Defining and Representing Preposition Senses: a preliminary analysis

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Abstract

In this document, we analyze several aspects related to the semantics of prepositions. We propose an approach and elements of a method to organize and to represent prepositions uses and senses. Complex polysemous behaviors are discussed, showing the use and limits of the approach.

1 Introduction

Most prepositions are highly polysemous and are often involved in a large number of derived, unexpected or metaphorical uses. Analyzing and representing the semantics of prepositions is a rather delicate and risky task, but of much importance for any application that requires even a simple form of understanding. Spatial and temporal prepositions have recieved a relatively in-depth study for a number of languages (e.g. (Boguraev et al. 87), (Verkuyl et al. 92)). The semantics of other types of prepositions describing manner, instrument, amount or accompaniement remains largely unexplored (with a few exceptions however, such as *avec* (with) (Mari 00)).

Our general application framework is knowledge extraction using linguistic and symbolic techniques. In this framework, the treatment of predicative forms is crucial to characterize actions, processes and states. Predicative forms include verbs, but also prepositions which have a heavy semantic weight by themselves. Of much interest are also the interactions verb-preposition-NP.

This short document is a brief analysis of how preposition uses (as arguments or adjuncts) and senses, in standard utterances, can be organized and characterized. The method presented here, applied to French, seems general and applicable to many languages. Our proposal is rather a feasability study and elements of a working method, with some results that require e.g. a lot of lexical tuning, than, obviously, a set of firmly established results. We propose an organization of preposition senses into families where basic usages as well as metaphorical ones are identified and contrasted. A semantic representation in Lexical Conceptual Structure (LCS) is proposed where a great attention is devoted to the economy and expressivity of the primitives used. An evaluation of the accuracy and relevance of the sense distinctions concludes this paper.

Prepositions are mainly studied in isolation. We think this first step is necessary before studying their interactions with verbs. These interactions are indeed very diverse, from standard composition (the most frequent case), to facet activation and to complex situations of mutual influence, involving non-monotonic forms of semantic composition.

2 Defining a preposition semantics for French: Methodological issues

2.1 Delimiting preposition senses

Before looking in more depth at the semantic representation of preposition senses, let us investigate a few elements for delimiting senses that settle our theoretical and practical perspective. We prefer to use the term 'strategy' to delimit senses since there is obviously no theory or even no 'formal' procedure. This task is extremely difficult, but necessary for any real NLP application with a quite wide coverage. Very informally, in our perspective, we assume that a sense (more or less large and constrained) of a lexeme has a basic form and basic expressions or usages (surface forms reflecting the basic sense). The basic sense originates derived usages, which are more or less constrained and limited, via metonymy, metaphor, slight sense-shiftings or co-composition (Pustejovsky, 1991, 1995). One of the difficulties is, given a set of usages, to partition them into semantically coherent sets, each set corresponding to a sense.

Sense delimitation is largely an open problem. It is

indeed almost impossible to state precise and general principles that characterize the boundaries of different senses of a lexeme and, finally, what a sense exactly is. The difficulty is then to elaborate a coherent system for sense delimitation and for characterizing sense and usage variations. Solutions have been proposed, which are not totally satisfactory. For example, WordNet (Fellbaum, 1997) tends to introduce one sense for each group of very closely related usages. For example, WordNet has 27 different senses for the verb *give*. Distinctions between senses are often very subtle and somewhat hard to represent in a semantic representation. This approach is very useful in the sense that it provides a very detailed description of the usages of a large number of words in English, but we think it lacks generalizations about language which are often useful for NLP systems to work efficiently. On the other side, are AI-based perspectives which tend to postulate a unique sense for a lexeme and very complex derivation procedures, involving complex logical systems, to produce different senses and possibly sub-senses.

The approach taken in WordNet is close to that taken by a number of paper dictionaries, where sense distinctions are very numerous and essentially based on usage. These distinctions are, in a large part, based on the semantic nature of the arguments. There are confusions between what we view as 'basic' senses and derived ones. Indeed, a number of situations that would be analyzed as metaphors or metonymies are identified as original senses. Consequently, dictionaries are certainly a very good tool to identify the different usages and senses of a lexeme, but they cannot be used directly in our framework. There are however a few very welcome exceptions such as the German-French Harrap's dictionary which has a very relevant and sound approach to multilinguism based on a conceptual analysis of language and of translation.

Our perspective is between these two 'extremes', lexicography and AI. We think that the different usages of a word should be organized around a small, relatively generic, number of senses. From these senses, generative procedures must produce or recognize derived usages. These procedures must obviously be sound, and must not over-generate (e.g. the rules claimed to be general in e.g. (Lakoff et ali. 99) must certainly not be taken for granted).

2.2 A few criteria for delimiting preposition senses

The identification of a preposition sense is essentially based on the observation of groups of usages. It is then confirmed by two criteria: (a) the nature and the stability within a certain semantic domain of the type of the head noun of the PP, that confirms the ontological basis of the sense and, concomitantly, (b) the restrictions required by the verb on the nature of the PP, if it is an argument. Dictionary definitions and multilingual considerations may also help. Pragmatic factors may also interfere, but this is outside the scope of this study (e.g. Busa 96).

Although prepositions have some idiosyncratic usages (probably much less in French than in English), most senses are relatively generic and can be characterized using relatively consensual and high-level ontology labels.

Let us consider the case of *par*[1]. The following 6 senses can be quite easily identified and characterized. They come from very diverse ontological domains but they seem to be all approximately at the same level of abstraction:

- proportion or distribution: *il gagne 1500 Euros par mois* (he earns 1500 Euros per month),
- causality: as in passives but also e.g. in *par mauvais temps, je ne ne sors pas* (by bad weather I don't go out),
- origin: *je le sais par des amis* (I know it from friends),
- via: *je passe par ce chemin* (I go via this path),
- tool or means: *je voyage par le train* (I travel by train),
- approximation of a value: *nous marchons par 3500m d'altitude* (we hike at an altitude of 3500m).

An important point is that uses with *par* do not necessarily cover all the conceptual field associated with each sense. For example, the expression of the idea of approximation using *par* is rather restricted to localization, speed or movement, not e.g. to amounts of money. One of the tasks is then to characterize, for each sense, what is the portion of the conceptual field which is covered. This is done via two means: (1) by a semantic characterization of the NP dominated by the preposition and (2) by the analysis of the restrictions imposed by the verb of the clause on the PP, or, conversely, by the type or family of the verb the preposition can be combined with, for that particular sense.

Let us now examine the basic restrictions for 3 senses of *par*. The 'VIA' sense is basically subcategorized by movement verbs; it is a path, subcategorizing for a noun of type 'way' or 'route' or, by a kind of metonymic extension, any object which can define a trajectory, e.g. an aperture (by the window). It has numerous metaphors in the psychological and epistemic

[1]This is obviously one possible characterization of the different meanings of *par* which is very much dependent on the theory of meaning one considers.

domains (e.g. *Il passe par des moments difficiles* (He experiences difficult moments)).

The 'ORIGIN' sense is more narrow, it is essentially used in conjunction with communication or epistemic verbs, the argument is usually of type place, and the head noun is of type 'human' *Il transite par Paris* (he commutes in Paris). We consider that nouns of type e.g. 'object with an informational content' introduce a metonymic extension, as in, e.g. *par la radio / la presse* (I know the news from the radio / the newspapers). Finally, note that there is a kind of continuum between Origin and Causality, as in: *I know she wears bracelets from the noise she makes when she moves*.

Finally, the 'TOOLS or MEANS' sense is used with verbs describing concrete actions (e.g. creation and movement verbs, if we refer to verb class systems (e.g. (Levin 93), (Fellbaum 93)). In general it is an adjunct. It is typed as a means, and the head noun of the PP must be e.g. a tool, or, more generally, an object that allows the action to be realized. This object could be found e.g. in the encyclopedic knowledge associated with the verb, or via a functional relation in a thesaurus. It has also numerous metaphoric extensions (e.g. *je traite ce phénomène par la logique temporelle* (I deal with this phenomena 'by' temporal logic)).

2.3 Some difficulties

However, there are many well-known difficulties inherent to the selectional restriction approach, where additional, non-trivial, world knowledge is required to make sense distinctions. Consider the usage:
'Dans followed by an NP of type location' (e.g. to be in a drawer).
Location is obviously too general a restriction (**to be in the shelf*). It is then necessary to enter into more complex descriptions, specifying that the location has a (salient) 'inside', that is not just a surface, etc. However, as far as only elementary spatial properties are concerned, this remains feasable.

More complex is the case of *boire dans un verre* (literally: drink in a glass). This example highlights the complex interactions between the verb and its PP. The preposition is part of the PP, not part of a verb complex form, this latter construction being quite unusual in French. The recipient is not neutral: while *verre, tasse, bol,...* are acceptable arguments, *bouteille, robinet* (bottle, faucet) are not, probably because of their narrow neck, which prevents the drinker from having his mouth in the recipient. This characterization becomes more complex and, probably, an interpretation for example in terms of Euclidean geometry could be necessary.

3 A preliminary semantic structure for French prepositions

3.1 A general classification

Here is an organization proposal of the different senses that French prepositions may have. Senses are organized on three levels:

1. a first level characterizes a **semantic family**, of a level roughly comparable to thematic roles: localization, manner, quantity, accompaniement, etc.,

2. a second level accounts for the different **facets** of the semantic family, e.g. source, destination, via, fixed position for the localization family,

3. a third level characterizes, roughly speaking, the **modalities of a facet** when appropriate. For example, the facet *manner and attitudes* is decomposed into 3 modalities: *basic manner, manner by comparison and manner with a reference point*. Due to space limitations, this latter level will not be developed in this document.

It is also important to note that each preposition sense is considered from the point of view of its basic usage and as the source of numerous metaphors. For example, origin is basically spatial, but has numerous metaphorical transpositions into the temporal, psychological and epistemic domains, to cite just a few generic cases.

Here is our classification, one or more examples follow to illustrate definitions, which cannot be given here in extenso due to space limitations:

- **Localization** with subsenses:
  - source,
  - destination,
  - via/passage,
  - fixed position.
  Destination may be decomposed into destination reached or not (possibly vague), but this is often contextual. From an ontological point of view, all of theses senses can, a priori, apply to spatial, temporal or to more abstract arguments.

- **Quantity** with subsenses:
  - **numerical or referencial quantity,**
  - frequency and iterativity,
  - proportion or ratio.
  Quantity can be either precise (*temperature is 5 degrees above 0*) or vague. Frequency and iterativity, e.g.: *he comes several times per week*.

- **Manner** with subsenses:
  - manners and attitudes,
  - means (instrument or abstract),

- imitation or analogy.
Imitation: *he walks like a robot; he behaves according to the law*,

- **Accompaniement** with subsenses:
  - adjunction,
  - simultaneity of events (co-events),
  - inclusion,
  - exclusion.
  Adjunction : *flat with terrace / steak with French fries / tea with milk*, Exclusion: *they all came except Paul*.

- **Choice and exchange** with subsenses:
  - exchange,
  - choice or alternative,
  - substitution.
  Substitution : *sign for your child*, Choice: *among all my friends, he is the funniest one*.

- **Causality** with subsenses :
  - cause,
  - goal or consequence,
  - intention.
  Cause: *the rock fell under the action of frost*.

- **Opposition** with two ontological distinctions: physical opposition and psychological or epistemic opposition. Opposition: *to act contrary to one's interests*.

- **Ordering** with subsenses:
  - priority,
  - subordination,
  - hierarchy,
  - ranking,
  - degree of importance.
  Ranking : *at school, she is ahead of me*.

- Minor groups:
  - About,
  - in spite of,
  - comparison.
  About: *a book concerning dinosaurs*.

Each of the facets described above is associated with a number of prepositions. Here is a brief description of the Ordering family, with its 2 subsequent levels:

Fig. 1 - prepositions of the Ordering family

facet	modality	preposition sense of
Priority	before after	avant après
Subordination	under above	sous sur
Hierarchy	under above	derrière, avant devant, après
Ranking	before after	devant derrière
Degree of importance	proximity comparison	à côté de, auprès de, par rapport à, pour, vis-à-vis de

3.2 Representing the meaning of preposition senses

Each sense is associated with a semantic representation, often largely underspecified. Lower levels in the hierarchy recieve a more precise representation, constructed in a monotonic way. Senses are described at two levels: (1) by means of a thematic grid characterizing the 'standard' function of each argument using the 21 thematic role system we have defined and, mainly (2) by means of the Lexical Conceptual Structure (LCS) (Jackendoff 90, 97), which seems to be sufficiently expressive for that purpose. Compared to the description in LCS of verbs, representing prepositions in LCS is rather straightforward and much more adequate.

A few principles guide this description: (1) the representation of generic senses (e.g. family level) subsumes the representation of their daughters, (2) different senses of a given preposition receive substancially different semantic representations, (3) metaphoric uses are characterized in part by semantic field substitution in the LCS, not by a different representation with different primitives, and (4) the number of primitives representing prepositions must be as limited as possible. These primitives are lower in the LCS primitive hierarchy than e.g. the GO, CAUSE or BE primitives.

Points 1 to 3 are studied formally in (Saint-Dizier and Vazquez 2000). To summarize, LCS representations are associated with (1) a typed-λ-calculus and (2) logical devices to represent and constrain underspecification (e.g. defaults, choices).

We have identified 68 primitives to cover all the senses we have defined. To give a flavor of their descriptive level, here are a few of them, definitions in English being quite informal:

Fig. 2 - a few LCS primitives for prepositions	
primitive	short definition
ABOUT	concerning, theme of verb
ABOVE	fixed position above something, no contact
ON	same as ABOVE but with contact
AS	manner via imitation
AT	fixed, precise localization no notion of container
CLOSE-TO	in neighbourhood, no contact
EXCEPT	exclusion
DURING	expression of a duration
END	fixed loc. at end of
INSTEAD	substitution, replacement
PER	reference, for a frequency
AROUND	area around another area
AMONG	selection in a set
CO	accompaniement, co-events
NEXT-TO	immediate proximity, possible contact adjacency
THROUGH	movement via a narrow passage
VIA	movement via an unconstrained area

These primitives are directly preposition names in the LCS meta-language, but they are not necessarily used directly for the corresponding preposition.

For example, 2 major senses of the preposition *avec* (with) (Mari 00) are:

- **accompaniement - simultaneity of events**, represented as:
  $\lambda I\ [_{manner}\ CO_{+loc}([_{thing}\ I\ ])]$,
  +loc indicates a physical accompaniement (*I go to the movies with Maria*), while +psy instead of +loc indicates a psychological accompaniement (*Maria investigated the problem with Joana*).

- **Manner - means - instrument**, represented as:
  $\lambda I\ [_{manner}\ BY-MEANS-OF([_{thing}\ I\ ])]$
  (*they opened the door with a knife*). This is, in fact, a generic representation for most prepositions introducing instruments (realized as: *à, à l'aide de, au moyen de, avec, par*).

Note that both senses are contrasted by different selectional restrictions on the NP, represented by the variable I.

More subtle is the representation of *contre* (approximately 'against'), for which we give the comprehensive representation of its 5 senses:

- A first sense describes a **physical object positioned against another one** (in the hierarchy above: localization - fixed position - spatial):
  $\lambda K\ [_{place}\ NEXT-TO_{+loc,c:+}([_{thing}\ K\ ])]$
  where NEXT-TO indicates a physical (+loc) proximity; contact is encoded by c:+ (Jackendoff 90) [2], between two objects, I and K, where I is against K. It is important to note that the idea of movement, if any (as in: *push the chair against the wall*), comes from the verb, not from the preposition.

- *Contre* is also used to express **opposition**: *to swim against the current* or, metaphorically in the epistemic or psychological domains: *to argue against a theory/ a practice*. The primitive OPPOSITE is used to capture the fundamental idea of antagonistic forces:
  $\lambda K\ [_{place}\ OPPOSITE_{+loc\vee+psy\vee+epist,c:-,ta:+}$
  $([_{thing}\ K\ ])]$.
  In that case, the physical contact is not relevant (c:-), while the agonist / antagonist force is present (noted ta:+, (Jackendoff 90), slightly simplified here).

- *Contre* can also be used to express notions like **provides a certain protection or defense** in the hierarchy 'causality - goal': *medecine for cought*. It is represented as follows:
  $\lambda\ X\ [_{event\vee state}\ FOR([_{event\vee thing}\ X\ ])]$

- The fourth sense captures the notion of **exchange** (in the hierarchy 'choice and exchange') : litt.: *I substitute my hors d'oeuvre against a desert*, representation is as follows:
  $\lambda\ X,\ \lambda\ Y\ [_{path}\ EXCH_{+poss}([_{thing\vee event}\ X\ ],$
  $[_{thing\vee event}\ Y\ ])]$.

- The last sense is related to the expression of the **ratio or proportion** (hierarchy 'quantity - proportion or ration): litt. *9 votes against 12*:
  $\lambda\ X\ [_{amount}\ AGAINST_{+quant}([_{amount}\ X\ ])]$.

As can be seen, representations are all substantially different. Substitutions on basic fields, in particular semantic fields, allow for the taking into account of numerous metaphorical uses within a sense.

4 Related work

The closest work to ours was developed about 6 years ago by Bonnie Dorr, it is accessible at: `http://www.umiacs.umd.edu/ b̃onnie/AZ-preps-English.lcs`. This is a very large database of preposition semantic representations, characterized by their LCS representation and, sometimes, by a thematic grid. There are about 500 entries (compared to our 170 entries), for probably all English prepositions. Although it is not easy to go into such a huge work dedicated to a different language and to make comparisons, we outline below some differences we feel have some importance.

Our perspective was first to organize preposition senses from usages, according to a certain theoretical view on what a sense is. The next goal was to

[2] In French, our analysis is that *contre* describes a position, not a path.

evaluate the results in order to confirm or invalidate our perspective. Then, came the semantic representations, with an analysis of the adequacy of the LCS system. We also took care of the complex interactions with verbs in order to identify as clearly as possible the semantic contribution of each element.

Each preposition sense in Bonnie Dorr's work receives a comprehensive semantic representation in LCS. Senses are paraphrased by an example, in a way close to synsets in WordNet. Some restrictions are added, and syntactic positions are made explicit.

Let us now compare some elements of these two systems. In our approach, we introduced disjunctions of semantic fields in order to account e.g. for metaphors. This limits the number of entries. For example, for *behind*, B. Dorr has 3 senses (locative, temporal and with movement) whereas we have just one with a disjunction for the 2 first cases.

We also tried to be compositional: in Bonnie Dorr's work, there is e.g. a primitive called AWAY-FROM, in addition to AWAY and FROM. We tend to consider that these two primitives can be combined compositionally and that the composite AWAY-FROM is not motivated.

Another difference is that we have considered a kind of 'minimal' semantics for prepositions, without considering potential combinations with verbs. As a result, in B. Door there is for *against* e.g. a sense describing a fixed position and another one describing a movement where the moved object reaches a position against another object. For this latter case, we think that the movement is only in the semantics of the verb and is compositionally induced at the level of the proposition. Same remark for most prepositions expressing positions (north, west, inside, etc.). We have only one representation for the fixed position.

Finally, depending on the fact that the source is given or not, *into* is represented by a combination of TOWARD(IN) or TO(IN). We do not see any reason for this distinction and think that origin and destination should be treated apart.

These relatively minor differences indicate that, probably, Bonnie Dorr had a more 'lexicographic' view than we had in the sense descriptions. One of her motivations was to efficiently use her work in a machine translation system, where senses need to be relatively narrow and explicit to allow e.g. for a simpler multi-lingual treatment of prepositions.

5 Evaluation

Let us now evaluate the accuracy of our sense distinctions. For that purpose, we considered 6 among the most frequent and polysemic prepositions, which also undergo a large number of metaphors. Two independent native speakers of French, with some light knowledge of linguistics, have been given a large sample with those prepositions and have been asked to classify them into one of the senses we have established. They recieved a minimal explanation of the task in order not to influence their judgments.

Preposition occurences have been extracted from the French *Encyclopedia Universalis*, a huge encyclopedia that covers most of the domains, written by a large number of authors.

5.1 Preposition distribution in French

Before making any evaluation, let us say a few words about preposition distribution in French. We have collected 14656 preposition usages which are are distributed as follows:

Fig. 3 - Preposition frequencies

preposition	occurences	frequency (%)
DE, DES, D', DU	8338	57
A, AU, AUX	1649	11.2
EN	856	5.8
POUR	719	4.9
SUR	704	4.8
DANS	462	3.1
PAR	413	2.8
AVEC	280	1.9
ENTRE	85	0.57
VERS	67	0.46
SOUS	66	0.45
CONTRE	62	0.44

The other prepositions occur less than 50 times, and in general less than 10 times. If we do not take into account DE and A and their morphological variants, frequencies need to be multiplied by 3.14 (no relation with the number π, though). The observation is that 16 prepositions occur more than 1%. They are not necessarily the most polysemic ones (e.g. *entre* is not very polysemic).

We have concentrated our evaluation on the other prepositions, which cover about 1/3 of the preposition uses. They are of much interest since they often introduce adjuncts, while *de* and *à* often introduce prepositional arguments of verbs or of predicative nouns. Prepositions introducing adjuncts are of much interest since they are the main linguistic marks that define the role of the NP w.r.t. to a predicate.

5.2 Evaluation of our sense distinctions

Let us now proceed to a preliminary evaluation of our sense distinctions. In order to have a more diverse sample for the 6 prepositions considered in our evaluation, we have considered additional texts from the encyclopedia (about 1200 pages) and texts from other sources (PhDs dissertations, newspapers). W.r.t. prepositions uses found in the corpus, we have defined three types of behaviors: (1) the classification into one of the senses we have elaborated is straightforward, (2) the classification is possible but not immediate:

for example some pragmatic considerations must be considered or there is a metaphorical or metonymic construction to identify, and (3) classification is not possible at all. This latter case includes, among others, collocations. We get the following preliminary results, where (1), (2) and (3), expressed in %, refer to the 3 criteria above:

Fig. 4 - Evaluation of sense distinctions

prep.	*contre*	*vers*	*dans*	*pour*	*sous*	*sur*
nb occ.	569	541	1890	2716	794	1439
(1)	61.4	72.6	66.7	86	93.1	75.1
(2)	38.6	27.4	33	11.6	3.9	22.4
(3)	0	0	0.3	2.4	3	2.5
nb of senses	5	3	2	8	4	6
sense distributions (%)	7.7 65 13 1.3	45.2 46.9 0.9 -	98.4 1.4 - -	14.9 65.2 4.6 4.2	29.3 29.3 10 31.2	73.8 73.8 1.3 2.4

Situation (2) occurs only with senses having by far a high number of uses (above 30%, but often more). There are several reasons to this observation: those senses are in general quite large, with a lot of extensions, metaphors, pragmatic implications and interactions. They often exhibit a large number of uses with abstract NPs. Finally, these senses are perhaps not sufficiently accurately defined.

Uses that do not fall into any of the senses (case (3)) are often fixed or semi-fixed forms or uses with a heavy pragmatic influence. Semi-fixed forms are, e.g. *sous le nom de* (under the name of) or *sur le plan de*, which are forms we have not included into our descriptions. Pragmatic factors are, for example: *Pierre a caché son livre sous son blouson*, where *sous* (=under his jacket) means *dans* (=in). Same for *La guerre avec l'Allemagne* (the war with Germany), where *avec* characterizes an opposition (*contre* (against) is more usual), due to the semantics of *war*, a use that needs some interpretation (there are a few such situations with aggression verbs, where semantic composition is necessary to get the meaning of the expression).

Finally, another test for sense distinctions we are carrying out is the coordination test where two different senses of a preposition should not, a priori, be coordinated: * *Un médicament contre la toux et contre l'avis du médecin*.

6 Conclusion

In this document, we have shown some elements of a method to identify, in a generative perspective, the behavior of prepositions in mono- and multi-lingual contexts. We have initialized a discussion on the delimitation of senses, from observed uses, and have proposed a semantic representation for each of them based on the LCS.

From the examples given in here, we can see that some regularities can be quite easily captured and dealt with by means of relatively simple tools, whereas a number of complex cases need much more attention and solutions seem to require a pragmatic interpretation, or long enumerations of specific realizations.

Besides the obvious need of several steps of evaluation, we now have in mind to develop a form a lexical tuning to enrich the semantic characterization of preposition senses, at three levels: selectional restrictions or constraints identifying senses, preferences among senses (some are much more prominent or prototypical than others) and refining the LCS representation to accommodate different forms of e.g. metaphors and metonymies.

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