A Typology and Discourse Semantics for Motion Verbs and Spatial PPs in French

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Abstract

In this paper we offer a semantic study of motion verbs and motion verb complexes determined by motion verbs and spatial prepositional phrase adjuncts. We propose a classification of motion verbs and of motion verb complexes. Unlike other semantic or syntactic studies, we build up the spatiotemporal semantic properties of motion verb complexes compositionally, on the basis of its semantic properties, the verbs and their arguments and adjuncts. We show how to combine this lexical information with discourse information to determine the spatiotemporal structure of texts and to help with lexical disambiguation.

1 Introduction

In this paper we offer a semantic study of motion verbs and motion verb complexes determined by motion verbs and spatial prepositional phrase adjuncts. We propose a classification of motion verbs and of motion verb complexes. Unlike other semantic or syntactic studies, we build up the spatiotemporal
semantic properties of motion verb complexes compositionally, on the basis of its semantic properties, the verbs and their arguments and adjuncts.

Motion verbs convey much more than just a simple and strict spatiotemporal description of motion activities (as we will see shortly). The immense richness of motion verbs is probably at the origin of the difficulties encountered by all those (including us) who have attempted to study them.

The organisation of this paper is as follows:

We first set out in Section 2 an ontology of eventualities and spatiotemporal extensions, which furnishes a philosophical background against which to analyze motion describing expressions.

Then, in Section 3 we present the typology for motion verbs in French. We have considered motion verbs without any adjuncts, in their atemporal form and out of any imaginable context in order to extract their, and only their, intrinsic semantics. To be sure even this requires certain ontological assumptions about processes, objects, boundaries and the like. We detail these in Section 2. We have also complemented our purely linguistic justifications for this typology with some considerations that stem from compositional preoccupations; the verb classes of our typology are organized according to a certain class of semantic properties so that we can monotonically specify possible (and linguistically accepted) paths of transition from one class to another when we add to the verb, for example, a given PP adjuncts. Further, in this way, motion complexes can be classified using the same classes as for motion verbs. We give rules of combination by means of which we can derive the properties and classification of a motion verb complex from the properties of the verb and its PP adjuncts. So we distinguish motion verbs and motion complexes. But since both levels use the same kind of classification, the transition to one (the motion verb level) to another (the motion complex level) is clearly and logically defined (unlike some other semantic studies to be discussed in Section 5).

In Section 4 we consider in greater detail one of the classes found in Section 3.3, namely the class of verbs of change of location. We refine this class with more precise spatial criteria. This allows us, in Section 4.5, to give compositional rules for those motion verbs and the spatial prepositional phrases they can be combined with. With these rules, we then obtain a classification of motion verb complexes. This spatiotemporal knowledge about motion verb complexes can then be used in the understanding processes of the spatiotemporal structure of texts, cf. Section 4.7.
In Section 5 we present and discuss the main ways people have tackled the difficult problem of the study of motion verbs / motion verb complexes, and propose a general comparative table of all these works including ours.

Finally, we give in Section 6 some evidence in favor of our typology and how it has been used for several other detailed investigations on motion.

Our typology is based on two principles.

- motion verbs have in themselves an intrinsic spatial and temporal semantics;
- the spatial and temporal semantics of a motion verb complex is a specifiable function of the spatial and temporal semantics of each component used in this complex (for example, Laur [Lau91] has studied the combination of displacement verbs and spatial prepositions in French).

We can quickly illustrate these two points with the following examples:

1. (a) entrer
   
   \textit{to go in}

   (b) sortir
   
   \textit{to go out}

   (c) s’approcher
   
   \textit{to approach}

2. (a) sortir du jardin
   
   \textit{to go out of the garden}

   (b) sortir par le jardin
   
   \textit{to go out by the garden}

   (c) sortir dans le jardin
   
   \textit{to go out into the garden}

   (d) s’iloigner dans la rue
   
   \textit{to go away on the street}
The first point is exemplified by comparing verbs like those in (1a) and (1b) or in (1a) and (1c). Verbs like (1a) require the moving entity to be outside some location before the process and inside after. In contrast, verbs like (1b) require the moving entity to be inside some location before the process begins and is outside after the process ends. Verbs like (1c) require the moving entity to be outside both before and after the process; but they also require that the position after the process has to be closer to the reference location than the position before the process.

The second point can be illustrated by contrasting the complexes given in (2a), (2b) and (2c). In these three examples, the same motion verb sortir and the same location le jardin is used. These complexes differ only in the preposition used to link the location in the PP to the motion verb. In (2a), the complex requires that the moving entity is inside the garden before the process and outside after; in (2b), the complex requires that the moving entity is inside some location before the process, outside it (i.e. inside another location) after the process, and that it must pass through the garden during its moving process; in (2c), the complex requires that the moving entity is inside some location, which is not the garden, before the process and inside the garden after it.

In (2a), (2b) and (2c), we have in fact changed just one component of the complex and we have seen that the resulting meaning has completely changed. But all the components can also change. Compare for example (2a) and (2d). We need to be able to calculate the meanings of such complexes in a rule-governed way.

Motion verbs and motion verb complexes are two different things that should not be indiscriminately mixed together in a typology. But if we consider them separately, we of course need something to connect them — they are obviously related. This is the aim of the compositional rules which compute of the semantics of a complex from the one of each component. The computation of the spatiotemporal properties of motion complexes is similar to the calculation of aspect, which has been studied in [Ver72], [Smi91], [Kri87].
2 Eventualities and SpatioTemporal Extensions

We are interested here in a typology of motion as it is expressed in natural language. Motion is a property of objects (i.e., objects move), but motions themselves are a type of event. Motions are changes of some sort of spatial position over time.

To explore motion, we must first make clear our ontological assumptions concerning eventualities and spatiotemporal extensions. Eventualities are concrete but complex objects. They may have both objects as constituents and also other eventualities. Every concrete entity, we suppose with Vieu [Vie91], has a spatiotemporal trajectory, which we will denote with the aid of a function $STref$. $STref(x)$ is the spatiotemporal extent of $x$. In DR-theoretic terms (Discourse Representation Theory or DRT of [Kam79]), $STref(x)$ is a new discourse entity designating the trajectory described by $x$ all along its “life”. $STref$ may be additionally parametrized with the aid of a temporal variable: $STref(x,e)$ (or $STref(x,t)$) denotes the “temporal slice” of $STref(x)$ whose time matches the time of the event $e$ (or the time $t$), if $e$ (or $t$) is temporally included in $STref(x)$; otherwise it is not defined. Spatiotemporal relations between these referents, such as inclusion ($P(x,y)$), overlap ($O(x,y)$) or contact ($EC(x,y)$) are axiomatized in a theory of space-time, derived from Clarke’s calculus of individuals ([Cla81] and [Cla85]), and which is based on mereology (Lesniewski, [Les27-31]). This theory, fully presented in [Aur91] and [Vie91], is used in [AV93] for representing the geometrical aspects of the lexical semantics of static relations such as $jtre$ dans to be in, $jtre$ sur to be on, $jtre$ devant to be in front of, and internal localization nouns such as le haut the top, le dessus the top surface, le coin the corner … It also can be used to encode various facts about the geometrical and topological properties of objects and processes or, rather, their $STref$ projections (cf. [Vie91]). We will suppose for simplicity that objects of the sort $STref(x)$ obey the laws of $\mathbb{R}^4$ and have a regular, metric topology.

We further suppose that all eventualities have a beginning or source, an end or goal, and a middle or path. Thus we will define Source($e$) as a “location” whose spatiotemporal referent contains or is in contact with $STref(e,Init(e))$, and similarly for Goal($e$). Finally, Path($e$) will be a set of sequences of “locations” $l_i$. A path is a set of sequences because we need
to allow for descriptions at different granularities, and this is necessary to handle the discourse relation Elaboration correctly. For each sequence of locations \( l_1, \ldots, l_n \searrow \) we have \( P(STref(e), \Sigma_i STref(l_i)) \), and for each \( i \), \( EC(STref(l_i), STref(l_{i+1})) \), i.e., adjacent locations in the sequence are externally connected. Source(e) and Goal(e) are not sets of “locations”, however. They are often lexicalized, thus uniquely identified within the discourse by a particular discourse referent introduced by the noun phrase; in other cases they are anaphorically identified, and in the remaining cases their existence is assumed through the introduction of discourse referents. As a consequence, we do not have (1) but only (2) and (3) since we should allow for refinements of the path within Source(e) or Goal(e).

\[ \forall x \in Path(e), x = \prec Source(e), \ldots, Goal(e) \succ \quad (1) \]

\[ \exists x \in Path(e), x = \prec Source(e), \ldots, Goal(e) \succ \quad (2) \]

\[ \forall x \in Path(e), (x = \prec l_1, \ldots, l_n \succ \Rightarrow (O(STref(l_1), STref(Source(e)))) \land \\
    O(STref(l_n), STref(Goal(e)))) \) \quad (3) \]

Our study also requires us to make explicit our assumptions concerning the semantics of motion expressions. We will follow roughly the approach of Davidson 1969 (an approach which is also used in DRT), on which eventualities, along with other objects, satisfy predicates derived from natural language verbs. In DR-theoretic terms eventuality discourse referents will be arguments to conditions introduced by the verbs, and in fact the eventuality discourse referents themselves are introduced by the inflection node in the syntactic tree. Such eventuality discourse referents also are arguments to various adverbial phrases, and in particular, spatial prepositional phrases. One of our tasks in this paper is to classify the various eventuality discourse referents that might be understood as representing movements and to determine those inferences that allow us to specify the spatiotemporal position of the eventuality as a whole or of its parts or actors with respect to various reference locations given in a text. In this paper we will present both a typology and rules for drawing inferences about the locational structure. Our ultimate aim is to use this lexical research to drive discourse reasoning.
about spatiotemporal structure (see for instance [Ash-al93]). But our task here is to make clear what inferences the lexical content of the verbal predicate on an eventuality along with the other modifiers allows. Further, we will restrict this study to verb complexes and ignore verbal nominalisation and adjectival phrases, among others. To simplify matters we will consider only transitive motion verbs and verb complexes with only one PP adjunct, though our theory straightforwardly extends to arbitrary spatial PP adjuncts as long as these are of different types of the sort that we will define below. We postpone the treatment of multiple spatial PPs of the same type in a single verbal complex for a future occasion.

3 The Typology

3.1 What are Locations?

One concept that plays an important role in a typology of motion is the concept of “location”. Despite first impressions, it not easy to give a definition of location. Boons [Boo85] and Laur [Lau91] used the concept in a rough and ready way, without any analysis. But this led to difficulties, especially at the level of inferences, where we need to specify the spatiotemporal position of one eventuality with respect to some reference location. Boons and Laur define their displacement verbs as "verbs absolutely requiring a change of location of a body, which suffers no modification of its shape nor of its substance during the process" [Boo85]. This definition is imprecise due to the non-specified nature of their concept of “location”, and it leads them to conflate verbs such as entrer to get in and courir to run, for example. Let us compare (3) and (4).

3. Demain j’entrerai ‘ la cuisine, sous un pretexte quelconque (Martin du Gard)

    Tomorrow, I will enter the kitchen under some pretext

4. Les joueurs courent sur le terrain de football

    The players run on the football field

5. Le gardien de but s’appuie contre le montant de ses buts
The goalkeeper leans against his goalpost

Both *entrer* in (3) and *courir* in (4) are displacement verbs (in the terms of Boons [Boo85] and Laur [Lau91]). Both imply a change of “location” in their sense of the moving entity(ies). The PPs in (3) and (4) give us a “location” : *la cuisine the kitchen*, and *le terrain de football the football ground*, respectively. Knowing that in both sentences there is a change of “location”, they would infer that in (3) there is a change of location with respect to *la cuisine*, what is absolutely true, and that in (4) there is a change of location with respect to *le terrain de football*, which is definitely false.

Indeed, in (3), the author is located, before the process, outside *the kitchen*, and will be located, after the process, inside *the kitchen*; there truly is a change of “location”. We can naturally talk about a change of location here\(^1\).

But in (4), the players were located, before the process, on *the football field*, and will still be located, after the process, on *the football field*. However, if we are in the context of a football game, they have surely passed several times from one sub-part of *the football field* to another, even if they always stay on *the football field*. So there truly are some changes of spatial properties. Compare for example (5). In the case of (4), we will speak not of change of location but of *change of position*\(^2\) and consider the *football field* as a **background location**. In the case of (5), we will speak of a *change of posture*\(^3\). Although it is probably possible to continue to refine the granularity of analysis and look at ever finer detailed movements, our study stops with changes of posture. The study of motion takes place always relative to objects that move, and for practically all purposes of which we can conceive, change of posture of an object of the right sort of granularity suffices to capture the nature of movement as expressed in natural language. Additionally, we suspect that further refinements of motion will lead to a disintegration of the concept — we will end up with a Heraclitean universe in which παντα ρη.

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\(^1\)To be more precise, we should talk about a change of relation between the whole moving entity and the location.

\(^2\)To be more precise, we should talk about a change of relation between the position defined by the moving entity and some referential fixed part of the background location (such as some particular or not border of it).

\(^3\)To be more precise, we should talk about a change of relation between some part of the moving entity and the location.
In the next section we analyze the concepts of location, position and posture more fully.

3.2 Locations, Positions and Postures

In this section we analyze the concepts of location, position, and posture more fully. But in order to do so, something has to be said concerning the relations between the locations, positions and postures and what is introduced by the PP in the sentence.

In the case of a complex which exemplifies a change of location, like in (3), what is introduced by the PP is definitely a location. This location can, as Laur [Lau91] has shown, have an initial polarity (ie. be considered as the Source(e)) or a final polarity (ie. be considered as the Goal(e)).

In the case of a change of position, what is introduced by the PP is a location too. This location is such that the process takes place inside it; it can be conceived, as we said earlier, as a background location. In such cases, as the name indicates, there is no change of location (the moving entity stays during the whole process inside this location), but rather a change of position. This position (cf. Definition 2 below) cannot be lexicalized and indeed cannot be expressed at all except with the help of deictic devices. Consequently, the PP always introduces a background location with such verbs. The positions referred to when we talk about change of position are generally either conceptualized by the hearer/reader of the sentence as spatial sub-parts of the background location, and what is important is just to know that the moving entity does not stays the whole process inside the same sub-part, either derived from contextual or world knowledge (directly from the world, or the previous discourse, or from both).

In the case of a change of posture, what is introduced by the PP is here again a location. In such cases, as the name indicates, there is no change of location nor position (the moving entity stays during the whole process within this location and at the same position), but rather a change of posture. The process then consists in realizing a special, physical relation between one or more parts of the moving entity and the location introduced by the PP. For example, in (6), it consists in realizing a physical contact between the knees and the bench; in (7) it consists of passing the head and

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4 The relevant parts of the moving entity which are concerned by the relation are not
the shoulders through the window.

6. S’agenouiller sur le banc

To kneel down on the bench

7. Se pencher par la fenêtre

To lean out of the window

In all cases, PPs used in combination with motion verbs always introduce a location.

We now propose the following analyses for our concepts of location (cf. Definition 1), position (cf. Definition 2) and posture (cf. Definition 3).

Definition 1 A location is analyzed as a portion of space which can be “designed” in natural language, and to which is associated a functionality. Locations are generally lexicalized by means of a real lexical item (e.g. la cuisine the kitchen in (3)) or a construction using a preposition and a real lexical item (e.g. derrière la maison behind the house). They can also be expressed with deictic constructions like here or where John was 5 minutes ago.

Definition 2 A position is analyzed as a portion of surface, without any functionality nor real lexical item associated, and only geometrically defined by the pragmatic shape (cf. Definition 4) associated with a given entity. A position thus is necessarily dependent on the entity used for its definition.

Definition 3 A posture is analyzed as a special way to be inside one’s pragmatic shape, with which is associated a certain functionality (cf. Definition 4). Postures are always postures of an entity and they are defined directly expressed in the sentence but they can generally be inferred from lexical informations derived from the motion verb.

5In our French terminology: un lieu.

6This portion of space can be a bit of ground, such as in the square or in the lawn, or the space occupied and defined by an object, the inside of which is a cavity, such as in the house, or not, such as in the bench.

7In our French terminology: un emplacement.

8They can only be lexicalized with deictic constructions like here, this position, the position Mary occupies now, ...

9In our French terminology: une posture.
by the relations between the parts of that entity. Postures are lexicalized by participial forms of verbs of changes of posture — e.g., assis sitting down or by adjectives like debout standing up.

**Definition 4** By pragmatic shape we mean the 3-D portion of space fully occupied by the entity, plus that space that would be occupied by the entity if it were to undergo a change of posture $\pi$, where $\pi$ is constrained such that if $\pi$ occurs from $t$ to $t'$ and posture($x, t$) = posture($x, t'$), then STref($x, t$) is at least roughly the same as STref($x, t'$).

We are now able to precisely define the generic concepts of Source, Goal and Path given in Section 2, with each of our location, position and posture. Source($e$), Init-position($e$) and Init-posture($e$) are a location, position and posture, respectively, whose spatiotemporal referent contains or is in contact with STref($e, \text{Init}(e)$); we define Goal($e$), Final-position($e$) and Final-posture($e$) analogously. Finally, Path($e$) will be a set of sequences of locations and Path-position($e$) and Path-posture($e$) will be a sequence of positions and postures, respectively.

### 3.3 The Four Subclasses of Motion Verbs

With the definitions of location, position and posture given in Section 3.2, we can now talk about class of motion verbs of change of location, of change of position and of change of posture.

But let us have a closer look at the verbs of change of position. Compare for example (4), that we give below again as (8), and (9). Compare also (10) and (11). Some of these verbs (like courir to run, danser to dance, voler to fly, ...) can be combined with sur place in place. Others (like se déplacer to move around, circuler to circulate, descendre to go down, s’îlever to go up, ...) cannot.

This shows that the latter always imply a change of position, while the former only suggest it. The latter class (e.g., se déplacer to move around) will keep the name of verbs of change of position. We will call verbs like courir to run verbs of inertial change of position.

We also distinguish verbs of inertial change of position from verbs of change of posture. Verbs of inertial change of position can describe a change of position (8), although they are not forced to (9). Nevertheless,
where they do, the change of location concerns the entity in its entirety. On the contrary, verbs of change of posture usually, as their name suggests, describe a change of posture (12). They can also describe some kind of change of position, but in this case, the change always concerns only parts of the entity (13). It never concerns the whole entity. Otherwise this would imply that (13) should have a meaning like the one of (14)!

8. Les joueurs courent sur le terrain de football
   *The players run on the football field*

9. A Los Angeles, la plupart des jogueurs courent sur place
   *In LA, most of the joggers run in place*

10. Pauline se déplace en bus au centre ville
    *Pauline takes the bus in the center of the city*

11. * Pauline se déplace en bus sur place
    * Pauline moves with the bus in place around

12. Gaby se penche pour caresser son chien
    *Gaby leans over to caress her dog*

13. Gaby se penche par la fenêtre
    *Gaby leans out of the window*

14. Gaby passe par / tombe de la fenêtre
    *Gaby passes through / falls out of the window*

We thus arrive at four classes of motion verbs. We name the classes below and give both a discursive and a logical definition (Definitions 5.1 to 8.1, and 5.2 to 8.2) for each of these classes.

To give our axioms, we need a formal language. We have already made use of a predicate calculus language for describing our spatiotemporal relations. First we extend this language with a conditional operator $\triangleright$, where
A > B means “if A then normally B” and represents a defeasible or generic rule. The semantics of this language is given in [AM91] and allows us to encode defaults about lexical entries. We will shortly be reasoning about the types and properties of eventualities that verbs and verb complexes introduce within our semantic representations. As we intend ultimately to talk of discourse structure using the framework of Asher [Ash93], our semantic representations for clauses will be DRSs and hence the representational elements that verbs will introduce will be predicative DRSs with abstractions over discourse referents. The types of eventualities that we shall discuss are in fact types of discourse referents. Predicative DRSs are functions from tuples of discourse referents of the appropriate type to conditions in a DRS. Our axioms will then apply these predicative DRSs to a sequence of discourse referents of particular types that occur as arguments to such verbs and spell out the consequences in terms of spatiotemporal conditions on those discourse referents. We will also generalize on the types of conditions; thus, we will have axioms that apply conditions of a certain type derived from those verbs and prepositions. These axioms should then be understood as rules for expanding a representational structure, similarly to the approach taken by Kamp and Rossdeutscher in a number of papers (see e.g. [KR92]). We will assume the existence of certain functional dependencies between eventualities and other discourse entities, e.g. Source(e), Path(e), Goal(e), Cible(e) — the moving entity — and Lref(e). We will forego the box notation of DRT, since for us nothing hangs on it at the level of the spatiotemporal information we address here\(^\text{10}\). We give below the properties for each group of verb.

**Definition 5** *Verbs of change of location*

1. A *verb of change of location*, entails that the moving entity changes location during the process.

   \(\text{ex: } \text{entrer to enter, arriver to arrive, atterrir to land, s'approcher to approach . . .}\)

\(^{10}\)This is of course no longer the case once we begin to look at more complex discourses with quantification and negation; there the structure of the DRS representations becomes very important for the analysis of anaphora, on which our work on spatiotemporal structure in discourse depends.
2. change−of−location(e) → Path(e) \neq \{ \prec Source(e) \succ \}

Definition 6  Verbs of change of position

1. A verb of change of position entails that the moving entity changes position during the process.

   \textit{ex:} se diplacer to move around, circuler to circulate, descendre to go down, s’ilever to go up . . .

2. change−of−position(e) → Path\_position(e) \neq \prec Init\_position(e) \succ

One may also wish to require that for changes of position, the moving entity at least by default stays in the same location during the whole process, but we will not do this here. So it is possible that a change of position is also a change of location.

Definition 7  Verbs of inertial change of position

1. By default a verb of inertial change of position implies a change of position for the moving entity.

   \textit{ex:} courir to run, danser to danse, voler to fly . . .

2. inertial−change−of−position(e) > Path\_position(e) \neq \prec Init\_position(e) \succ

Definition 8  Verbs of change of posture

1. Verbs of change of posture entails that the moving entity stays in the same location and at the same position during the whole process, but also changes of posture during the process
ex: se pencher to lean over/towards/forward/back, s’asseoir to sit down, se baisser to bend down . . .

2. \(\text{change-of-posture}(e) \rightarrow \text{Path}_{\text{posture}}(e) \neq \prec \text{Init}_{\text{posture}}(e) \succ\)
\(\text{change-of-posture}(e) \rightarrow \text{Path}_{\text{position}}(e) = \prec \text{Init}_{\text{position}}(e) \succ\)

Note that change of posture is not any change of posture, but just those that are expressed by certain verbs. Changes of posture in our sense, those that are expressed by verbs in French (and we suppose for other languages too), do not allow for changes of position — and, hence, changes of location.

### 3.4 Embedding Classes

To each subclass of motion verb defined in Section 3.3 are attached truth conditional properties expressed in our formal language. These properties reflect the minimal intrinsic core meaning common to all the verbs belonging to a given class. The three first subclasses are not exclusive; they in fact are embedded one in another in the order of their presentation. In other words, the spatial properties of the minimal core meaning of verbs of change of location are more constrained than those of verbs of change of position, which, in their turn, are more constrained than those of verbs of inertial change of position.

Indeed, one cannot change location if one does not change position during the process of changing of location; and one cannot change position if one does not inertially change position during the process.

Our taxonomy allows for a monotonic calculation of constraints for a verb complex. That is, the combination of a verb and its PP or other arguments (direct object, for example) can only add to the spatiotemporal properties that affect the Source, Goal and Path of the targets’ posture, position or location. There is an evident advantage in doing this. Non-monotonic constraint propagation would require us to assume the existence of something like an intensional operator that might block the truth conditional content of the verb itself — in the sense that \(\text{Believe}(\phi)\) fails to entail \(\phi\) — or to rephrase all our constraints at the default level. The latter makes lexical semantics very complex (for a discussion see [LA93], and we do not see our
way through. The former seems semantically unmotivated. With monotonic constraint propagation, we need resort to neither alternative\textsuperscript{11}.

Take, as an illustration, the following verbs *courir* to run, *voyager* to travel and *entrer* to enter, which are verb of inertial change of position, of change of position and of change of location, respectively.

The composition of *to run* with some other element can either result in a complex having the same constraints (such as in (15)), or more constraints (such as in (16)), or even more constraints (such as in (17)).

In the case of the verb *to travel*, the compositionality can either result in a complex having the same constraints on the movements of the moving entity (such as in (18)), or more constraints (such as in (19)), but never fewer constraints (as (20) shows).

In the case of the verb *to enter*, which already belongs to the class placing the most constraints on the movement of the moving entity (of the three classes considered here), only a complex having the same constraints can result from any compositionality (cf. for example (21)).

15. Courir sur place

*To run in place*

16. Courir autour du stade

*To run round the stadium*

17. Courir vers la maison

*To run towards the house*

18. Voyager en Europe

*To travel inside Europe*

\textsuperscript{11}This classification though developed principally with an eye to preserving monotonic constraint propagation nevertheless also has a linguistic basis. Work in progress at Toulouse, realized by Laure Sarda, shows that this distinction is also triggered by syntactical grounds. Indeed, transitive French motion verbs, having a medial polarity, belong only to the class of verbs of change of position, while intransitive French motion verbs, also having a medial polarity, cover both the classes of verbs of change of position and of inertial change of position.
19. Voyager de Toulouse à Austin, Texas

To travel from Toulouse to Austin, Texas

20. * Voyager sur place

* To travel in place

21. Entrer dans une maison

To enter a house

22. S’asseoir sur une chaise

To sit on a chair

23. S’asseoir par terre

To sit down

The composition of verbs of change of posture with any other element (cf. (22) and (23)) will always result in a complex having the same constraints as the one of the verb.

If one does not change position or posture during the process described by a verb or verbal complex, then this “process” can only be a static one.

4 From Lexical Semantics to Discourse Understanding

4.1 The Verbs of Change of Location

In this Section 4, we focus on verbs of change of location and ignore the three other groups we have defined in Section 3.3. Verbs of change of location are propitious to a detailed analysis of how the space is organized in and around the location with respect to which the displacement take sense. They describe displacement going from outside this location to the inside of it, or the reverse displacement. Nevertheless, a coarse organization of the space in only two “zones”, the interior and the exterior of the location, quickly proves its insufficiency. Compare for example (24) with (25) and (26) with (27).
24. Abby est sortie de la maison

   *Abby has gone out of the house*

25. Abby est partie de la maison

   *Abby has gone away from the house*

26. L'avion a atterri sur la piste 4

   *The plane has touched down on runway 4*

27. L'avion s'est approchi de la piste 4

   *The plane has approached runway 4*

In both (24) and (25), *Abby* has gone from the inside of the *house* to the outside of it. But if *sortir* in (24) only describes this displacement, *partir* in (25) forces *Abby* to continue her displacement till she is away from the house, at a sufficient distance. Under a certain critical distance, the verb *partir* could not be used. For example, if *Abby* took two minutes to talk in the garden with her neighbour Peggy, and if someone asked Al, who is inside the house, ""Abby est-elle partie ?" "Has Abby gone away?", Al will surely answer no if he can hear her talking or see her through a window.

This critical distance is a function of many parameters, like, for example, the size of the moving entity and of the location, but also the presence and the size of other referents (locations and/or objects) in the scene, the perceptual (visual, auditory, ...) capabilities in the case of human beings, and other elements of the context. The critical distance will be different if we know that *Abby* intends to go away by foot or by car, for example. It is very difficult to circumscribe and almost impossible to compute precisely this critical distance. We believe that these contextual factors must be handled non-monotonically. But we shall do no more here than assume that there is some contextually given and pragmatically constrained minimal distance.

With (26) and (27), the *plane* stays during its whole motion, outside the location which here is the *runway 4*. Nevertheless, the displacement is not the same in the two sentences. In (26), the *plane* touches down and thus finally comes in contact with the *runway*, whereas in (27) it comes near the *runway* but without touching it.
In order to be able to take into account and to represent formally these differences, we propose seven relations (cf. Section 4.2). We talk about (spatial / spatiotemporal) relations and not about (spatial / spatiotemporal) zones here for the following reason. Consider for example our plane and our runway of the sentences 26 and 27. If we want to define a zone of contact between the plane and the runway, we have to construct this zone as the union of all the spatial positions the plane can occupy so long as it is, in one or another way, in contact with the runway. This will result in a zone which height is equal to the greater dimension of the plane (generally from the nose to the rear, if we imagine the plane in a vertical position in contact with the runway by its nose). It is then easy to place in such a zone the plane in its canonical position at, let’s say one meter up from the ground. So, the plane is inside the zone of contact but definitely not in a relation of contact with the runway.

In conclusion, it would be false to say that the plane is in contact with the runway just because it belongs to the zone of contact. Belonging to the zone of contact is a necessary but not a sufficient condition to be in contact.

4.2 Seven Spatial Relations

We introduce our relations discursively (Definitions 9.1 to 15.1) and offer a formal definition (Definitions 9.2 to 15.2). In the logical formulation,

12We thank Laure Vieu for this example.

13We use the following mereological and topological relations in our definitions :
- PP(x,y) : x is a proper part of y
- EC(x,y) : x is externally connected to y
- f-int(y,x) : return the functional interior of y with respect to x
- f-ext(y,x) : return the functional exterior of y with respect to x
- weak-contact(x,y) : x is in “natural contact” with y
- prox(y,x,C) : relation deciding if x is “in proximity” of y. This kind of decision needs informations about the context (C). Under the name “context” we group here together things like what we know from the discourse, from the world knowledge, about the nature of x and y and about the presence of other individuals around. In the following of this paper, we will not write this third argument C in order to simplify the notations.
make use of the mereology of Lesniewski [Les27-31], formalized by Clarke ([Cla81] and [Cla85]). In [AV93], the reader can find an extension of the Mereology and an application for the formal representation of the semantics of space and space-time in natural language.

**Definition 9**  
$x$ is in a relation of **inner-halo** with $y$

1. $x$ is strictly in the functional$^{14}$ inside of $y$, ie. without sharing any of its points with the frontier of $y$.

2. $\text{inner-halo}(x,y) \equiv_{def} PP(x,f\text{-int}(y,x))$

**Definition 10**  
$x$ is in a relation of **contact** with $y$

1. $x$ is in the functional outside of $y$ and is weakly connected to $y$, ie. $x$ and $y$ are in contact but share no points (Aurnague and Vieu talk about a “natural contact” in [AV93])

2. $\text{contact}(x,y) \equiv_{def} PP(x,f\text{-ext}(y,x)) \land \text{weak-contact}(x,y)$

**Definition 11**  
$x$ is in a relation of **outer-halo** with $y$

1. $x$ is in the functional outside of $y$ but at a distance lesser than the critical distance, ie. $x$ is “in proximity” of $y$

2. $\text{outer-halo}(x,y,C) \equiv_{def} PP(x,\text{prox}(y,x,C))$

**Definition 12**  
$x$ is in a relation of **outer-most** with $y$

1. $x$ is in the functional outside of $y$ and at a distance greater than the critical distance, ie. $x$ is not “in proximity” of $y$

2. $\text{outer-most}(x,y,C) \equiv_{def} PP(x,f\text{-ext}(y,x)) \land \neg PP(x,\text{prox}(y,x,C))$

$^{14}$We use the functional interior defined by Aurnague and Vieu in [AV93]
Definition 13  $x$ is in a relation of inner-transit with $y$

1. $x$ shares at least one of its points with the frontier of $y$
2. $\text{inner-transit}(x,y) \equiv_{\text{def}} \text{EC}(x,y)$

Definition 14  $x$ is in a relation of contact-transit with $y$

1. $x$ shares at least one of its points with the frontier delimiting the fact to be in contact with $y$ and the fact to be in an outer-halo relation with $y$
2. $\text{contact-transit}(x,y) \equiv_{\text{def}} \text{contact}(x,y) \land \text{outer-halo}(x,y)$

Definition 15  $x$ is in a relation of outer-transit with $y$

1. $x$ shares at least one of its points with the frontier delimiting the fact to be in a relation of outer-halo with $y$ and the fact to be in a relation of outer-most with $y$
2. $\text{outer-transit}(x,y) \equiv_{\text{def}} \text{outer-halo}(x,y) \land \text{outer-most}(x,y)$

4.3 A Subclassification for Verbs of Change of Location

With our relations defined in Section 4.2, we have at our disposal seven generic locations linked to a given referent (see Figure 1). To talk about locations, however, suggests considering zones and not relations. But we have showed why such zones cannot be defined simply relative to the reference location but rather must be defined relative to the referent, the target and some relation of spatial inclusion\textsuperscript{15}. We given then the following Axioms 1 to 7. For example, the Axiom 2 connects the zone of contact $Z\text{-contact}(x,y)$ and the relation of contact $\text{contact}(x,y)$.

\textsuperscript{15}We can here use the mereological relation $P(x,y) : x$ is a part of $y$.
Axiom 1

inner-halo(x, y) → P(x, Z-inner-halo(x, y))

Axiom 2

contact(x, y) → P(x, Z-contact(x, y))

Axiom 3

outer-halo(x, y) → P(x, Z-outer-halo(x, y))

Axiom 4

outer-most(x, y) → P(x, Z-outer-most(x, y))

Axiom 5

inner-transit(x, y) → P(x, Z-inner-transit(x, y))

Axiom 6

contact-transit(x, y) → P(x, Z-contact-transit(x, y))

Axiom 7

outer-transit(x, y) → P(x, Z-outer-transit(x, y))

We are, in this Section 4, interested by the verbs of change of location. The zones we have so constructed can be considered as locations; they have functionality and they can, even if they are rarely for some of them, be lexicalized by different ways. We are then able to subclassify these verbs on the basis of which locations the moving entity is inside, at the beginning, the middle and at the end of its motion, respectively. All the possibilities are not lexicalized in French. We have listed 216 lexical entries for French intransitive verbs of change of location, that can be dispatched in 10 groups. Nine of them correspond to a change of location in the pure sense of location. The tenth one is a little more special and we will return to it at the end of this Section 4.3.
1. **Name of the Group**: S’approcher *to approach*

   **Logical Definition**: Approach(e) $\rightarrow$ 
   \[ \{P(Source(e), Z-outer-most(cible(e), Lref(e))) \land \\ P(Path(e), Z-outer-halo(cible(e), Lref(e))) \land \\ P(Goal(e), Z-outer-halo(cible(e), Lref(e)))\} \]

   **Lexical Entries**: 6
   **Examples**: s’avancer *to move forward*; accourir *to rush up*

   **Explanation**: Such verbs describe a motion going from a far away outside to a near outside of a location of reference.

2. **Name of the Group**: Arriver *to arrive*

   **Logical Definition**: Arrive(e) $\rightarrow$
   \[ \{P(Source(e), Z-outer-most(cible(e), Lref(e))) \land \\ P(Path(e), Z-outer-halo(cible(e), Lref(e))) \land \\ P(Goal(e), Z-inner-halo(cible(e), Lref(e)))\} \]
Lexical Entries : 23

Examples : aller to go ; venir to come

Explanation : Such verbs describe a motion going from a far away outside to the inside of a location of reference, via a near outside of this location.

3. Name of the Group : Entrer to enter

Logical Definition : Enter (e) →
{P(Source(e),Z-outer-halo(cible(e),Lref(e))) ∧
{P(Path(e),Z-inner-transit(cible(e),Lref(e))) ∧
{P(Goal(e),Z-inner-halo(cible(e),Lref(e)))}

Lexical Entries : 43

Examples : s’embarquer to board ; pénétrer to penetrate

Explanation : Such verbs describe a motion going from a near outside to the inside of a location of reference, crossing its “frontier”.

4. Name of the Group : Se poser to alight ; to land

Logical Definition : Land (e) →
{P(Source(e),Z-outer-halo(cible(e),Lref(e))) ∧
{P(Path(e),Z-contact-transit(cible(e),Lref(e))) ∧
{P(Goal(e),Z-contact(cible(e),Lref(e)))}

Lexical Entries : 44

Examples : se jucher to perch ; se suspendre to hang

Explanation : Such verbs describe a motion going from a near outside of a location of reference to an external contact with this location of reference.

5. Name of the Group : S’isoler to distance oneself from

Logical Definition : Distance-from (e) →
{P(Source(e),Z-outer-halo(cible(e),Lref(e))) ∧
{P(Path(e),Z-outer-transit(cible(e),Lref(e))) ∧
{P(Goal(e),Z-outer-most(cible(e),Lref(e)))}

Lexical Entries : 8

Examples : s’isoler to become isolated ; se reculer to move back
Explanation: Such verbs describe a motion going from a near outside to a far away outside of a location of reference.

6. Name of the Group: Partir *to leave*

Logical Definition: Leave $(e) \rightarrow$
\[
\{ P(\text{Source}(e), Z\text{-inner-halo}(cible(e), Lref(e))) \land \\
P(\text{Path}(e), Z\text{-outer-halo}(cible(e), Lref(e))) \land \\
\} P(\text{Goal}(e), Z\text{-outer-most}(cible(e), Lref(e)))) \}
\]

Lexical Entries: 44
Examples: *s’en aller to go away; désérer to desert*

Explanation: Such verbs describe a motion going from the inside to a far away outside of a location of reference, via a near outside of this location.

7. Name of the Group: Sortir *to go out*

Logical Definition: Go-out $(e) \rightarrow$
\[
\{ P(\text{Source}(e), Z\text{-inner-halo}(cible(e), Lref(e))) \land \\
P(\text{Path}(e), Z\text{-inner-transit}(cible(e), Lref(e))) \land \\
\} P(\text{Goal}(e), Z\text{-outer-halo}(cible(e), Lref(e)))) \}
\]

Lexical Entries: 16
Examples: *débarquer to land; jaillir to spring (up)*

Explanation: Such verbs describe a motion going from the inside to a near outside of a location of reference, crossing its “frontier”.

8. Name of the Group: Dicoller *to take off*

Logical Definition: Take-off $(e) \rightarrow$
\[
\{ P(\text{Source}(e), Z\text{-contact}(cible(e), Lref(e))) \land \\
P(\text{Path}(e), Z\text{-contact-transit}(cible(e), Lref(e))) \land \\
\} P(\text{Goal}(e), Z\text{-outer-halo}(cible(e), Lref(e)))) \}
\]

Lexical Entries: 11
Examples: *se décoller to come unstuck; déconnecter to disconnect*

Explanation: Such verbs describe a motion going from an external contact with a location of reference to a near outside of this location.
9. **Name of the Group**: Passer (par) *to go through; to cross*

**Logical Definition**: $\text{Cross} (e) \rightarrow$

\[
\{ P(\text{Source}(e), \text{Z-outer-halo}(\text{cible}(e), \text{Lref}(e))) \land \\
\{ P(\text{Path}(e), \text{Z-inner-halo}(\text{cible}(e), \text{Lref}(e))) \land \\
\{ P(\text{Goal}(e), \text{Z-outer-halo}(\text{cible}(e), \text{Lref}(e))) \}\}
\]

**Lexical Entries**: 4

**Examples**: couper *to cross*; repasser (par) *to pass by again*

**Explanation**: Such verbs describe a motion going from a near outside to a location of reference, entering the location, crossing it, and going outside to a near outside of this location.

10. **Name of the Group**: Dévier *to deviate*

**Logical Definition**: $\text{Deviate} (e) \rightarrow$

\[
\{ P(\text{Source}(e), \text{Z-inner-halo}(\text{cible}(e), \text{Lref}(e))) \land \\
\{ P(\text{Path}(e), \text{Z-inner-transit}(\text{cible}(e), \text{Lref}(e))) \land \\
\{ P(\text{Goal}(e), \text{Z-outer-halo}(\text{cible}(e), \text{Lref}(e))) \}\}
\]

**Lexical Entries**: 17

**Examples**: dévier *to deviate*; bifurquer *to turn off*

**Explanation**: Such verbs describe a motion going from the inside to a near outside of an ideal trajectory.

Now, as promised, some words about the tenth group, ie. the group of verbs such as *S’icarter*. In contrast with the other groups for which there is a change of location in the pure definition of the term location, here, the location considered is a little special. The location does not consist in a “normal” portion of space, but rather in an ideal trajectory, or ideal path which might be captured by means of axioms using $\triangleright$. This reminds us of elements of the English progressive in which similarly we appeal to “ideal” or “inertial” paths. With these progressive, such paths are naturally captured in a non-monotonic formalism [Ash92a]. These ideal paths have the same properties as “normal” locations plus some others (like, for example, a direction of motion and a stronger link with time), about which we will say nothing further in this paper.

We propose the following illustration (Figure 2) for our ten groups of verbs of **change of location**.
Figure 2: The 10 Groups of Verbs of Change of Location

We will make, especially in Section 4.5, use of the Initial, Medial and Final polarities defined in Boons [Boo85] and Laur [Lau91].

Our groups S’iloigner, Partir, Sortir, Dicoller and S’icarter have an Initial polarity.

Our groups S’approcher, Arriver, Entrer and Se poser have a Final polarity.

Our group Passer has a Medial polarity.
4.4 A Classification for Spatial Prepositions

As we have said since the beginning, we are interested in the compositional determination of the spatio temporal properties of motion complexes consisting of a verb of change of location and a spatial preposition. In order to formulate rules of combination (cf. Section 4.5), we briefly present in this Section a classification for French spatial prepositions. It is based on a classification proposed in [Lau91], that we have extended using our spatial relations defined in Section 4.2.

Under the term “preposition”, following [Lau91], we consider simple prepositions (such as dans in) and complex prepositions, i.e. prepositional phrases, (such as en face de in front of).

We separate prepositions into two main groups: the positional prepositions, which just describe a relation of localization (such as dans in), and the directional prepositions, which in addition of a relation of localization also suggest a direction of motion (such as de from, which has an Initial polarity, or par through, which has a Medial polarity, or jusqu’ à to, which has a Final polarity).

We propose the classification in Figure 3.

<table>
<thead>
<tr>
<th>Prepositions</th>
<th>inner-halo</th>
<th>contact</th>
<th>outer-halo</th>
<th>outer-most</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positional</td>
<td>chez; dans</td>
<td>sur; contre</td>
<td>sous; derrière</td>
<td>loin de</td>
</tr>
<tr>
<td></td>
<td>at; in</td>
<td>on; against</td>
<td>below; behind</td>
<td>far away from</td>
</tr>
<tr>
<td>Initial</td>
<td>de chez</td>
<td>de sur</td>
<td>de derrière</td>
<td>de dehors</td>
</tr>
<tr>
<td>Directional</td>
<td>from ‘s</td>
<td>from onto</td>
<td>from behind</td>
<td>from the outside</td>
</tr>
<tr>
<td></td>
<td>dehors</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Medial</td>
<td>par</td>
<td>au fil de</td>
<td>le long de</td>
<td>au-del’ de</td>
</tr>
<tr>
<td>Positional</td>
<td></td>
<td></td>
<td>along</td>
<td>beyond</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final</td>
<td>jusque dans</td>
<td>jusque sur</td>
<td>vers</td>
<td>pour</td>
</tr>
<tr>
<td>Positional</td>
<td>up to the inside of</td>
<td>up onto</td>
<td>towards</td>
<td>for</td>
</tr>
</tbody>
</table>

Figure 3: Classification of French Spatial Prepositions

199 French prepositions have then been listed and classified.

4.5 Combinational Rules

We extend our language by introducing the following notations: we will use $\phi$ as a variable for the semantic representation of motion complexes,
ie. those conditions in the DRS that are derived from the motion complex
together with its arguments; $\text{Polv}(\phi)$ and $\text{Polp}(\phi)$ will be used to denote the
polarity of the verb and the preposition; $\text{IZone}(\phi,c(e),l)$, $\text{MZone}(\phi,c(e),l)$
and $\text{FZone}(\phi,c(e),l)$ to denote the kind of initial, medial and final zone
intrinsically implied by the verb and its spatial adjuncts (the cible, ie. the
moving entity, and a location, that may depend on $e$); $\text{PrepZone}(\phi,c(e),l)$
to denote the kind of zone intrinsically implied by the preposition and its
arguments; $\text{Ns}(\phi)$ to denote the location introduced by the noun phrase in
the PP of the motion complex; and the question mark (?) to denote a location
that will have to be matched with some location given by the discourse (in
previous or following sentences) by anaphora resolution in DRT [AW89]. We
will just use the question mark in order to simplify the notations, but, to
follow the language used in DICE, we would normally would have to write
$x = ?(\beta)$ for denoting that this constraints is element of $\text{Con}(\beta)$, the condition
list of $\beta$, which is itself a DRS.

We propose the Figure 4 showing for each of our ten groups of verbs of
change of location, its polarity $\text{Polv}(\phi)$ and the zones in which the moving
entity is located at the initial (variable $\text{IZone}(\phi,c(e),l)$), medial (variable
$\text{MZone}(\phi,c(e),l)$), and final (variable $\text{FZone}(\phi,c(e),l)$) stage of its dis-
placement, respectively. These zones will be related to the $\text{Source}(e)$, $\text{Path}(e)$
and $\text{Goal}(e)$ by axioms latter on in this Section.

We show in Figure 5, for each group of directional prepositions its polarity
($\text{Polp}(\phi)$) and the spatial “zone” it suggests ($\text{PrepZone}(\phi,c(e),l)$). This
“zone” (cf. remark made in Section 4.3) is a function of the moving entity,
the location introduced by the preposition and the preposition itself.

Finally, we show in Figure 6, for each group of positional prepositions the
spatial “zone” ($\text{PrepZone}(\phi,c(e),l)$) it suggests.

Now, we propose the following compositional rules (under the form of log-
ical axioms), with some discursive explanations. In Axioms 16 and 17, $>$ de-
notes the weak conditional of DICE used in [Ash-al93], [LA93] and [Ash92b].
As in the treatment of “Discourse in Commonsense Entailment” or DICE
developed in [LA93], [Ash93] and [LA91], we will later label constituents of
a discourse representation as having certain properties, and we will reason

---

16The datas contained in Figure 4 and the following Figures 5 and 6 are also written
under the form of logical axioms. Nevertheless, we here prefer, for more clarity, present
these results under the form of tables.
### Groups of Verbs of Change of Location

<table>
<thead>
<tr>
<th>Group</th>
<th>polv</th>
<th>IZone</th>
<th>MZone</th>
<th>FZone</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dicoller</td>
<td>I</td>
<td>Z-contact</td>
<td>Z-contact-transit</td>
<td>Z-outer-halo</td>
</tr>
<tr>
<td>Sortir</td>
<td>I</td>
<td>Z-inner-halo</td>
<td>Z-inner-transit</td>
<td>Z-outer-halo</td>
</tr>
<tr>
<td>Partir</td>
<td>I</td>
<td>Z-inner-halo</td>
<td>Z-outer-halo</td>
<td>Z-outer-most</td>
</tr>
<tr>
<td>S’iloigner</td>
<td>I</td>
<td>Z-outer-halo</td>
<td>Z-outer-transit</td>
<td>Z-outer-most</td>
</tr>
<tr>
<td>Dévier</td>
<td>I</td>
<td>Z-inner-halo</td>
<td>Z-inner-transit</td>
<td>Z-outer-halo</td>
</tr>
<tr>
<td>S’approcher</td>
<td>F</td>
<td>Z-outer-most</td>
<td>Z-outer-transit</td>
<td>Z-outer-halo</td>
</tr>
<tr>
<td>Arriver</td>
<td>F</td>
<td>Z-outer-most</td>
<td>Z-outer-halo</td>
<td>Z-inner-halo</td>
</tr>
<tr>
<td>Entrer</td>
<td>F</td>
<td>Z-outer-halo</td>
<td>Z-inner-transit</td>
<td>Z-inner-halo</td>
</tr>
<tr>
<td>Se poser</td>
<td>F</td>
<td>Z-outer-halo</td>
<td>Z-contact-transit</td>
<td>Z-contact</td>
</tr>
<tr>
<td>Passer</td>
<td>M</td>
<td>Z-outer-halo</td>
<td>Z-inner-halo</td>
<td>Z-outer-halo</td>
</tr>
</tbody>
</table>

Figure 4: Data Table for French Verbs of Change of Location

### Directional Prepositions

<table>
<thead>
<tr>
<th>Prepositions</th>
<th>Polp</th>
<th>PrepZone</th>
</tr>
</thead>
<tbody>
<tr>
<td>de chez</td>
<td>I</td>
<td>Z-inner-halo</td>
</tr>
<tr>
<td>de sur</td>
<td>I</td>
<td>Z-contact</td>
</tr>
<tr>
<td>de derrière</td>
<td>I</td>
<td>Z-outer-halo</td>
</tr>
<tr>
<td>de dehors</td>
<td>I</td>
<td>Z-outer-most</td>
</tr>
<tr>
<td>jusque dans</td>
<td>F</td>
<td>Z-inner-halo</td>
</tr>
<tr>
<td>jusque sur</td>
<td>F</td>
<td>Z-contact</td>
</tr>
<tr>
<td>vers</td>
<td>F</td>
<td>Z-outer-halo</td>
</tr>
<tr>
<td>pour</td>
<td>F</td>
<td>Z-outer-most</td>
</tr>
<tr>
<td>par</td>
<td>M</td>
<td>Z-inner-halo</td>
</tr>
<tr>
<td>au fil de</td>
<td>M</td>
<td>Z-contact</td>
</tr>
<tr>
<td>le long de</td>
<td>M</td>
<td>Z-outer-halo</td>
</tr>
<tr>
<td>au-delà de</td>
<td>M</td>
<td>Z-outer-most</td>
</tr>
</tbody>
</table>

Figure 5: Data Table for French Directional Prepositions
about lexical properties within Commonsense Entailment.

Axiom 8

\[ \{ \phi(e) \land \text{Change-of-location}(e) \} \rightarrow P(\text{Source}(e), I\text{Zone}(\phi, \text{Cible}(e), \text{Lref}(e))) \]

Axiom 9

\[ \{ \phi(e) \land \text{Change-of-location}(e) \} \rightarrow P(\text{Path}(e), M\text{Zone}(\phi, \text{Cible}(e), \text{Lref}(e))) \]

Axiom 10

\[ \{ \phi(e) \land \text{Change-of-location}(e) \} \rightarrow P(\text{Goal}(e), F\text{Zone}(\phi, \text{Cible}(e), \text{Lref}(e))) \]

The Axioms 8, 9 and 10 say that the Source, the Path and the Goal of a motion are always a part of a zone given by the verb via IZone, MZone and FZone, and processed with respect to the reference location Lref.

Axiom 11

\[ \{ \phi(e) \land \text{Change-of-location}(e) \land \text{Directional}_\text{Prep}(\phi) \land \text{Polv}(\phi) = \text{Polp}(\phi) \} \rightarrow \text{Lref}(e) = \text{PrepZone}(\phi, \text{Cible}(e), stref(Ns(\phi))) \]

The Axiom 11 says that, when the preposition is directional with the same polarity as the verb (e.g. *sortir de la maison* to *go out of the house*), the reference location (Lref(e)) is a zone given via PrepZone (Z-inner-halo, in our example) and processed with respect to the Ns (*la maison* in our example). Compare for example with *sortir de derrière la maison* to *go out of the back of the house*, where the reference location (Lref(e)) cannot directly correspond to the location introduced by the noun phrase (here *la maison*), but has to be built using the PrepZone (here Z-outer-halo for the preposition *de derrière*) to give the zone of the *back of the house*.
Axiom 12
\[
\{ \phi(e) \land \text{Change-of-location}(e) \land \text{Directional}_\text{Prep}(\phi) \\
\land \text{Polv}(\phi) \neq \text{Polp}(\phi) \land \text{Polp}(\phi) = I \}
\rightarrow \{ P(\text{Source}(e), \text{PrepZone}(\phi, \text{Cible}(e), \text{stref}(\text{Ns}(\phi)))) \land \text{Lref}(e) = ? \}
\]

Axiom 13
\[
\{ \phi(e) \land \text{Change-of-location}(e) \land \text{Directional}_\text{Prep}(\phi) \\
\land \text{Polv}(\phi) \neq \text{Polp}(\phi) \land \text{Polp}(\phi) = M \}
\rightarrow \{ P(\text{Path}(e), \text{PrepZone}(\phi, \text{Cible}(e), \text{stref}(\text{Ns}(\phi)))) \land \text{Lref}(e) = ? \}
\]

Axiom 14
\[
\{ \phi(e) \land \text{Change-of-location}(e) \land \text{Directional}_\text{Prep}(\phi) \\
\land \text{Polv}(\phi) \neq \text{Polp}(\phi) \land \text{Polp}(\phi) = F \}
\rightarrow \{ P(\text{Goal}(e), \text{PrepZone}(\phi, \text{Cible}(e), \text{stref}(\text{Ns}(\phi)))) \land \text{Lref}(e) = ? \}
\]

The Axioms 12, 13 and 14 say that, when the preposition is directional with a polarity different from the verb (which is Initial (e.g. sortir par to go out through), Medial or Final), the Source, Path or Goal, respectively, is a part of a zone given via PrepZone, and processed with respect to the Ns; the reference location remains unmatched.

Axiom 15
\[
\{ \phi(e) \land \text{Change-of-location}(e) \land \text{Positional}_\text{Prep}(\phi) \land \text{Polv}(\phi) = I \}
\rightarrow \{ P(\text{Goal}(e), \text{PrepZone}(\phi, \text{Cible}(e), \text{stref}(\text{Ns}(\phi)))) \land \text{Lref}(e) = ? \}
\]

The Axiom 15 says that, when the preposition is positional and the verb Initial (e.g. sortir dans to go out in/into), the Goal is a part of a zone given via PrepZone, and processed with respect to Ns; the reference location remains unmatched.

Axiom 16
\[
\{ \phi(e) \land \text{Change-of-location}(e) \land \text{Positional}_\text{Prep}(\phi) \land \text{Polv}(\phi) = M \}
\rightarrow \{ \text{Lref}(e) = \text{PrepZone}(\phi, \text{Cible}(e), \text{stref}(\text{Ns}(\phi))) \}
\]
The Axiom 16 says that, when the preposition is positional and the verb Medial (e.g. courir dans to run in), by default, we have that the reference location is the zone given via PrepZone, and processed with respect to Ns.

**Axiom 17**

\[
\{ \phi(e) \land \text{Change-of-location}(e) \land \text{Positional}_\text{Prep}(\phi) \land \text{Polv}(\phi) = M \} \\
\supset \{ P(\text{Goal}(e), \text{PrepZone}(\phi, \text{Cible}(e), \text{stref}(\text{Ns}(\phi)))) \land \text{Lref}(e) = ? \} 
\]

The Axiom 17 says that, when the preposition is positional and the verb Medial (e.g. courir dans to run into), by default, we have that the Goal is a part of a zone given via PrepZone, and processed with respect to the Ns; the reference location remains unmatched.

**Axiom 18**

\[
\{ \phi(e) \land \text{Change-of-location}(e) \land \text{Positional}_\text{Prep}(\phi) \land \text{Polv}(\phi) = F \} \\
\rightarrow \text{Lref}(e) = \text{PrepZone}(\phi, \text{Cible}(e), \text{stref}(\text{Ns}(\phi))) 
\]

The Axiom 18 says that, when the preposition is positional and the verb Final (e.g. entrer dans to go into), the reference location is the zone given via PrepZone, and processed with respect to the Ns.

Let’s study the examples in (28), (29) and (30).

28. Eva est sortie de derrihre la maison
   
   *Eva has get out of behind the house*

29. Leticia est arrivie par le jardin
   
   *Leticia has arrived by the garden*

30. Inhs est passie sous le porche
   
   *Inhs has passed under the porch*
In (28), \textit{sortir} implies that $\text{Polv}(\phi) = I \land IZone = Z\text{–inner–halo} \land MZone = Z\text{–inner–transit} \land FZone = Z\text{–outer–halo}$. We have a directional preposition \textit{de derrière} which implies that $\text{Polp}(\phi) = I \land \text{PrepZone} = Z\text{–outer–halo}$. Because of the directional preposition and $\text{Polv}(\phi) = \text{Polp}(\phi)$, we apply the Axiom 11, which give us: $Lref(e) = \text{PrepZone}(\phi, \text{Cible}(e), \text{stref}(N))$, i.e. $Lref(e) = Z\text{–outer–halo}(\text{stref}(\text{Eva}), \text{stref}(\text{la maison}))$. We can then use the Axioms 8, 9 and 10, and obtain:

$$\{\phi(e) \land \text{Change-of-location}(e)\} \rightarrow \{P(\text{Source}(e), Z\text{–inner–halo}(\text{stref}(\text{Eva})), Z\text{–outer–halo}(\text{stref}(\text{Eva}), \text{stref}(\text{la maison}))) \land P(\text{Path}(e), Z\text{–inner–transit}(\text{stref}(\text{Eva})), Z\text{–outer–halo}(\text{stref}(\text{Eva}), \text{stref}(\text{la maison}))) \land P(\text{Goal}(e), Z\text{–outer–halo}(\text{stref}(\text{Eva}), \text{stref}(\text{la maison})))\}$$

This says that \textit{Eva} is in a zone of inner-halo, at the beginning of her displacement, with respect to a zone defined as the outer-halo\textsuperscript{17} of the house, in a zone of inner-transit, at the middle of her displacement, and in a zone of outer-halo, at the end, always with respect to the same zone.

In (29), \textit{arriver} implies that $\text{Polv}(\phi) = F \land IZone = Z\text{–outer–most} \land MZone = Z\text{–outer–halo} \land FZone = Z\text{–inner–halo}$. We have the directional preposition \textit{par} which implies that $\text{Polp}(\phi) = M \land \text{PrepZone} = Z\text{–inner–halo}$. Because of the directional preposition and $\text{Polv}(\phi) \neq \text{Polp}(\phi)$ and $\text{Polp}(\phi) = M$, we can apply the Axioms 13, which give us: $P(\text{Path}(e), Z\text{–inner–halo}(\text{stref}(\text{le jardin}))) \land Lref(e) = ?$. We can then use the Axioms 8, 9 and 10, and obtain:

$$\{\phi(e) \land \text{Change-of-location}(e)\} \rightarrow \{P(\text{Source}(e), Z\text{–outer–most}(\text{stref}(\text{Leticia}), Lref(e))) \land \text{stref}(\text{le jardin})\}$$

\textsuperscript{17}The computation make use of the moving entity, but has also to make use of the geometrical semantics of the preposition. Here \textit{de derrière} is different from \textit{de devant}, for example. This in fact concerns a semantical study on geometrical aspects of spatial prepositions we will not treat in this paper.
\[ P(\text{Path}(e), Z-\text{outer}-\text{halo}(\text{stref}(\text{Leticia}), Lref(e))) \land \\
P(\text{Goal}(e), Z-\text{inner}-\text{halo}(\text{stref}(\text{Leticia}), Lref(e))))\} \\
\land P(\text{Path}(e), Z-\text{inner}-\text{halo}(\text{stref}(\text{Leticia}), \text{stref}(\text{le jardin}))) \]

In (30), passer implies that \( Polv(\phi) = M \land I\text{Zone} = Z-\text{outer}-\text{halo} \land \\
M\text{Zone} = Z-\text{inner}-\text{halo} \land F\text{Zone} = Z-\text{outer}-\text{halo}. \) We have the positional preposition sous, which implies that \( \text{PrepZone} = Z-\text{outer}-\text{halo}. \) Because of the positional preposition and \( Polv(\phi) = M \), we can apply the two non-monotonic Axioms 16 and 17, which give us : \( Lref(e) = Z-\text{outer}-\text{halo}(\text{stref}(\text{Ines}), \text{stref}(\text{le porche})) \) or \( P(\text{Goal}(e), Z-\text{outer}-\text{halo}(\text{stref}(\text{Ines}), \text{stref}(\text{le jardin}))) =? \). We can then use the Axioms 8, 9 and 10, and obtain :

\[
\{ \phi(e) \land \text{Change-of-location}(e) \} \rightarrow \\
\{ P(\text{Source}(e), Z-\text{outer}-\text{halo}(\text{stref}(\text{Ines}), \\
Z-\text{outer}-\text{halo}(\text{stref}(\text{Ines}), \text{stref}(\text{le porche})))) \land \\
P(\text{Path}(e), Z-\text{inner}-\text{halo}(\text{stref}(\text{Ines}), \\
Z-\text{outer}-\text{halo}(\text{stref}(\text{Ines}), \text{stref}(\text{le porche}))))) \land \\
P(\text{Goal}(e), Z-\text{outer}-\text{halo}(\text{stref}(\text{Ines}), \text{stref}(\text{le porche}))))\} \\
\]

or :

\[
\{ \phi(e) \land \text{Change-of-location}(e) \} \rightarrow \\
\{ P(\text{Source}(e), Z-\text{outer}-\text{halo}(\text{stref}(\text{Ines}), Lref(e))) \land \\
P(\text{Path}(e), Z-\text{inner}-\text{halo}(\text{stref}(\text{Ines}), Lref(e))) \land \\
P(\text{Goal}(e), Z-\text{outer}-\text{halo}(\text{stref}(\text{Ines}), Lref(e))))\} \\
\land P(\text{Goal}(e), Z-\text{outer}-\text{halo}(\text{stref}(\text{Ines}), \text{stref}(\text{le porche}))) \\
\]

We then obtain two interpretations, both possible in natural language. The first one, the medial interpretation, where Inhs is before the porche, goes through it, and reaches the other side. The second one, the final interpretation, where the location sous le porche is the ending point of her displacement.
4.6 Linear and Nonlinear Motions in Expressions

Along any of the dimensions of a change of location, a change of position
or a change of posture, we can distinguish motions that are “linear” from
those that are “nonlinear” or circular. Roughly, circular motions are those
in which there is a sequence of locations in the path of the eventuality such
that the sequence contains a repeated element.

But there are various kinds of linear and nonlinear motion and these
motions must be calculated with respect to the types of verb and prepositions
if any in the adjunct. Luckily, we can use the same definitions of linearity
for prepositions, verbs and verb complexes. Below we illustrate the relevant
definitions of linear and nonlinear motion just for motions that are changes
of location. The definitions for changes of position or posture are entirely
analogous.

Definition 16 A change of location verbal complex or verb, or a preposition
\( \phi \) is strongly nonlinear iff \( \phi(e) \rightarrow \text{Source}(e) = \text{Goal}(e) \)

Definition 17 A change of location verbal complex or verb, or a preposition
\( \phi \) is weakly nonlinear iff \( \phi(e) \rightarrow \exists x ( x \in \text{Path}(e) \land \exists l_i \exists l_j (l_i \text{ occurs in the sequence } x \land \neg i = j \land l_i = l_j)) \)

Definition 18 A change of location verbal complex or verb, or a preposition
\( \phi \) is strongly linear iff \( \phi(e) \rightarrow \neg \exists x ( x \in \text{Path}(e) \land \exists l_i \exists l_j (l_i \text{ occurs in the sequence } x \land \neg i = j \land l_i = l_j)) \)

Definition 19 A change of location verbal complex or verb, or a preposition
\( \phi \) is weakly linear iff \( \phi(e) \rightarrow \text{Source}(e) \neq \text{Goal}(e) \)

As an example of a nonlinear preposition, we have autour de round.
Weakly linear prepositions are jusqu’à to, depuis from; for verbs we have
weakly linear verbs like partir to leave, quitter to leave, aller to go, venir
to come, while weakly nonlinear verbs are boucler to loop and graviter to
orbit. There are no prepositions that are strongly linear, and for strongly
linear verbs we have only potential candidates like tomber to fall or monter
to go up, and even those it is not clear that their paths never cross. One can
only get the effect of a strongly nonlinear motion in a verbal complex like
John went to Paris and then returned, which we would in fact analyze as two
motions. Strong linearity also is only found in complex expressions that are rather standardized as in, the airplane climbed continuously at 1000ft/min for 30 seconds. If one sees this in an NTSB accident report, one would conclude that the airplane’s path was strongly linear in this case. Some verbs of change of position like graviter to orbit are non-linear though most others are weakly linear like the displacement verbs. Some verbs of inertial change of place like courir to run do not make any demands on the locational path of the eventuality they describe — they are neither linear nor nonlinear.

Just as we saw that one could calculate the position for the target compositionally on the basis of the properties of the verbs and prepositions, we can also easily calculate the properties of linearity of verb complexes based on the properties of the prepositions and constituent verbs. Roughly, the calculation is simply a matter of unification. If a verb or preposition is linear it may not combine with something with a nonlinear value. Again we can use the notation of here of a first order language in which we reason declaratively about constraints on constituents. Because there are few if any strongly linear motion verbs or prepositions we look only at the weakly linear cases. After each axiom we offer as example a verb complex governed by it. We give axioms that cover all the change of location verbs and change of place verbs.

Axiom 19 Non-linear(Verb) \(\land\) WeaklyLinear(Preposition) \(\rightarrow\) \(\bot\)

Example : * graviter jusqu’à Mars
to orbit to Mars

Axiom 20 Non-linear(Preposition) \(\land\) Linear(Verb) \(\rightarrow\) \(\bot\)

Example : * aller autour du Gers
to go round the Gers

Axiom 21 Weakly-linear(Preposition) \(\land\) Weakly-linear(Verb) \(\rightarrow\) Weakly-Linear(Verb-complex)

Example : aller jusqu’à Paris
to go to Paris
Axiom 22 \( \text{Non-linear(Preposition)} \land \text{Non-linear(Verb)} \rightarrow \text{Non-linear(Verb-complex)} \)

Example: graviter autour d'une planète

to orbit round a planet

4.7 From Lexical Semantics to Discourse

We are now in a position to combine our lexical information with discourse information. We follow the studies of [Ash92b] and [Ash-al93]. We will work within the framework of Segmented Discourse Representation Theory [Ash93]. SDRT consists in a nontrivial extension of Kamp’s Discourse Representation Theory in which the dynamic propositions (DRSs) that can be derived from each clause in a discourse are related to each other by means of one or more discourse relations. The resulting structure is known as an SDRS (segmented DRS); it is recursively defined and may have SDRSs as constituents. SDRSs are constructed through a bottom up procedure that is described at length in [Ash93] and investigated for spatial applications in [Ash-al93]). Here we will only look at simple two sentence discourses to see how our more detailed lexical information interacts with the discourse structure. [Ash-al93] have at least preliminary results for more complex texts.

To do this, we must introduce a crucial element that links the lexical semantics of the motion verb complexes with the discourse structure. This is the notion of a constituent salient location or CSL for each moving actor in the movement described. Each will have as well as a constituent salient position and posture but here we concentrate only on the constituent salient location or CSL for the one target in our motion verb complexes. Tense affects the CSL; here we consider the CSL only for sentences in the simple past (passé simple or passé composé with the passé simple sense); for a more complete study see [AB94], forthcoming. The CSL in our restricted study is the spatiotemporal location of the target once the action has been completed. Thus, we can formulate the following Axiom 23 relative to our verb complex types where the verb has the passé simple tense (PS).

Axiom 23 \( PS(\alpha) \rightarrow CSL(\alpha) = Goal(e_\alpha) \)

The axioms governing the various zones and the reference point will help us situate the CSL relative to locations mentioned in the constituent \( \alpha \).
On the discourse side, we have several discourse relations that can affect the relationships of the CSLs of one constituent with another. The following Axioms 24 to 33 come again from the studies of [Ash92b] and [Ash-al93], in which the discourse relations examined were Narration, Background, Precondition, Elaboration, Explanation and Result. Their definitions and semantics can be found in [Ash-al93] or [Ash93].

**Axiom 24** Narration($\alpha, \beta$) → (Target($e_\alpha$) = Target($e_\beta$) → Source($e_\beta$) = CSL($\alpha$))

Narration thus links the actions described in two constituents together.

With backgrounding, the location of the background location forms a setting for the action that is foregrounded.

**Axiom 25** Background($\alpha, \beta$) → O(CSL($\beta$), CSL($\alpha$))

**Axiom 26** (Background($\alpha, \beta$) ∧ Motion−Verb($\alpha$)) > P(CSL($\alpha$), CSL($\beta$))

With elaboration, the CSL of the constituent that is elaborated contains the CSL of the elaborating constituent, while with precondition and explanation, the element that is the explanans or the precondition is part of a causal sequence of eventualities itself defining an event leading to the CSL of the constituent that is explained or that has the precondition. With result, we have the inverse relation between constituents as with explanation.

**Axiom 27** (Elaboration($\alpha, \beta$) ∧ ¬∃$\gamma$Narration($\gamma, \beta$)) > Source($e_\beta$) = Source($e_\alpha$)

**Axiom 28** Elaboration($\alpha, \beta$) → ∀$x \in Path(e_\beta)$∃$y \in Path(e_\alpha)$Subsequence($x, y$)

**Axiom 29** Precondition($\alpha, \beta$) → ∃$e \exists x \in Path(e)$∃$li$ (li occurs in the sequence $x$ ∧ P(STref($e_\beta$), STref($li$)) ∧ goal($e$) = CSL($\alpha$))

**Axiom 30** Explanation($\alpha, \beta$) → ∃$e \exists x \in Path(e) \forall y \in Path(e_\beta)$ (Subsequence($y, x$) ∧ goal($e$) = source($e_\alpha$))

**Axiom 31** Explanation($\alpha, \beta$) > goal($e_\beta$) = source($e_\alpha$)
\textbf{Axiom 32} \( \text{Result}(\alpha, \beta) \rightarrow \exists e \exists y \in \text{Path}(e) \forall x \in \text{Path}(e_{\alpha}) (\text{Subsequence}(y, x) \land \text{goal}(e) = \text{source}(e_{\beta})) \)

\textbf{Axiom 33} \( \text{Result}(\alpha, \beta) > \text{goal}(e_{\alpha}) = \text{source}(e_{\beta}) \)

Now we look at examples of Discourse Structure Calculation:

We first begin with some examples of Narration. Consider the following examples.

31. Pierre est allé dans le jardin. Il a dansé.

\textit{Pierre is gone into the garden. He danced.}

32. Pierre est allé dans le jardin. Il s’est assis.

\textit{Pierre is gone into the garden. He sat down.}

33. Pierre est allé dans le jardin. Puis il a couru jusqu’à la fac.

\textit{Pierre is gone into the garden. He then ran to the Fac.}

The deduction of which discourse relation relates the two constituents takes place as with [Ash-al93] within a nonmonotonic framework, which was first elaborated in [LA91] and [LA93]. Narration is the discourse relation that we infer by default between constituents when no other information overrides this default. This is the case here. In example (31), the first clause has a motion verb complex that fits the antecedent of Axiom 18, which makes \textit{the garden} the location of reference. Thus, we have, by the Axiom 10, that the goal of the action is situated in \textit{the garden}, and we know, by the Axiom 23, that the CSL is in \textit{the garden} too. Axiom 18 also disambiguates \textit{dans} for us, since it in effect makes the preposition directional, specifying the goal. Since Narration holds between the two constituents, we can apply the Axiom 24 and have that CSL(\(\alpha\)) = source(\(e_{\beta}\)). But since the verb in \(\beta\) is not a verb of change of location, we conclude that the source(\(e_{\beta}\)) = goal(\(e_{\beta}\)), ie. they occur in the same location, which is specified by the previous clause. This entails that he \textit{danced in the garden}, which is what is desired.

Similarly, with the second discourse (32) except that we know that \textit{s’asseoir to sit down} is a change of posture verb; if we assume that changes of posture and changes of position do not change location, then the Axiom 24 for Narration yields that he \textit{sat down in the garden}. 

40
Finally, the sequence of motion verbs in the third discourse (33), assuming once again that Narration holds between the two constituents, shows us that the source of the *running* is in *the garden*, but that with the help of Axiom 17, we know that the goal of the *running* is not just a simple inertial change of position but a displacement to another location — *the Fac*.

Narration is not the only discourse relation that can be inferred in discourse contexts, of course. The following pair shows how we can disambiguate prepositions using the discourse context and particular discourse relations.

34. Jean a couru dans le jardin. Il a vu le chat à travers la fenêtre et a voulu l’attraper.

   *John ran into the garden. He saw the cat through the window and wanted to catch it.*

35. Jean a couru dans le jardin. Il a voulu s’entrainer pour la compétition.

   *John ran in the garden. He wanted to train for the competition.*

In both cases (34) and (35), we conclude Explanation, rather than Narration because of a particular juxtaposition of event types: an action by the target, followed by a statement about the target’s desires. We believe it to be a general default pattern that when such event types are joined together in the discourse that the intended or preferred discourse relation is Explanation. We might express this as:

**Axiom 34**  \[ \prec \tau, \alpha, \beta \succ \land \text{Action-by-}x(\alpha) \land \text{volition-expressed}(\beta) \succ \text{Explanation}(\alpha, \beta) \]

Where > is the weak conditional of DICE used in [Ash-al93], [LA93] and [Ash92b]. We will revise this rule shortly, but already this approximation serves to indicate how inferences in DICE exploit defaults. Since the antecedent of this conditional entails the more general antecedent to the default for Narration given below,

**Axiom 35**  \( \prec \tau, \alpha, \beta \succ \succ \text{Narration}(\alpha, \beta) \)
Explanation and Narration are incompatible relations because they imply contradictory temporal information; but the more specific default about Explanation overrides the more general one about Narration and so we conclude Explanation in DICE (see [LA93] and [Ash-al93] for details).

Notice however, that we have two different inferences about dans in these examples. How is this possible? We have in the first sentence of (34) and (35) a verb of inertial change of location (meaning that it is highly likely that the target will change position from the pre to the post state of running but it is not obligatory). Such verbs may combine with either the locational in or directional into sense of dans, as we see and as our axioms predict. What does disambiguate dans is the second sentence, which supplies an explanation. Let us consider (34) first. The second sentence of (34) is itself complex; the first clause gives a cause of and results in the volition in the second clause. Now volitional expressions about x described in a constituent β are typically taken in the absence of other information to contribute explanatory causes of actions by x described in α if the two are related in the discourse and further α must be part of a plan to get the goal described in β. That is, we have the rule:

**Axiom 36**

\[
\langle \tau, \alpha, \beta \rangle \quad \land \quad \text{volition} \rightarrow \text{by} - x(\beta) \quad \land \quad \text{action} \rightarrow \text{by} - x(\alpha) \\
\land \quad \text{Cons}(\text{Post} - \text{state}(e_\beta), \text{Pre} - \text{state}(e_\alpha)) \]

\[
> \quad \{ \text{Explanation}(\alpha, \beta) \\
\quad \land \quad \alpha \text{ part-of a plan that leads to goal of volition}(\beta) \} \]

These notions involving plans can be made formally precise, but the inference is quite complicated. Only if α is a displacement from inside the salon to outside the salon and the enclosure (house or apartment) can it be taken to be part of a plan of catching the cat. For in order to catch the cat one has to go where the cat is — and the cat is, as is stated in β, outside the enclosure while the target Jean is inside the enclosure, something which we know from the first clause of the second sentence from the semantics of à travers through. By Explanation and the axioms governing the CSL, we conclude that the source of courir to run must be inside the enclosure, and in attempting to make the action of running part of the plan to get the cat, we infer that the goal of the running is the garden and thus disambiguate the
preposition **dans**. The same explanation goes for (35). The second sentence of the second discourse gives us again an explanation in terms of plans. But a quite different plan is involved. Again depending on extralinguistic information about plans and also about intentional states, we can get different semantic effects.

## 5 Survey of the Literature

In this last Section, we propose a discussion of the litterature on the subject and a comparison with our own work.

Two different approaches can be found in the litterature: a *syntactic* one (followed among others by Wunderlich, Maienborn, Guillet, ...), and a *semantic* one (followed among others by Hays, Dervillez-Bastuji, Lamiroy, Boons, Laur, ...). These approaches are quite different but have also some common points, at the same time.

### 5.1 Syntactic Approaches

Wunderlich [Wun91] differentiates between *spatial verbs* (like in (36)), which are subcategorized for a spatial PP\(^\text{18}\), and *non-spatial verbs* which are not. He classifies spatial verbs into three categories: those which require a locative PP (like those in (36), (37) and (38)) which he calls **verbs of location**; those which require only directional prepositions (like those in (39) and (40)) which he calls **verbs of placement**; and those which can accept all dynamic prepositions (like those in (41)), which he calls **verbs of movement**. He consequently groups together as **verbs of location** all verbs for which there is no change of location that is, all our verbs of change and inertial change of position, of change of posture and all the static verbs (like those in (36)). This group is very large and quite some heterogeneous. In contrast, his **verbs of placement** are very few, and represent those verbs of change of location whose polarity is final and which require an agent to realize the change of location of the object. Finally, his class of **verbs of movement** is not very precisely defined and seems only to be used to put into it all the verbs which not enter one of the two first classes. They seem to correspond to our verbs of change of location except those which are verbs

\(^{18}\)Ie. they require the incorporation of a spatial PP.
of placement, but we also find in the examples he gives verbs like wandern to hike which are verbs of change of position for us. The syntactic criteria used here appear to be not completely adequate for the kind of classification we need.

36. The ball is under the tree
37. She plays under the tree
38. The ball is rolling under the tree / in the room
39. The ball is rolling under the tree / into the room
40. He puts the ball under the tree
41. He went into the kitchen

Maienborn ([Mai92]) distinguishes between Positionsverben (which correspond to (part of) the verbs of location of Wunderlich), and Bewegungsverben (which correspond both to the verbs of placement and the verbs of movement of Wunderlich). Her subclassification is also based on a difference between locative and directional PPs. She nevertheless does not differentiate verbs which accept only directional (final) prepositions from those which accept all dynamic prepositions. She notes rather that locative PPs denote the property to be localized in a “region”, while directional PPs denote the property to be localized with respect to a “path”.

This classification is closer to ours than the one of Wunderlich is. Bewegungsverben are our verbs of change of location; Positionsverben are our verbs of change and inertial change of position and change of posture\(^{19}\). She also considers the differentiation between “region” and “path” as important for the notion of localization.

Guillet [Gui90] prefers to talk about locative verbs, which are those verbs which accept a locative “complement”. By locative “complement”, Guillet means a “complement” answering the question oy ? where ?, but it is not a circumstantial “complement” of location (the French ‘compliment

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\(^{19}\) Indeed, it does not seems that the Positionsverben of Maienborn want to cover static verbs, in contrast with the verbs of location of Wunderlich.
circonstanciel de lieu). He does not refine his class of locative verbs nor give precise definition of it, but we can nevertheless see, through his work, that he distinguishes verbs which, for him, do not clearly denote a change of location (like eg. braquer to turn (the wheel), remuer to move / to fidget, ...). With this consideration, we can say that all these verbs are our verbs of change of posture, and the remaining ones, his “locative verbs”, our verbs of change of location and change and inertial change of position.

These syntactic approaches then do not furnish completely adequate and precise criteria for a classification of motion verbs. Also, the syntactic approaches unfortunately do not cover all the verbs we would like. As Wunderlich remarks himself [Wun91], his definitions work well only for simple verbs in English or German, such as sitzen to sit, stellen to put, werfen to throw, gehen to walk, ... But there are many other verbs which already contain the locative predicate\(^{20}\). He gives the exemple of the English verb to enter, of the German\(^{21}\) verb bereisen to travel in, of the Spanish verbs entrar to move into, salir to move out, pasar to move by, ... We can also add the French verb quitter to leave, ... It is true that some of them allow the expression of the relatum of the location by a direct object, which plaid for the syntactic approach; but not all of them, unfortunately.

We can remark that those verbs, which run into trouble with a syntactic approach, are easily recognized as “motion verbs” with a semantic approach.

Other very problematic verbs, such as chercher to look for or sonner to ring, are clearly rejected by a syntactic approach, but could eventually be recognized by a semantic approach, if there is some need of them for some particular application.

We do not want, with this negative conclusion, to intend that a syntactic approach for motion verbs classification is useless. In contrast, we think that this kind of approach alone is not sufficient, but that it can bring some important elements to corroborate semantical criteria built on classifications.

\(^{20}\)As an incorporated directional or path oriented location

\(^{21}\)A locative preposition is often incorporated in the German prefix verbs.
5.2 Semantic Approaches

Hays [Hay89], following [LSH78], makes a distinction between transposition verbs and non-transposition verbs, in the specific domain concerned by the VITRA project. The latter include concepts such as “rotate”, “tremble” and “sway”. Her transposition verbs in fact cover our verbs of change of location and change and inertial change of position; her non-transposition verbs are our verbs of change of posture. She also makes a second level subclassification by refining her transposition verb class, using the two following criteria. The first one consists of a distinction between a change and an absence of change over some dimension (i.e. in speed or direction, eg.). The second one consists of a distinction between concepts referring to continuous change (eg. walking) and those that refer to discrete-state changes (eg. stopping, starting, turning). This kind of criterion differs from any of those we have presented in this paper. We nevertheless are agreed with Hays that refinement of the classification in terms of meaning components (cf. [LR92]) is essential. But this has to remain as a second level classification. That is both levels have to be accessible, depending on which kind of applications it is used for. In other work, not presented here, we have circumscribed 35 different meaning components concerning French verbs of change of location (cf. [AS94] in preparation), which lead to a very fine grained classification (the larger class has 11 lexical items, and most of less than 3). This kind of classification is perhaps needed in applications such as automatic translation, for example, but does help us understand basic inferences concerning movement, which is our task here.

Dervillez-Bastuji [DB82] makes use of two kinds of criterion: the change versus the non-change of location; and the orientation. Motion does not always denote an orientation; the location of reference could be the “background” location of the process, in contrast with the initial and the final locations for displacement. Motion only specifies the “manner” the process is realized. A displacement is always oriented.

“The motion, concret or metaphoric, is a necessary condition for a change of location, but in no cases a sufficient condition. It is why so many linguists and also sometimes psycholinguists, forgetting this consideration of change vs. non-change of the referential system, have put together as “motion verbs” verbs such as remuer
to move / to fidget, danser to dance, se promener to take a walk and verbs such as venir to come, partir to leave or entrer to get into." [DB82]

“Every non-oriented motion is equivalent with a state. This state can manifests itself as rest or as agitation. To this rest or this free motion is opposed displacement, which is considered as an oriented-path directed motion defined by its direction and, in a second time, by its meaning.” [DB82]

The displacement verbs of Dervillez-Bastuji cover then our verbs of change of location; her agitation verbs our verbs of change of posture. Dervillez-Bastuji does not distinguishes between our two classes of change of position verbs. She uses a directional criterion to make distinctions, which we do not. Verbs like longer to go along denote oriented-path directed motion, and then are displacement verbs; verbs like errer to wander denote free motion, and then are agitation verbs.

Lamiroy [Lam87] uses the concept of change of position in space. She defines three classes for motion verbs.

The first class contains verbs of direction, which are polarised and telic verbs always having a starting point or a final point for the motion. They use in the Passi Composi the auxiliairy jtre. Examples are entrer to get into, arriver to arrive, sortir to get out, partir to leave, ... They correspond to our verbs of change of location.

The second class contains verbs of displacement. They either denote a way of moving (eg. marcher to walk, trotter to trot, diambuler to stroll about), or a speed of moving (eg. se pricipiter to dash at/in/out, foncer to rush), or a direction of moving (eg. se diriger to navigate / to make one’s way (towards), obliqué to take an oblique direction). They use in the Passi Composi the auxiliary avoir. They correspond to both our verbs of change and inertial change of position.

The third class contains verbs of movement of the body, which denote neither a direction, nor a displacement from one location to another, but rather a change of posture or of state. They correspond to our verbs of change of posture.
Boons, [Boo85] and [Boo87], is the most careful of these authors. He
thinks that the class of “motion verbs” is one of the most curious and in-
teresting lexical class of the language. But he nevertheless realizes that this
class is completely vague. Such verbs can denote a proper displacement of
a body as well as displacements of one part with respect to the other parts
of a body. He then prefers to focus on verbs of the first interpretation and
not trying to delimitate precisely the general class of the so-called “motion
verbs”.

He considers, as does Dervillez-Bastuji [DB82], the distinction between
the change and the non-change of location as a crucial one. This (theoret-
ically) leads him to the distinction between motion verbs and displacement verb. Our verbs of change of location clearly belong to his motion verbs and our verbs of change of posture to his displacement verb. But
for our verbs of change and inertial change of position, the situation is abso-
lutely unclear. If we refer to the definitions given by Boons, they must belong
to the class of his motion verbs. But in the fact, through the examples and
the lists he has given, they appear in the class of his displacement verb.

Laur [Lau91] uses the concept of change. But unlike Lamirov who is
talking about only change of position in space, she is talking about change
of state, shape, posture or position of animate or inanimate bodies. She
has also raised the ambiguity present in the work of Boons by subdivising
the displacement verbs into three subclasses with respect to a criterion of
polarity (already introduced by Boons), that is the differentiation between
verbs with an initial, a medial or a final polarity. Such verbs are naturally
called initial verbs, medial verbs and final verbs. She has this time
realized list of verbs in accord with the definitions used. Initial and final
verbs are our verbs of change of location. Medial verbs are our verbs of
change and inertial change of position.

To synthesize both the presentation of all these works and their compar-
ison, we propose the table given in Figure 7.

When we look at all these works it seems that the class of “motion verbs”
is a really complex class, especially because of the different terminologies
and the different ways and “tools” used by each author to take this difficult
problem. But the presentation under a form of confrontation and superposi-
tion we have realized in this Section let’s appear that all these works obtain finally compatible classifications (as the table in Figure 7 shows it clearly). This is a very important result. The fact that these works have been realized on the basis of different kinds of criteria, such as syntactical, semantical and conceptual criteria, and that they have arrived to compatible classifications, gives to these classifications a very strong validity.

6 Conclusion

We have presented along this paper a typology for motion verbs and motion verb complexes which enables us to draw a detailed spatiotemporal semantics of motion expressions. We have also show that a formalization of the calculus for our compositional semantics can be integrated in a Discourse Representation framework (SDRT). Our lexical information combined with discourse information allows for the understanding processes of the spatiotemporal structures of texts and for lexical disambiguation, which are essential when calculating the localization of eventualities denoting motion with respect to various locations given in the text.

This work, presented in this paper, is also at the basis of other detailed investigations on motion in progress at the LRC (Language, Reasoning, Computation) in Toulouse:

- a finer grained typology of verbs of change of location, based on the one presented here, and using in addition a 35 meaning components drive of categorization;

- an aspectual study of verbs of change of location for which the seven spatial (spatiotemporal) relations, used here for the typology, lead to more detailed notions of the Aktionsart;

- linguistic comparative studies realized on Basquian (M. Aurnague) and Japanese (J. Saito) languages which corroborate our own results for French.

The approach and the methodology we have followed for this work seem to bring some evidences of their merits and we are presently continuing our investigations on these basis.
References


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<th>Prepositional Prepositions</th>
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<tr>
<td>chez; dans</td>
<td>Z-inner-halo</td>
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<tr>
<td>sur; contre</td>
<td>Z-contact</td>
</tr>
<tr>
<td>sous; derrière</td>
<td>Z-outer-halo</td>
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<td>loin de</td>
<td>Z-outer-most</td>
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Figure 6: Data Table for French Positional Prepositions

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<th>Source</th>
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<td>verbs of change of location</td>
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<tr>
<td></td>
<td>verbs of change of position</td>
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<tr>
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<td>verbs of movement</td>
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<td>other verbs</td>
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<tr>
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<td>Displacement verbs</td>
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<td>Agitation verbs</td>
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<td>verbs of displacement</td>
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<td>Laur</td>
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<td>Medial verbs</td>
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</table>

Figure 7: Comparaison of Classifications on Motion Verbs