example, there are links between bread and breakfast and lunch, but there should also be one between bread and starter. These links enable the semantic schema to work out which foods generally go with which meal, thus providing contexts for various meals. This diagram could be extended with information about the situation within which a meal is eaten: the time, implements used, the extent to which it is cooked, the people eating the meal, etc.

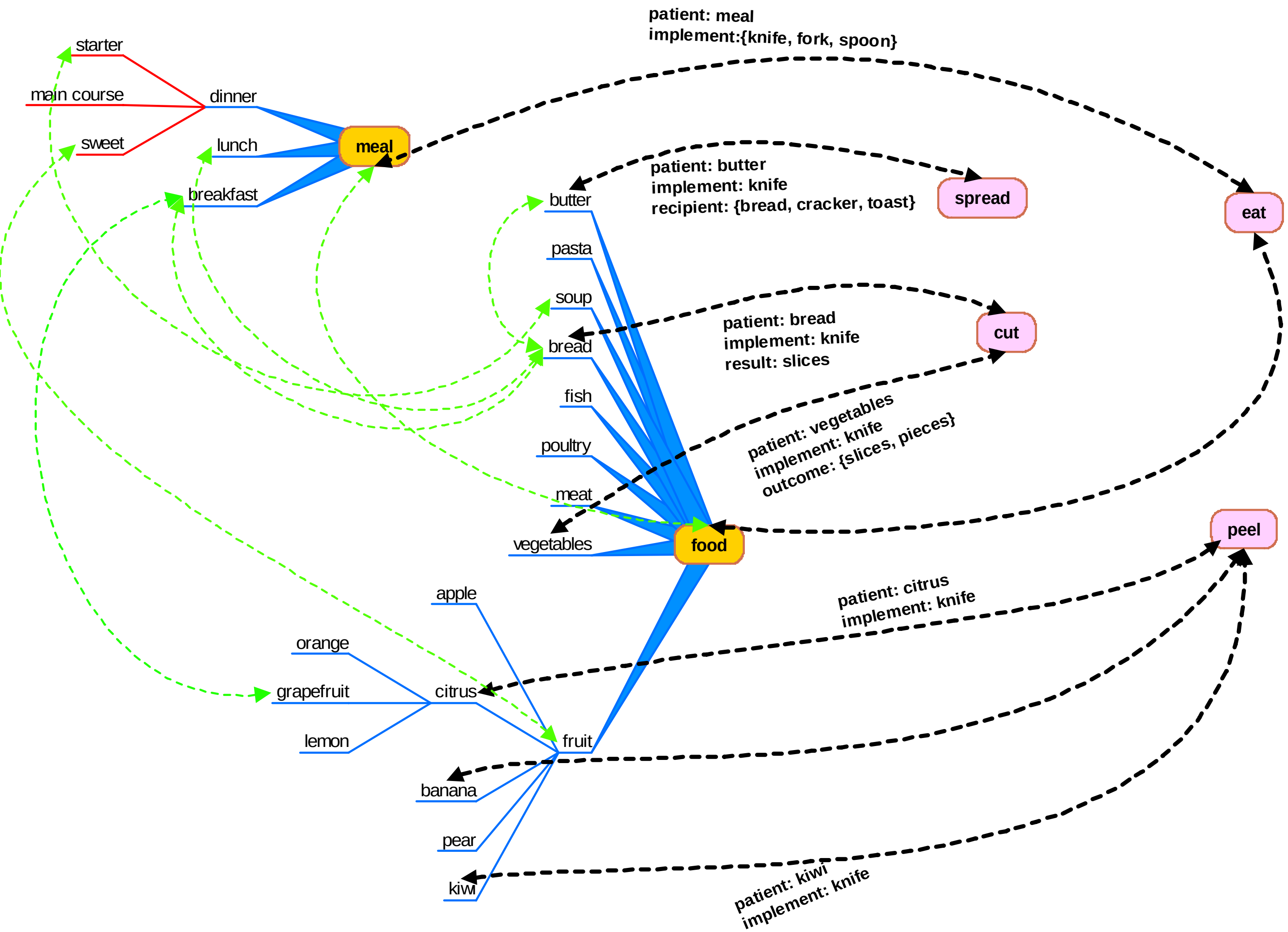

Figure 19: A more detailed, but incomplete, example of how the object and predicate ontologies link together.

6. CONCLUSIONS

In this paper we have given an outline of a new model for lexical representation within the framework of RRG. In doing this, a number of crucial issues have been explored: (i) the search for a core set of semantic primitives; (ii) the systematic use of the mathematical notion of interval; (iii) the design of two ontologies - a predicate and an object ontology - as a mechanism for capturing the rich set of semantic, syntactic and pragmatc properties of predicates; (iv) the incorporation of fuzzy logic and fuzzy set theory into lexical representation.

This new perspective forms the basis of a new paradigm provisionally termed U(niversal) L(exical) M(odel), which will be further developed in future works. Finally, this new paradigm has also come to fill a gap, the computational implementation of the linking algorithm in RRG.

NOTES

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2. For a full coverage of the differences between lexical functions and intervals, see (Mairal Usón and Guest fc).

3. Abundant exemplification of the way pragmatic information is coded within a lexical entry is provided in (Faber, 1999).

4. Note that computer scientists have been using fuzzy logic and fuzzy set theory to capture this range of meanings. This approach has been found useful for applications in summarising texts (Lee, 2005), and searching

the world wide web. (Nikravesh, 2004, Chau, 2004, Quan, 2004). Other applications include vehicle and robot control, speech recognition, internet searching, and data mining.

5. Conceptual maps have been used to represent and reason with complex issues such as defining a fisheries policy (Pitcher, 2003) or for developing complex ontologies (Garcia, 2005). Some researchers have extended the reasoning capabilities of conceptual maps by weighting the links between the various items. The links are weighted by treating the map as if it was an artificial neural network and using standard neural network learning techniques to determine what the weights should be (Carlsson, 1996, Nikravesh, 2004). The idea of conceptual maps is also used in current development of knowledge representation. For example, CODE4 (Skuce, 1995) groups knowledge into “metaconcepts” and the commercial system Cyc (www.cyc.com) groups its knowledge into “micro theories”, which overlap in their extent.

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