In: Emar Maier, Corien Bary & Janneke Huitink, eds. (2005) "Proceedings of SuB9"
www.ru.nl/ncs/sub9

WHERE LEXICAL SEMANTICS MEETS SPATIAL DESCRIPTION: A FRAMEWORK FOR KLETTERN AND STEIGEN

Matthias Weisgerber
Universität Konstanz
matthias.weisgerber@uni-konstanz.de

Abstract

When representing motion linguistically, more information is hidden in the interaction of verb, subject, object and directional PP than current linguistic theories normally use. In order to capture this information interplay lexical verb entries must look deeper into the situation, using a formalization of conceptual knowledge – the information gained can be used to make lexical entries of verbs more simple and more efficient. After a case study of German *steigen* and *klettern* (both: *climb*) we want to propose a toolkit to model both semantic and conceptual knowledge and their interaction, thereby proposing a three-level framework. As a result, we will present both lexical entries and *conceptual knowledge modules* of the associated parts of information, to the effect that lexical entries can be kept less complex than suggested in previous theories.

1 Introduction

When encoding real world situations in language, various kinds of information are dealt with. Words in a sentence have meanings, and the sentence meaning depends on both the word meanings and the way these are combined. While representation of word meaning is just a matter of the right framework – there is a choice between a vast number of semantic theories –, it means more than just combining word meanings mechanically 'in the right way' to derive a sentence meaning that represents a real world situation: There are interactions between verb meanings and subjects and objects (*to ride a horse* vs. *to ride a bus*) or between preposition meanings and objects (like in *on the table* vs. *on the wall*). As a consequence, this has led to complex lexical representations of word meanings that have to account for possible subcategorizations and exclude impossible cases.

In this paper, we discuss the linguistic representation of motion verbs and motion situations. These are promising candidates for an exploration of the extent to which verbal lexical entries are able to deal with situational information, since the situations described by motion verbs are clear-cut – they can easily be judged on the basis of normal portion of spatial and physical intuition. On the other hand, staying in the domain of linguistics, motion situations cause a vast amount of problems whose solution is hidden to purely linguistic analysis. There are sentences which are semantically good but, nevertheless, describe situations physically impossible in our world (e. g. (1)):

(1) a. ?? Peter climbed onto the cloud
    b. ?? The balloon climbed out of the hole [and we know that the hole's only exit is at its bottom]

While in (1a) the information is needed that a cloud has no solid surface, in (1b) things are even worse: No linguistic analysis will be able to falsify this sentence in this situation without including further knowledge about the situation described.

We will claim that information is hidden in the interaction of verb, subject, object and directional PP that is not used in most theories. We will present ideas on how to capture this information interplay suggesting lexical entries that look deeper into the situation. Technically, we propose distributing information into three parts: On the *semantic level*, the word meanings are represented in a way so as to enable semantic composition of meaning. On the *conceptual level*, more conceptual knowledge about objects and events is stored. This knowledge is used to filter out sentences that are conceptually odd. Additionally, there will be a third level, whose task will be to model everyday world knowledge (like ‘gravity causes that things normally fall down’), on the one hand, conceptual knowledge about *words*, on the other. We will call this the *simulated world level*.

In doing this, we are building on the tradition of Conceptual Semantics developed by Jackendoff (1983,1991), a core point of which is what we call the ‘CS triangle’: Spatial knowledge and representation, on the one hand, and linguistic knowledge and representation, on the other, is not directly connected, but mediated by a conceptual representation: the model of world and situations we have in mind.

We will find that the verb is responsible for compiling an interaction between the Subject, which is source of a MANNER of movement, and the Object, which interacts with a PATH. We will discuss current theories, suggest and develop some basics of a framework to model both semantic and conceptual knowledge and their interaction and, in the end, propose lexical entries and *conceptual knowledge modules*.

2 A Case Study on Motion Verbs: *klettern*, *steigen*, and *climb*

Motion verbs are an ideal example for the interaction of information that takes place between verb, complements, concepts and context. All these different movement concepts have one core structure in common: There is motion, there is a MANNER of motion (whether explicitly referred to or not); and there is a PATH made up from the places in space the subject has occupied some point of time. In this paper, we focus on one special kind of motion verbs: we will call them MANNER-PATH-*verbs* (MPVs) and define them as

Definition 1 (MANNER-PATH-verbs) := *Verbs of* ***motion*** *in combination with a* { *goal object NP, directional PP, directional adverb* } *where an* ***object*** *moves along a* ***path*** *in a certain* ***manner****.*

2.1 German *klettern* and *steigen*: First analysis

As a sample, let us focus more narrowly on two verbs: German *klettern* and *steigen*. At first sight, both verbs are equivalents of English *to climb*. However, they differ in meaning: while *klettern* is approximately equivalent to *clamber* and *climb*, *steigen* has the meaning of *climb*, *go up*, *ascend* and *increase*.

This seems to be a systematic difference: Looking at the core meaning of the verbs, we find that although both *klettern* and *steigen* express information about the **direction** of movement and about **manner**, there seems to be a systematic effect of emphasis: *steigen* puts more emphasis on the direction, while *klettern* puts more emphasis on the manner. This can be seen in examples where no object is present at all and where only one of the options is semantically good:

(2) a. Das Flugzeug {steigt / *klettert}.
(The plane is climbing (go up).)
b. Der Affe {klettert / *steigt}.
(The monkey is climbing (clamber).)

This fact, however, constrains the choice of subjects. While (2a) only expresses an increase of height, (2b) only expresses the manner of the monkey's movement.

A prepositional phrase given as a second argument introcuces a PATH (where at least one of {goal, route, source} is specified). As soon as a PATH is explicitly introduced, an interdependence of PATH and DIRECTION can be found: If the subject needs contact to the ground and if the object has a solid surface, then the path adapts to the object's shape. Hence, it is no longer true in all cases that UPWARD holds:

(3) a. Peter {steigt / klettert} auf den Berg.
(Peter is climbing (go up) the mountain.)
b. Das Kind {steigt / klettert} auf den Stuhl.
(The child is climbing onto the chair (in order to stand on it).)
c. dem Felsen entlang {steigen / klettern}
(climb along the rock)
d. aus der Tonne {steigen / klettern}
(climb out of the bin)
e. *Peter klettert auf die Wolke
(Peter climbs onto the cloud)

So far, the lexical entries for both verbs would look like in (4), where x denotes the subject and P a path, and where the brackets denote the 'default' status:

(4)

'steigen'(x,P) go(x,P) DIRECTION: [upward]	,	'klettern'(x,P) go(x,P) MANNER: clambering

This is not all, however. Consider the following contrast:

(5) a. Peter klettert auf das Dach.
(Peter climbs onto-the roof)
b. Peter klettert vom Dach herunter.
(Peter climbs from-the roof down)
c. Die Lokomotive der Zahnradbahn klettert bergwärts.
(The locomotive of-the rack railway is climbing up-the-mountain.)
d. ??Die Lokomotive der Zahnradbahn klettert talwärts.
(The locomotive of-the rack railway is climbing down-the-mountain.)

In these examples we observe that a sentence becomes semantically problematic if both the PATH has been adapted to downward direction and the subject is a vehicle instead of an animate entity. We conclude that PATH adaptation to the object is just one aspect; the meaning additionally depends on the subject and, therefore, on MANNER information. This point will be taken up again later.

Before we go on to develop our own framework we will, in the next section, review a framework Jackendoff (1985) proposed for the verb *climb*.

2.2 Jackendoff (1985): *climb*

Jackendoff (1985) analyzes the verb *to climb* in a case study, and he lists evidence for both *climb* cases where only 'upward' and cases where only 'clambering' occurs as a feature. It follows that none of these features are necessary features, but at least one of these features must be present. Jackendoff proposes a lexical representation for *climb*, based on his 'Semantics and Cognition' (1983) framework (there are two architectural changes in Jackendoff (1991b), p .76, which matter only notationally), where both 'clambering' and 'upward' are treated as default features (marked with a P) in a so called 'preference rule system', which is a "collection of features or conditions on a category judgment, (i) any single one of which, under proper circumstances, is sufficient for a positive jugment. (ii) In the absence of evidence against any such feature in an item that has already been categorized on the basis of other features, the feature is assumed present by default. (iii) The more of the preference features that can be satisfied in a particular instance, the more secure the judgment, and the more stereotypical the instance will be judged. (iv) None of the features is necessary. But if none of the preference features in the system can be satisfied, a negative judgment results" [Jackendoff (1985), enumeration added]. In the Semantics and Cognition framework, five operators create trajectories: VIA / TO / TOWARDS / FROM and AWAY FROM (cf. Landau and Jackendoff (1993)). There is one optional subcategorization of an object phrase, denoted by $[\_\_\_\ (\text{XP}_j)]$. The curly brackets denote a choice of semantic constituents: depending on the semantic category (here: **Thing** or **Path**), one of the analyses is automatically chosen:

(6)
$$\left[\begin{array}{l} \textit{climb} \\ +\text{V}, -\text{N} \\ [\_\_\_\ (\text{XP}_j)] \\ \left[\begin{array}{l} \text{GO}(i, \left[\begin{array}{l} \left\{\begin{array}{l} \{j\} \\ \text{TO TOP OF } [_{\textbf{Thing}}\ j]\ \text{VIA } \left[_{\textbf{Place}}\ \text{ON } [_{\textbf{Thing}}\ j]\right] \end{array}\right\} \\ P(\text{UPWARD}) \\ \textbf{Path} \end{array}\right]) \\ P([_{\textbf{Manner}}\ \text{CLAMBERING}]) \\ \textbf{Event} \end{array}\right] \end{array}\right]$$

This architecture is able to cope with all situations Jackendoff discusses. Consider, for example:

(7)
$$\left[\begin{array}{l} \text{GO}(\text{Bill}, \left[\begin{array}{l} \text{TO TOP OF } [_{\textbf{Thing}}\ \text{ladder}] \\ \quad \text{VIA } \left[_{\textbf{Place}}\ \text{ON } [_{\textbf{Thing}}\ \text{ladder}]\right] \\ \text{UPWARD} \\ \textbf{Path} \end{array}\right]) \\ [_{\textbf{Manner}}\ \text{CLAMBERING}] \\ \textbf{Event} \end{array}\right] \; / \; \left[\begin{array}{l} \text{GO}(\text{Train}, \left[\begin{array}{l} \text{TO TOP OF } [_{\textbf{Thing}}\ \text{mountain}] \\ \quad \text{VIA } \left[_{\textbf{Place}}\ \text{ON } [_{\textbf{Thing}}\ \text{mountain}]\right] \\ \text{UPWARD} \\ \textbf{Path} \end{array}\right]) \\ \textbf{Event} \end{array}\right]$$

Bill is climbing (onto) the ladder. / The train is climbing (onto) the mountain.

(8) $\begin{bmatrix} \text{GO(Train, } [_{\textbf{Path}}\ \text{UPWARD}]) \\ [_{\textbf{Manner}}\ \text{CLAMBERING}] \\ \textbf{Event} \end{bmatrix}$ / * $\begin{bmatrix} \text{GO(Train, } [_{\textbf{Path}}\ \emptyset]) \\ \textbf{Event} \end{bmatrix}$

Bill is climbing. / * The train is climbing down the mountain.

However – looking closer, there are some critical points concerning this framework. We want to mention three of them. The first point of critique concerns the separation from neighbouring words. Consider example (9):

(9) a. The train climbed.
b. *The train went.

(10) a. The train climbed the mountain.
b. The train went up the mountain.

There are syntactic differences that are responsible for (9b)'s being syntactically wrong. In Jackendoffs lexical entry, this would be captured by different subcategorization rules. But, compare (10a) and (10b). One would like to claim that there are semantic differences, that there is more to the meaning of *climb* than only 'upward movement'. However, since 'clambering' is deleted with non-animate subjects, no difference to a simple *go* remains in Jackendoffs architecture for non-animate subjects.[1]

The second point we want to criticize is the way default constituents are used: "If the PP is incompatible with 'Upward', though, then 'Upward', as only a preferred condition, is suppressed (Jackendoff 1985)". This has two consequences. On the one hand, the default presence of features is representationally justified by the fact that stereotypicality increases with the presence of features. What is missing, on the other hand, is a justification of the deleting / suppressing mechanism: features are not deleted due to active counterevidence, but only due to incompatibilities in assigning features to objects, which results in both incorrect deleting and incorrect not-deleting. Consider (11):

(11) a. Bill climbed out of the hole.
b. Bill climbed out of the hole [and we know the hole's exit is at its bottom end]

In (11b) the 'Upward'-feature must be deleted in order to describe the situation. But, semantically, since *out of* is neutral with respect to vertical direction, there is no reason to eliminate 'Upward'. So, where does this information come from? Both syntax and semantics are not able to contribute that piece of information. In fact, Jackendoff's default deletion does not work here, since the information needed does not come from Semantics but from world knowledge. The deletion mechanism is more like a passive 'veto policy'

[1]For animate subjects the difference we feel can get quite small. Compare:

(i) a. Peter climbed the ladder / the stairs.
b. Peter went up the ladder / the stairs.

triggered by Syntax and Semantics, instead of an active search for a consistent solution.

The third point we want to criticize is a technical one: Despite the promise to offer a theory which is able to represent stereotypicality and family resemblance effects, the resulting architecture is not a framework where representations are derived from a prototypical core-meaning – but, in fact, it emerges as list architecture by simply rewriting (12a) as (12b):

(12) a.

	+UPWARD	−UPWARD
+CLAMB	Bill climbed up the hill	Bill climbed down the hill
−CLAMB	The train climbed up the hill	*The train climbed down the hill

b. climb_1: [... + UPWARD, +CLAMB ...]
climb_2: [... + UPWARD, −CLAMB ...]
climb_3: [... − UPWARD, +CLAMB ...]

To conclude, there is a class of context factors which Jackendoff's account is not able to deal with. Reviewing the discussion of neighbouring words, feature deletion and list architecture, three questions arise that a theory will have to cope with: First, what exactly does a feature (e. g. 'clambering') encode? Can the same be encoded in a more general way? Second, how can a lexical semantic verb entry both account for and profit from 'situation knowledge' instead of assigning and deleting features by rules? Third, is it possible to get a core meaning architecture from which possible readings are derived from several kinds of knowledge?

Keeping in mind both the questions that arose in the last chapter as a wish list which a new framework should be a able to cope with, and the type of problems Jackendoffs framework has to cope with, we will now take a new route towards a different framework. We will ask what exactly is the conceptual knowledge involved in motion processes, then propose a framework, give some formal definitions and end up with lexical and conceptual entries for the *climb* test case.

3 A conceptual toolkit

To begin with, we advance some hypotheses concerning architectural issues and check the inventory of formal conceptual knowledge encoding proposed in literature. To resume: In linguistic motion encoding, there is an interaction between subject / manner, path, and object.

> *This interaction is mainly located on the conceptual level. When one has in mind a concept of the moving subject, a concept of the path, and a concept of the object, then the movement patterns the object provides put restrictions on a possible path, which is also restricted by the shape and material character of the object. When providing all knowledge used, all motion situations of the kind klettern / steigen / climb can be lexically represented simply as 'a subject moves along a path by performing suitable manner patterns, where the path is located relative to the object in a position that the subject is technically able to be at'.*

Along these lines, discussion will lead us to the need for involving some pieces of physical knowledge in the analysis, for example in order to decide about the 'possible positions' subjects can take in space. In spite of their central role here, we will not discuss manner patterns in great detail – we have to postpone that to further work. What we will focus on here is the notion of PATH, which has attracted several attention in literature: There is a great variety of different definitions for PATH.

3.1 Path theories

Kaufmann (1993) and Piñón (1993) do not believe that the PATH information can be of any help in semantic modelling. Kaufmann (1993) argues that "… ontologically there is no such thing like a single object 'path'. […] 'path' is to be interpreted as some instantiation of the relevant properties. (p. 224)", while Piñón (1993) proposes a model-theoretic version, using an event-semantics, in which verbs are analyzed as predicates of events. He makes the assumption that Jackendoff's 'projected world' is identical to the real world. Hence, paths are entities in the real world, and thus play no role in modelling.

Eschenbach, Tschander, Habel and Kulik (2000) distinguish a *linguistic level* and a *spatial level* and see a path as a "bounded linear oriented structure" on the spatial level. A path has a geometry. In their framework, PP and verb specify motion: "The semantics of the verbs of motion is responsible for connecting the path with the bearer of motion". They use a first order predicate logic with λ calculus for representing semantic structure in a decompositional manner and link situations to paths via the predicate OCCURS-ON$(s, \text{GO}(\cdot, w))$. A Path is defined via a linear ordering relation: $\prec (w, Q, Q')$ and has marked points stpt(w) (starting point) and fpt(w) (final point). Hence, since a path is only fixed via stpt and fpt, it cannot be further localized in space. Finally, they hold the view that MANNER is completely independent from PATH.

Zwarts (2004) 's understanding of paths is more algebraic: He defines a path as having "a starting point, an end point, and points inbetween on which the path imposes an ordering:

> I will assume constructed paths, defined as continuous functions from the real unit interval $[0, 1]$ to positions in some model of space. The relation with positions is straightforward: the starting point of path p is $p(0)$, the end point is $p(1)$ and for any $i \in [0, 1]$ $p(i)$ is the corresponding point of the path. (Zwarts 2004)

Zwarts develops a *path algebra* $\langle P, \leq, + \rangle$ which we review as a promising approach: it copes with bounded vs. unbounded (*to* vs. *towards*) paths (cf. as well Zwarts (2003)). The formal definition of path combines two ways of modelling a path: Its architecture strikes a middle ground between a Kaufmann / Piñón -like notion of path, where nothing more than Source, Via and Goal make up a path, and a purely spatial notion of path where a path is modelled as a chain of points localized in space.

Comparing the theories mentioned so far, it turns out that not only PATH has been defined from different theoretical perspectives, but, looking deeper, there are different conceptions of how 'conceptual knowledge' is to be modelled and what its duty is in linguistic representation. The conceptions of conceptual knowledge can be roughly divided in (1) theories that strongly focus on the semantic side and use the conceptual side as 'all remaining information that is not semantics' and (2) theories that focus on the interplay between semantic and conceptual structure – which requires a more formal view of what conceptual knowledge is. And, to go one step further, when formalizing conceptual knowledge, one has to establish a definitional border between conceptual knowledge and a type of knowledge that is 'world knowledge'. We will discuss the role of spatial knowledge in the next subsection.

3.2 Conceptual vs. spatial knowledge

Jackendoff (1983, 1991) maintains the idea of an indirect linking of spatial cognition to language via conceptual structure which is seen as an interface between both. He defines PATH as 'the quantity of space traversed'. Although this looks like a spatial approach, the definition fits into the Conceptual approach, since conceptual constituents (like path) refer to entities in the *projected world* (and therefore not to entities in the real world). The interface to syntax and semantics is defined via the role of prepositional phrase constituents: Certain types of PPs are used referentially to pick out paths. 'On the other end of' conceptual knowledge there is the interface with the so called *Spatial Representation*, which encodes geometric properties of the world and relationships among them in space. Spatial Representations define TRAJECTORIES and PATHS. In a footnote, Jackendoff (1991a) underlines the need for specialized representations: 'However, conceptual structure is not the only form of representation available to encode one's understanding of the world. Aspects of the world that are understood spatially are encoded in another central representation whose properties resemble Marr's (1982) 3D model structure [discussed in many places in Jackendoff]; there may well be other central representations as well, for instance a "body representation" that encodes the position and state of the body. What distinguishes conceptual structure from these others is its *algebraic* character – its being formalized in terms of features and functions – and its capacity to encode abstractions' (p. 10, fn. 2).

Nikanne (2003), starting out from Jackendoff's (1983) indirect linking theory, discusses an example of the kind (13):

(13) Twenty scientists went to Konstanz

Semantically, the meaning of this sentence is that a movement of individuals has taken place and that, as a result, the individuals are located in Konstanz. Conceptually, we get the information that there is a Path whose goal point is Konstanz. This is where most analyses stop. Looking deeper, however, in order to see which situations can be described by the sentence, we become aware of an ambiguity that both semantic and conceptual information was not able to find: Two possible spatial settings arise from the plurality of subjects – either each single object is moving along its own path and all paths have the place Konstanz as a goal point, or the group of travelling scientists is treated as one group of objects traveling at the same time at the same speed in the same direction (like in 'the group of scientists is travelling together').

As a result, Nikanne claims the need for a framework with three levels, including interactions between them: first, the Linguistic Representation level. Each sentence on this level must have an interpretation in conceptual structure – the interpretation of sentences cannot violate the well-formedness constraints of conceptual structure. Second, there is the Conceptual Representation level. This level contains the PATH information that one of the features SOURCE, ROUTE (defined as a set of points) and GOAL must be present. In the current example (13) this is the information that the goal of the path is the place called Konstanz. The third representational level in Nikanne's proposal is the Spatial Representation level. It is the job of this level to derive spatial models for the possible situations arising from the information processing of Semantic- and Conceptual levels. In our example, a linguistic expression with a single (abstract) path may require *several separate paths* at the spatial level.

Note that one key point in Nikanne's proposal is that due to the filtering function of the Conceptual Level Semantic and Spatial level do not influence each other directly. We consider that proposal a desirable approach, since it promises to ensure a modular and encapsulated processing of both linguistic (i. e. general) and spatial (i. e. situational) information and to model information interaction via interfaces and inheritance processes. And, the strongest argument in favour of the three-level model, the lexical representation will be simpler due to shared responsibilities and avoidance of duplication of information among the levels.

In the next section, we develop these ideas towards an implementation in a formal framework. We will first define and describe the three levels we will use, then define interfaces between them as mapping functions, then infer a suitable architecture of lexical verb entries, and in the end come back to the case study described above in order to test the new framework.

4 The three-level model, formalized

Assuming the need of a third modelling level, and motivated by Nikanne's statement, we will propose some basic architectural issues of a three-level framework, keeping in mind the key features that information will be distributed among levels, duplication of information across levels will be minimized, and interfaces between the levels generate interaction – which will lead, altogether and due to specialization, to more simple lexical entries (both semantic and conceptual).

4.1 The levels

Semantic and Conceptual Levels. We distinguish the *Semantic Level*, the *Conceptual Level* and the *σ- (Simulated World-) Level.* On the *Semantic level*, relations among sentence participants are modelled compositionally (via structures accounted for by syntax): The verb selects arguments and builds relations between referents, while adjectives and adverbs modify parts of this structure. Each word has a (generalized) lexicalized meaning which will be part of the sentence meaning. On the *Conceptual Level*, conceptual knowledge about the relations and the referents used is encoded. For example, the conceptual knowledge of a PATH comprises that it has a GOAL, a VIA and a SOURCE information.

Parallel to the semantic composition process, the conceptual knowledge of the situation will be updated – in the PATH example, PLACES will be identified with GOAL, VIA or SOURCE.

The Simulated World Level. The third level is the *Simulated World (σ-) Level*. Its contribution is to simulate the relations between referents in a model, a process initialized by the Conceptual Level, which provides prestructured conceptual information as input. The σ-Level knows about settings in the real world – like the structure of space and time, physical laws like gravitation. Given conceptual knowledge of a potential situation, it proposes *possible configurations* and sends back a judgement of how situations described by a sentence fit into the reality the sentence producer is talking about (e. g. real world, space, fictive worlds, etc.). Note that unlike the other levels this level is not a level that provides data on objects and events, but rather specializes in inferring consequences following from relations between them. Its only ability is to 'know' real world's general settings. In a linguistic analysis, the its only concern will be the judgement if a sentence will make any sense in terms of the situation it describes and the environment the situation is expected to live in. However, given a framework interested in implementing events in real world – presumably a concern of AI research – this level can be used as an efficient interface to linguistic analysis.

Going back to the example of encoding motion verbs and situations, one (but not the only) crucial point is physical knowledge about space, objects, paths, gravitation, and so forth. In order to explain what is going on on these levels, we will build a fragment of a framework which will be able to deal with *klettern* and *steigen* situations. Let us start with some definitions.

Definition 2 (σ-world, σPoS, NEIGHBOUR(x_i, x_j)) *The σ-world is a model of a situation in the real world of this, where all influences of known forces and other known effects (physical forces, social influences) are taken into account. The set $\sigma\text{POS} = \{p_i \in$ 3dimensional Euclidean Space$\}$ is the set of all 'points of simulated space'. These points make up the σ-**world**. The position of the object in real world is mapped on point positions, where each object conceptually represented in a situation gets its place and role. Furthermore, let* NEIGHBOUR(x_i, x_j) *be a topological neighbourhood relation.*

Definition 3 (σ-Path) *A **Path** in the σ-world is a chain of points, two of which are designated as source and goal:*

$$\text{PATH} = \Big\{x_i \in \text{POS}, i \in [0..1] : \text{NEIGHBOUR}(x_i, x_j)\,\&\,\text{NEIGHBOUR}(x_j, x_k) \textit{ iff } i < j < k, x_0 = \text{'source'}, x_1 = \text{'goal'}\Big\}.$$

Note. It is not trivial to define *direction*: its basic definition would be a vector. But, the definition of the *direction of a path* is ambiguous: Since a path is defined as a set of points, each pair of points describes a vector. Vectors between neighbours as well as the vector from source to goal are candidates for specification of direction.[2] On the conceptual level, the same ambiguity can be found: What is the direction of a crisscross path? Is it 'criss-cross'? Or is it defined inherently via turn left, than right, then . . . ', or is

[2] One might define the first as *local* and the second as *global direction*.

it defined globally as 'from a to b, not mentioning the detours? Due to space limitations in this paper further details of this discussion are left out here.

Note. A path can have even more features. A curved path, for example, may have a radius and a middle point.

4.2 The interfaces

The task of the σ level is to build physical models of the situation, according to the knowledge provided by semantic and conceptual levels, in order to judge for physical (im)possibility of a situation described in the actual world settings. The procedure is as follows: In a first step, information about paths and things etc. is mapped from the conceptual level to σ level, using the function PoT:.

Definition 4 (PoT) *The function*

$$\textsc{PoT} : \textsc{Thing} \longrightarrow \textsc{PoS}$$

assigns to a thing $a \in \textsc{Thing}$ *(in the conceptual level) a set of points* $\textsc{PoT}(a) \subset \textsc{PoS}$ *('points of thing', in the* σ *level) such that* $\textsc{PoT}(a)$ *is a model of* a *in that it has identical shape and measure relations.*

Since conceptual knowledge does not offer all the information PoT needs to build a model, further knowledge has to be retrieved (be it from world knowledge, from looking at referents, or wherever else). This is exactly where impossible situations are filtered out. Imagine the processing of a sentence like *Peter climbed onto the cloud*. As soon PoT has built a model of a cloud and tries to fix the points of the path on it, the consistency of the cloud interferes and creates a contradiction. In a third step, the information that it is not possible to fix a path on a cloud such that an object can stand on it having contact to the ground is passed back via the conceptual level to the semantic level and creates the 'semantic oddness marks' ('??') as output. Note that there is no transitivity in that mapping, which means that each step has to be performed separately.

In order to deal with examples like *cloud*, the notion of a *surface* offers an interface to conceptual knowledge about objects:

Definition 5 (surface) *The set* $\textsc{Surface}(a)$ *denotes the points that physically form the surface of thing* a*:*

$\textsc{Surface}(a) =$
$\big\{x \in \textsc{PoT}(a) : \exists y \in \textsc{PoT}(a), \exists z \notin \textsc{PoT}(a) \left(\textsc{Neighbour}(x,y) \wedge \textsc{Neighbour}(x,z)\right)\big\}$

A thing a *has a* ***defined shape*** *iff*

$$\forall p \in \textsc{Surface}(a) \textit{ most'}\ q\big(\textsc{Neighbour}(p,q) \Rightarrow q \in \textsc{Surface}(a)\big).$$

Note that, for example, with *cloud* the model PoT will still consist of a defined number of points, but there will be no contiguous surface. In such cases we will need the set BoundingBox, which can be defined like that:

$$\forall p \in \textsc{PoT}(a) : \textsc{Inside}\big(p, \textsc{BoundingBox}(a)\big).$$

After having defined the levels and some interfaces, we are able to define the core parts of the framework: the information units, namely the concrete bits of information stored in the lexicon.

4.3 Towards a lexical entry

There are two kinds of information units which are both stored in lexicon: *lexical entries*, and *conceptual knowledge modules*. For the sake of an efficient design of the lexical entries (p. 6), one of our goals is to strictly avoid redundancy. Every piece of information is stored in only one place. We will present this in our toy scenario for *klettern* / *steigen*.

Lexical entries, conceptual knowledge modules. In the above discussion, we raised the questions if, first, there is a more general means of representation that can replace the feature pair ‘upward’ and ‘clambering’ that did not work out in all situations, second, whether situational knowledge can be made use of, and, third, whether this can lead to a core meaning architecture from which possible readings are derived due to several kind of knowledge.

We now list the lexical entries (in square brackets notation and with lambda variables) and the conceptual knowledge modules (in square boxes notation, partially formal). To start with, three verb entries, cf. (14):

(14) $$\lambda P \lambda x \begin{bmatrix} \textit{gehen} \\ \text{GO}(x,P) \end{bmatrix} \lambda P \lambda x \begin{bmatrix} \textit{steigen} \\ \text{GO}(x,P) \\ P : \text{HDP} \end{bmatrix} \lambda P \lambda x \begin{bmatrix} \textit{klettern} \\ \text{GO}(x,P) \\ \text{MANNER : CLAMBERING} \end{bmatrix}$$

In this information processing, the verb entries in (14) access the conceptual knowledge modules in (15b) and (15b):

(15) a.

GO(x, P): x : MOVABLE P : PATH “apply x’s default movement pattern ⇒ linearly change x’s position in the order given by P.”

b.

NTP (NONTRIVIALPATH) – RPP (RAREPLACESPATH) – HDP (HEIGHTDIFFERENCEPATH): going up by default.

In (15b), both RAREPLACESPATH and HEIGHTDIFFERENCEPATH are different kinds of NONTRIVIALPATHs, the first one defined via PLACE=“where an object can stand in its normal standing position” and the second using measuring distances in absolute height.

In (16) the ‘reach the top’ feature of ***be****steigen* is made necessary part via the unification of the PATH’s goal with y.OUTSTANDINGPLACE, which is the uppermost place of the object y one can stand on.

(16) $$\lambda y \lambda x \begin{bmatrix} \textit{besteigen} \\ \text{GO}(x,P) \\ P : \text{HDP} \\ y : \text{SOLID.OBJECT} \\ P.\text{GOAL} = y.\text{OUTSTANDINGPLACE} \end{bmatrix}$$

Finally, we are able to give a lexical entry for *climb* (17), which is a kind of unification of the entries proposed for the German equivalents:

(17) $(\lambda P/\lambda y)\lambda x \begin{bmatrix} \textit{climb} \\ \textsc{Go}(x, P) \\ P : \textsc{ntP} \\ P.\textsc{goal} = y.\textsc{outstandingPlace} \end{bmatrix}$

Choose the right features. In order to check if these lexical entries meet our intuition, let us track some features we would expect to play a role in the representation of the MANNER-PATH-verbs *klettern* and *steigen* – cf. table 1:

'movement'	definition of GO(x, P)
'upward'	conceptually encoded in the PATH constraints
'to the top' (in resultatives only)	(1) GO(x, P) $\Rightarrow$ reach `P.goal` iff P bounded (telic) (Zwarts 2004) $\wedge$ (2) P.GOAL=y.OUTSTANDINGPLACE $\wedge$ (3) conceptual definition of OUTSTANDINGPLACE.
'manner'	explicit in *klettern*, follows from SHAPE(P) in other cases.
'surface and contact'	definition of GO(X,P) together with type of x. $\rightarrow$ manner.

4.4 Applications

In order to test the proposed bits of information, we will now discuss a few example cases.

(18) ??Der Affe steigt. (the monkey is climbing (go up).)

In (18), x is of type ANIMATEOBJECT. Therefore 'GO(x, P)', links to conceptual knowledge about moving objects (like '[repeat(STANDON(PLACE $\subset$ PATH))]'). It follows that CONTACT is required – but there is no PATH in (18). Therefore, the sentence is not valid. In (19) the 'MANNER : clambering' doesn't fit the non-animate object.

(19) ??Das Flugzeug klettert. (the plane is climbing (clamber)).

Adding PPs. In all cases, the PP P introduces a PATH – the information PATH.GOAL := PLACE$(P.$GOAL$)$ is added. In (20b) *auf* links to being on a PLACE and having CONTACT. This is impossible since there is no solid surface. The case is different in (20c). In (20d) the definition of PLACE as horizontal solid area to stand on contradicts the fact that the wall is completely vertical. This is a case where the σ-level finds the contradiction.

(20) a. Peter steigt / klettert auf den Berg. (Peter is climbing the mountain.)
b. ?? Das Flugzeug steigt auf die Wolken. (The plane is climbing onto the clouds.)
c. Das Flugzeug steigt über die Wolken. (The plane is climbing to over the clouds.)
d. ??Die Fliege steigt die Wand hoch. (The fly is climbing (going up) the wall.)

Other directions. Since it is conceptually encoded that most subjects need contact to the ground ('x : ANIMATEOBJECT $\rightarrow \exists y \in$ SOLID.THING : PATH $\subset$ SURFACE(y)'), the path has to adapt in shape. Consider the following examples:

(21) a. Peter steigt / klettert der Dachrinne entlang.
(Peter is climbing the eaves gutter along.)
b. $\forall$ segment $\subset$ PATH : segment $\subset$ SURFACE(y) $(y$: SOLID.OBJECT$)$

(22) a. Peter steigt / klettert [vom Dach herunter]$_P$.
(Peter is climbing from-the roof down.)
b. PATH.GOAL := PLACE$(P$.GOAL$)$

(23) a. Peter steigt / klettert über den [Zaun]$_y$.
(Peter is climbing over the fence.)
b. PATH.GOAL := PLACE(RELBEHIND(y))
$\wedge\exists$ segment $\subset$ Path : OVER(segment, BBOX(x))

Other objects

(24) ??Das U-Boot steigt nach unten.
(The submarine is climbing to down.)

In (24), the submarine is freely floating without contact. The default feature ‘upward’ of the PATH cannot be deleted, since there is no object the path can adapt to. This fact, however, contradicts the PP meaning *to down*.

5 Conclusion

Analyzing the MANNER-PATH-verbs *klettern* and *steigen* in a case study, we found that there are situations in which knowledge available on the semantic and conceptual level is not enough to judge sentences describing situations. Therefore, we proposed a three-level division of representational knowledge into semantical, conceptual, and σ (simulated) level. Aiming at avoiding redundancies, this led to very simple lexical entries (and even a core meaning architecture), that access ‘conceptual knowledge modules’ when processing representational information. The retrieved information is checked by the σ-level, which may return ‘contradiction alarm’ in case the situation modelled does not fit physical reality in the world settings the situation lives in.

The framework we propose is different from frameworks proposed so far for MANNER-PATH-verbs in various respects. Its main goal is to derive information from the interplay between MANNER- and PATH-information and from the types of the objects involved. It uses conceptual and world knowledge, but keeps that information separate, which leads to small lexical verb entries. In contrast to Jackendoff (1985)’s analysis, our theory avoids family resemblance structure – it instead changes parts of the lexical entry depending on information provided by the objects. Technically, our framework uses formalizations of spatial representation, and in particular, the notion of PATH.

In a nutshell, what we want to argue for is not to exclude conceptual and world knowledge when doing lexical semantics but rather use their different architectures and viewpoints on information in order to make both linguistic representation and flow of information more efficient.

References

Eschenbach, C., Tschander, L., Habel, C. and Kulik, L.: 2000, Lexical specifications of paths, *in* W. B. C. Freksa, C. Habel and K. Wender (eds), *Spatial Cognition II - Integrating Abstract Theories, Empirical Studies, Formal Methods, and Practical Applications*, Springer, Berlin, pp. 127–144.

Jackendoff, R. S.: 1983, *Semantics and Cognition*, number 8 in *Current studies in linguistics series*, MIT press, Cambridge, Mass./London.

Jackendoff, R. S.: 1985, Multiple Subcategorization and the Θ-Criterion: The Case of CLIMB, *Natural Language and Linguistic Theory* **3**, 271–295.

Jackendoff, R. S.: 1991a, Parts and boundaries, *Cognition* **41**, 9–45.

Jackendoff, R. S.: 1991b, *Semantic structures*, number 18 in *Current studies in linguistics series*, MIT Press, Cambridge, Mass.

Kaufmann, I.: 1993, Semantic and conceptual aspects of the preposition ’durch’, *in* C. Zelinsky-Wibbelt (ed.), *The Semantics of prepositions. From Mental Processing to Natural Processing*, de Gruyter, Berlin, pp. 221–247.

Landau, B. and Jackendoff, R.: 1993, ’What’ and ’Where’ in spatial language and spatial cognition, *Behavioral and Brain Sciences* **16**, 217–238,255–266.

Marr, D.: 1982, *Vision*, Freeman, San Francisco.

Nikanne, U.: 2003, Some restrictions in linguistic expresssions of spatial movement, *in* van der Zee and Slack (2003), pp. 77–93.

Piñón, C. J.: 1993, Paths and their names, *in* K. Beals et al. (eds), *Chicago Linguistics Society 29*, Vol. 2, Chicago Linguistics Society, Chicago, pp. 287–303.

van der Zee, E. and Slack, J. (eds): 2003, *Representing direction in language and space*, Oxford Univ. Press, Oxford.

Zwarts, J.: 2003, Vectors across Spatial Domains: From palce to size, orientation, shape, and parts., *in* van der Zee and Slack (2003), pp. 39–68.

Zwarts, J.: 2004, Prepositional aspect and the algebra of paths, *Technical report*, Utrecht Institute of Linguitics, Utrecht Institute of Linguitics. unpublished paper, `http://www.let.uu.nl/users/Joost.Zwarts/personal/downloads.htm`.