Where Lexical Semantics Meets Physics: 
Towards an Algorithmic Lexical Framework for Modelling 
Path Motion

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Abstract

In linguistic encoding of motion situations, more information is hidden in  
the interaction of verb, subject, object and directional PP than a semantic  
composition framework is technically able to catch. One main concern of this  
paper is to show how this information can be used for situation determination  
and disambiguation in the domain of modeling linguistically encoded motion  
situations. In order to capture this information interplay, lexical verb entries  
share the responsibility to “look deeper into the situation”, using a formaliza-  
tion of conceptual knowledge. It will become clear that in such a model the  
path, as it spatially correlates the moving object and the reference environ-  
ment, is the main source of conceptual information emerging from situation  
modelling. After a case study of German steigen and klettern (both: climb)  
I propose a toolkit to model both semantic and conceptual knowledge and  
their interaction in modelling motion along a path: I will present both lexical  
entries and conceptual knowledge modules of the associated parts of informa-  
tion, to the effect that lexical entries take responsibility for the integration of  
the relevant bits of conceptual and contextual information.

1 Introduction

When we encode 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 (i.e. the generative  
view). However, it means more than just combining word meanings mechanically ‘in  
the right way’ to derive a sentence meaning that corresponds (truth-conditionally)  
to a real-world situation. This has led to complex lexical representations of word  
meanings that have to account for possible subcategorizations and exclude impossi-  
ble cases.
In this paper, the linguistic representation of motion verbs in the lexicon is discussed—and, thus, the linguistic representation of 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 (compared to more abstract linguistic domains): they can easily be judged on the basis of a normal portion of spatial and physical intuition, and straightforwardly modelled using physical models of objects, force antagonism and, resulting from the motion participants’ interplay, localisation in space. On the other hand, motion situations cause a vast amount of problems whose solution is hidden to purely linguistic analysis: Semantics as a “sparse and sparing knowledge system” does not in all cases capture all the information that is necessary to fully “understand” a real-world situation referred to by a linguistic utterance. There are effects constraining subcategorization that are deeply rooted in the conceptual representation of the interplay of all involved participants. Let me show some examples.

In (1), knowledge about the **object** is needed to validate the sentence in a situation: a cloud has no solid surface that could offer support, unlike the situational settings are changed (i.e. the context is shifted to fictuous). Thus, the sentence is marked as semantically implausible in “usual” world settings.\(^1\):

\[(1) ?? Paul stieg auf die Wolke. \\
(Paul climbed onto the cloud)\]

In (2), knowledge about the **manner information** in the verb is of central importance for a validation of the sentence in a situation:

\[(2) \begin{align*}
\text{a. } & \text{Das Kind / ??die Spinne / ?der Zug / ?? das Flugzeug stieg auf den Berg.} \\
& \text{(The child / ? the spider / ? the train / ?? the plane climbed onto the mountain)} \\
\text{b. } & \text{Paul / ???. das Flugzeug stieg herunter.} \\
& \text{(Paul / The airplane climbed down)}
\end{align*}\]

In (3), knowledge about both the **path** and the objects as conceptual entities play the central role (implying the question of what is, finally, the global direction, which will be discussed below):

\[(3) Paul stieg vom Gipfel ins Tal. \\
(Paul climbed from the summit into the valley)\]

And in (4), finally, reasoning about the final **spatial situation** is of central importance: how does the spatial setting determine truth, i.e., under which spatial

\(^1\)In this paper, one to three marks ‘?’ added initially to example sentences represent semantic or conceptual (un)acceptability not absolutely but only on a range from “semantic markedness” to, in the extreme case, implausibility.
circumstances can the moving object succeed in performing the described motion? In other words, can the model suggest a world setting which makes the utterance true according to what is physically possible in an explicit setting?

(4) Paul / ??Der Ballon stieg aus der umgefallenen Tonne
(Paul / ??The balloon climbed out of the hole [and we know that the hole’s only exit is at its bottom] )

1.1 Where does relevant knowledge come from?

The interaction of verb, subject, object and directional PP is a source of hidden information. When words are combined into a sentence in order to form an utterance which normally has an informative value, several steps of combining bits of information, searching for more information, and reasoning about consequences have to be applied. The initial information about meaning of a given sentence is ensured by syntax and semantics: On the semantic level, the word meanings are represented in a way so as to enable semantic composition of meaning. The verb selects arguments, and builds relations between the referents. From a conceptualist stance, syntax and semantics together can be said to behave as an interface between grammar and concept.

So – how should concept be defined? The tradition of Conceptual Semantics put forward by Jackendoff (1983, 1987, 1990), defines concept as “how people grasp the world”. The basic makeup of the conceptualist view is what I want to 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 which is the model of both world and situations we have in mind. Yeh and Barsalou (2000) define concepts as perceptual schemata, i.e. symbols: “We define a concept as the accumulated information in memory abstracted for a category, where a category is a set of things in the world perceived as the same type of thing (for one of many possible reasons).”. In Barsalou, Yeh, Luka, Olseth, Mix and Wu (n.d.) a differentiation between concept and word meaning is argued for: “concepts are models for types of individuals in world models; concepts are contextualized and local in scope to situations; word meanings use concepts but are not concepts.”

The theory in the current paper is building on the conceptual semantics tradition (but not necessarily bound to all its details, as will be discussed). For the purpose of this paper, concept is thus defined as a more or less underspecified symbolic model about objects, events and relations, making up an interface between the perceptual level, the semantic knowledge about linguistic participants in an utterance, and a possible real world situation the utterance refers to. Technically, on the conceptual

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2 Being aware of the fact that this is not a paper about defining concepts, I only distillate a working definition here, and refer to resources like ‘the big book of concepts’ (Murphy 2002) and all the conceptual semantics work by Jackendoff.
level, knowledge about objects and events is stored. This knowledge is used to enrich the situation representation with information that has been left undetermined by semantic processing. The flow of information while modelling is such that the model allows the semantic meaning composition to overgenerate readings (i.e. sentences that will be proposed by syntactic-semantic composition are taken into consideration, even if conceptually odd), and only later gets rid of conceptually inappropriate sentences while conceptually enriching the information structure and, in case, finding fact- or type mismatches that cannot be resolved. Thus, it is the concepts’ duty to filter out sentences that are conceptually odd. At the upper end of the scale of specifying an information structure, the situation model (here called σ-World) is located: it is almost fully specified; and it simulates the relations between referents in a model that knows about objects, gravitation, etc. It is able to propose possible real-world configurations. Note that the situation model is not to be considered a representation level of its own, it is rather the goal state that the specification process approaches while involving more and more situational knowledge. The situation model can be thus seen as the interface to real world situations with all their informative details.

In the current paper, I will present ideas on how to capture this information interplay and suggest that lexical entries are ‘algorithms’ that actively trigger the whole information flow. The data domain will be “motion encoding in language”. I will first present and discuss an example case and then suggest and develop some basics of a framework to model both semantic and conceptual knowledge and their interaction. The framework will systematically develop as a toy model for the verb cases under observation, and modelling will finally cumulate in proposals for lexical entries, and conceptual knowledge modules, and examples for conceptual rules and processes like Path Shape adaptation.

The hypothesis is that relevant information is hidden in the interaction of verb, subject, objects, and directional PP, and that this interplay of information can be challenged via lexical entries of algorithmic nature. The plan is, thus, to demonstrate how single components of the physical structure of a motion event can be taken as a “recipe to catch the interplay”. Therefore, a technical conceptual-semantic toolkit will be proposed and developed, which describes linguistic motion modeling as an algorithmic proceeding from sparse semantics towards fully-determined situation models.

Doing so, I am aware of the fact that in the course of modeling the entire situation description we gradually leave the realm of semantics, concepts and even linguistics and approach disciplines like artificial intelligence (when reasoning), ontology (when deriving information about object types), and other kinds of knowledge management (when involving even more related bits of knowledge). In this respect, this paper puts its emphasis “on the first few meters” of this path from words in a lexicon to a situation model; however it will not deny the necessity of further steps of combining knowledge, and even will sketch some of them, where the need arises. There will be cases where the conceptual level alone would not succeed – these are all cases where sentences are ‘out’ not due to conceptual factors but due to factors which
are brought in only by the contextual setting of the scenery. To deal with these cases – but not only these, as we will see – the model will be suited with tools how to include a formal finite subset of everyday world knowledge (like e.g. ‘gravity normally causes things to fall down’) in order to physically simulate and model solutions in accordance with the semantic and the conceptual level. I will refer to this inferencing tool as the simulated world.

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

Motion verbs are an ideal example for the interaction of information that takes place between verb, arguments, concepts and context: In the motion event, the object is normally responsible for (or even source of) a MANNER of motion (i.e. a collective term for all information about the process of an object moving, like how the motion is produced, and how the motion especially looks in terms of physical patterns); and this motion is located on a PATH which is made up from the places in space the subject has occupied at some point of time and related to background reference objects that offer physical support (which may be referred to as objects of motion sentences). Especially, the framework assumes manner information as implicitly omnipresent, even if not explicitly referred to as in verbs like *arrive* or *go*.

In this paper, I focus on one special kind of motion verbs: I call them MANNER-Path-verbs and define them as “Verbs of motion in combination with a { goal object NP / directional PP / directional adverb } where an m(oving)-object moves along a path in a certain manner , driven by forces, having support by a r(eference)-object.” English examples are verbs like *swim*, *climb*, *run*, *crawl*, among many others. As a sample, let me focus more narrowly on two German verbs: *klettern* and *steigen*. In a case study, I will focus on two questions: (1) how can *steigen* / *klettern* readings be formally described; which are selection restrictions, and to what degree do the meanings (not) overlap? (2) How does semantics, concept and situation both influence combinability with a Path PP and ‘profit from conceptual PATH information?

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

At first sight, both German verbs *klettern* and *steigen* 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.³

Path, direction, and the object. To begin with, consider examples where no object is present at all. While (5a) only seems to express an increase of height, (5b)
only expresses the manner of the monkey's movement; and in both cases only one of the options *steigen / klettern* is semantically good:

(5)  
   a. Das Flugzeug \{steigt / ??? klettern\}.  
       (The plane is climbing,)  
   b. Der Affe \{klettern / ?? steigt\}.  
       (The monkey is climbing.)

This distribution may lead to assuming that *steigen* is the path verb, semantically encoding a ‘+Upward’ feature, and *klettern* is the manner verb in a pair. Things become more complex, however, when a prepositional phrase comes into play, given as a second argument and introducing a PATH and an r-object. Given a PATH, at least one of \{goal, route, source\} is specified, which leads to a differentiation of *directions*: The overall direction of the motion in question is rooted in a correlation between the PATH specification (SOURCE and GOAL), manner patterns and features of the ground-object that offers support.

With animate r-objects *klettern* and *steigen* can be applied. The PATH specifies either GOAL, cf. (6a), VIA points, cf. (6b), or SOURCE, cf. (6c), of the motion at hand:

(6)  
   a. Peter \{steigt / klettern\} auf den Berg.  
       Peter is climbing up the mountain.  
   b. Peter \{steigt / klettern\} dem Felsen entlang.  
       Peter is climbing the rock along.  
   c. Peter \{steigt / klettern\} aus der Tonne / in die Tonne.  
       Peter is climbing out of the bin / into the bin.

Note that unlike (7), where the PATH explicitly introduces a downward direction (*herunter*), in (6) the feature +UPWARD has remained unchallenged as semantic piece of information, as it seems. However, neither (6b) nor (6c) explicitly specifies upward direction. Hence, it need no longer be true in all cases that UPWARD holds: in (6b) the sentence denotes a movement along the surface of an r-object – which may be vertical and then lead to a path that is no longer upward.

More knowledge. As we saw, there are cases where semantic information alone is not able to fully determine the spatial setting. The problem becomes even more clear in (8), where it is only world knowledge that causes an inference to the ‘downward’ setting:

(8)  
   vom Gipfel in das Tal \{steigen / klettern\}
(climb from the summit into the valley)

It may be in the concept of *Gipfel* (*summit*) that it is the highest point of a mountain, and it may be in the concept of *Tal* (*valley*) that it is the deeper region near a mountain, but the fact that the fact that a Path from a summit to a valley is globally downwards, first, only arises from spatial reasoning and, second, need not even always be true – consider the case of the summit as a local summit and the valley as being located even higher within the global geographic setting.

In this family of cases one can also find situations where not the meaning encoded in the verb finally causes rejection of a sentence, but alone the conceptual knowledge about the object. For instance, the knowledge that a cloud cannot offer support for a human (in a normal nonfictuous setting) makes (9) odd:

(9) ???Peter steigt / klettert auf die Wolke.
   (Peter climbs onto the cloud)

In more general terms, what such cases suggest is that modelling of the path in a motion situation will here proceed towards a process where the Path adapts according to the r-object’s shape, the m-object’s support request, and the shape of the motion patterns involved. This will be discussed in detail further down.

**Inanimate m-objects.** Jackendoff (1985) observes for *climb* that a sentence becomes semantically problematic if both the Path denotes a downward direction and the subject is a vehicle and thus no animate entity. Coming back to this circumstance at length in both the current and the modelling section, I will claim, however, that this is only a syntax/semantic distinction, and that things are not as clear, though.

Compare now situations with animate object (cf. (10) below), with inanimate but moving object (cf. (11)), and with abstract object (cf. (12)).

(10) a. ???Der Affe *steigt*.
    the monkey is climbing (go-upward)

b. Der Affe *klettert*.
   the monkey is climbing (clamber)

c. Der Affe *steigt / klettert* auf den Baum.
   the monkey is climbing on the tree

(11) a. Das Flugzeug *steigt*.
    the plane is climbing (go-upward)

b. ???Das Flugzeug *klettert*.
   the plane is climbing (clamber)
c. Das Flugzeug steigt / (?) klettern auf 10000m Höhe.
the plane is climbing to 10000 meters of altitude

(12) a. Die Temperatur steigt.
the temperature is increasing (go-upward)
b. Die Temperatur klettern.
the temperature is increasing (clamber)
c. Die Temperatur steigt / klettern auf 30 Grad Celsius.
the temperature is climbing to 30 degrees Celsius

It can be observed that in all cases where a PATH is involved, both klettern and steigen readings become more acceptable, independent of the animateness of the m-object. An interpretation can be that exactly if the verb denotes a motion pattern (‘a manner’) which is architecturally available in the m-object, then it may denote an activity; and an implicit path, which need not be explicitly not mentioned, can be conceptually inferred from the motion patterns involved. In such situations, the VP alone makes up a reasonable sentence. A +dir-PP which is explicitly mentioned (as in the c. cases) then explicitly denotes PATH information, which is conceptually integrated in the motion scenario (i.e. co-composition in frameworks like Pustejovsky (1995)). If, however, the verb denotes a motion method which is not basically in the objects’ motion methods (as Affe steigt), it cannot be an activity, and an implicit path cannot be inferred from motion method patterns. In these cases, the path co-composes to the (undetermined!) fact that any motion takes place, and the pattern denoted by the verb is then ‘superimposed’ on the situation at hand, which only at the surface appears like ‘adding a path to a motion pattern’. Thus, the combination of Path and verb yield new possible scenarios (c.-cases). (I elaborate on this effect in Weisgerber (2007).)

2.2 klettern and steigen: which features, finally?

So far, we have seen that the meaning of German klettern and steigen in all the possible scenarios is a complex combination of direction, motion methods which the m-object can offer, and support features the m-object requests and the r-object provides: The height-difference structure of the path shape is significant, especially that the path is not entirely flat, but that it is by no means the case that all klettern and steigen situations denote an upward motion. The overall direction of the global path (i.e. the direction of the whole motion as such) is a product of its more fine grained sequences, and path shape of the motions described are dependent of the interplay of the motion methods of the m-object and the support topography provided by the r-object. Altogether, it looks as if a conceptual description of what is exactly going on in a specific motion, subsumed in what linguists have called ‘manner’, plays a key role in modelling the meaning of both verbs. Thus, we have to decide, which semantic and conceptual description should be entered in the lexicon for to model steigen and klettern. Consider four more example cases in several varations:
One can observe the following: *klettern* better models the motion of the m-object rack railway locomotive than *steigen*, and *klettern* better models upward motion than downward. Only in combination with an explicit measure phrase for absolute altitude (bis 1000 Meter), *steigen* becomes a good alternative. There is no effect based on the −ANIMATE feature. This leads to the suspicion that it is indeed not this feature that plays a role for meaning distinction in *klettern* and *steigen*.

An explanation for the case ‘mountain train’ can be given regarding a feature ‘Effort’: If *klettern*+‘Upward’ is acceptable (13a), but not *steigen*+‘Upward’ (13b), then one can argue that a bias towards effort is involved in the situations, and that this feature is part of the concept *klettern* but not *steigen*. This also explains why in situations with a strong focus on effort even *klettern*+‘Downward’ (13c) becomes acceptable, but not *steigen*+‘Downward’ (13d).  

An explanation for the measure phrase (13e) (*steigt bis*) can be given along the following lines: We have seen that *steigen*, without an r-object mentioned, has a strong focus to express an ‘Upward’ path motion, while *klettern* in the same setting has a strong focus to express an activity with no path in focus. Adding an r-object, this focus is shifted to the motion patterns in interaction with the support of the r-object, which leads to path shape adaptation (see below for technical details) and

\[4\]

*For English *climb*, the case seems to be even more clear cut: In their analysis for *climb*, Geuder and Weisgeber (2002) suggest a distribution along two dimensions ‘direction’ and ‘effort’, similar to Dimitrova-Vulchanova, Martinez, Edsberg and Røst (forthcoming) in this volume.
which is then to be checked for conceptual consistency as in cases a. to d. ; while adding a measure phrase for absolute altitude evokes a strong focus on the global path feature ‘Direction’ in both verbs.

Consider now the ‘balloon’ case:

(14) ‘Case: Balloon’

a. Der Heißluftballon steigt / ???klettert.
   The hot air balloon is climbing (go up) / is climbing (clamber)

b. Der Heißluftballon / das Flugzeug steigt / ? klettert auf über 1000
   The hot air balloon / the plane is climbing to over 1000
   Meter.
   meters

c. #Der Heißluftballon / das Flugzeug steigt / klettert auf den Baum.
   The hot air balloon / the plane is climbing on the tree

As in the ‘airplane’ case, the motion at hand seems significantly different to patterns discussed so long. Both airplane and balloon do not interact with an r-object with a hard surface, and the balloon seems not even to be actively involved in an interaction with its environment in order to get support.

Since klettern “is not too good” here, we do learn anything new from that (but we even get support for the ‘effort’ hypothesis: if a sentence like b.2 ‘Das Flugzeug klettert’ can be uttered, it almost metaphorically points to a situation involving big effort). If looking more closely at the steigen situations in a. and b., there is one significant fact in common: in these, as well as in all imaginable klettern / steigen situations, the object is able to overcome gravitation since it is in interaction with a supporting ground object or medium. If it does not actively move, as in the balloon case, this force antagonism is part of its defining features: a balloon is built such that it overcomes gravitation by architecture. In Weisgerber and Geuder (2007) we thus defend the hypothesis that it is “Common to all steigen situations […] that the object provides a force to overcome gravitation”. Within a theorizing about conceptual and mental representation of motion physics, we conclude that thus the object is conceptualised as having an upward impetus.

This however means that force constellation is defining for spatiophysical situations, and not alone manner information, as Jackendoff and other theories put it. Especially, it follows that the resulting direction of a motion is not encoded in the verb’s concept or semantics, but depends on the interaction of m-object and r-object, which may be only a ‘medium’, along a Path. Upward motion is then only a consequence in some settings. In Weisgerber and Geuder (2007) we argue for English climb down that the motion pattern only in sum yields a downwards motion, these local patterns in which force is involved, i.e. ‘making steps’, all include putting force vertically against gravitation. That means, conceptually there is indeed a common conceptual core for steigen, which is: “vertical force exertion against gravity”!
The failing of the utterance in c. is due to another reason: Conceptual reasoning about possible paths that result from flying or lying in the air, as planes and balloons do, cannot result in goals like on the tree – which is simply due to spatiophyscial reasons.

At this point, it seems necessary to come back to two examples which seem to cause irritation with respect to both the force distribution and the role of the feet in steigen and klettern: Consider (15) with the animate object snake, whose manner of movement involves active force, but no feet, and, in contrast, whose manner of movement involves feet, but makes the impression not to involve effort:

\[(\text{15) ‘Case: Snake’})\]

\[
\begin{align*}
\text{a. } & \text{Die Schlange } \textit{steigt} \quad \text{auf den Baum / vom Baum} \\
& \text{The snake is climbing (go up) on the tree / from-the tree} \\
& \text{herunter.} \\
\text{b. } & \text{Die Schlange } \textit{klettern} \quad \text{auf den Baum / vom Baum} \\
& \text{The snake is climbing (clamber) on the tree / from-the tree} \\
& \text{herunter.} \\
\text{c. } & \text{Die Schlange } \textit{kriecht} \quad \text{auf den Baum / vom Baum} \\
& \text{The snake is crawling/creeping on the tree / from-the tree} \\
& \text{herunter.}
\end{align*}
\]

\[(\text{16) ‘Case: Spider’})\]

\[
\begin{align*}
\text{a. } & \text{Die Spinne } ???\textit{steigt} \quad / ???\textit{klettern} \quad / \textit{krabbelt} \\
& \text{The spider is climbing (go up) / is climbing (clamber) / is creeping} \\
& \text{+PATH} \\
& \text{+PATH}
\end{align*}
\]

In both cases, both klettern and steigen seem to be bad alternatives, and other manner verbs are preferred, especially, the reader may share the author’s intuition that the steigen variants are even worse than klettern. Since steigen semantically require the use of feet for all objects that interact with a ground object, it can be excluded. How, however, can the klettern case be explained, especially for the spider case?

A straightforward explanation could be given by blocking: since there is a “more suitable verb”, namely kriechen (crawl/creep) for snake, and krabbeln (crawl on limbs) for spider, both steigen and klettern are simply linguistically blocked. However, let us look for a more conceptually triggered explanation.
The marginal effect that for Spinne, klettern is better then steigen points again to the ‘Effort’ feature: if a spider’s motion involves height difference, there seems not to be more effort involved. This points to the following explanation, which can be subsumed as ‘conceptual blocking’: given that a spider is able to sit on the wall, which is physically possible due to adhesion forces, these forces are stronger and conceptually more central as gravity. Therefore, it can be argued that for the spider case, as well as the snake case, the reference system which must be conceptually applied is not directed towards absolute down (as in the gravity case) but orthogonally against the surface, i.e. in the case of wall or tree trunk it is turned by 90 degrees. This conceptually blocke the application of the ‘antagonism against gravity’ setting, and thus, an analysis in terms of klettern and steigen.

There is another explanation, which speaks in favour of the krabbeln (creep on limbs) pattern for the spider case, and which explains another reading of steigen, and focuses on another contrast between steigen and klettern. Consider the ‘step over’ case:

(17) ‘Case: Step over’

a. Paul steigt / ??? klettert über das Matschloch
   Paul is stepping / climbing over the hole of mud
b. Die Spinne ?? steigt / ??? klettert über das Matschloch
   The spider is stepping / climbing over the hole of mud
c. #Der Heißluftballon steigt über das Matschloch
   The hot air balloon * is stepping over / is climbing to-over the hole of mud

In a step over situation, not too much force is involved – and what constrains the situation is simply the available steplength the m-object can provide (which may, again, cause rejection of sentences due to not-semantic reasons). Thus, the stepping over pattern is conceptually defined as applying the limb-motion pattern exactly once and ending up located at the other side of the r-object. This is what excludes both klettern as pattern and Spinne as m-object. The conceptual core of klettern includes that at each point of time, there is a support situation which is physically stable, i.e., could last for a longer time; this is not the case in steigen which involves unstable dynamic settings in each cycle.\(^5\)

\(^5\)This has an interesting consequence, which points at a conceptual explanation for the bias of steigen towards being a ‘Path verb’, and klettern being a ‘Manner verb’: steigen is clearly divided in cyclic episodes, which follow each other, and thus, by repetition of episodes, the complexity of the pattern does not increase. In klettern on the other hand one cannot find these different cycles (which is then a reason that klettern is not a child of the make steps concept, while steigen is): klettern is not “trivially iterative”, but consists of interrelated patterns of being localized in a stable fashion with some limbs, and moving other limbs in the same time to replace this stable constellation in space by another one. In sum, this points to a contrast where klettern, as a more complex situation concept, is perceived as a texture, while steigen is perceived as a Sequence. This
Reading c. fails due to the fact that the balloon does not offer a motion method involving feet, therefore the scenario must be interpreted as a ‘Goal of PATH’ reading.

To conclude: I propose that klettern and steigen is based on the core concept that the object provides a force to overcome gravitation. All features that make up concrete steigen and klettern scenarios can be derived from this core concept based on information about the m-object with its motion methods, the r-object with its support features, and the their complex interaction while moving along a path. Comparing different readings, we find that the distinction between klettern and steigen involves a systematic effect: steigen puts more emphasis on the direction which is upward or adapted due to interaction; a significant set of steigen situations involve limb motion along the surface of an r-object, or even contain no manner information at all. On the other hand, klettern puts more emphasis on effortful manner with a stable support situation at each point of time. Possible paths follow from this via spatial reasoning. The common feature ‘Effort’ follows, in the steigen case, more from height difference, and in the klettern case more from the complexity of the stability-of-support pattern.

<table>
<thead>
<tr>
<th>Common core: Force against gravity.</th>
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<tbody>
<tr>
<td>steigen</td>
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<td>∅</td>
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<tr>
<td>Path ‘Upward’ unless adapted</td>
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<td>‘instable dynamic intervals’</td>
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Before I go on to develop the current framework I will, in the next section, review the framework proposed by Jackendoff (1985) for the verb climb.

### 2.3 Jackendoff (1985): climb

Jackendoff (1985) lists evidence for both climb cases where only ‘upward’ and cases where only ‘clambering’ occurs as a feature: he concludes from English examples that none of these features are necessary features, but at least one of these features must be present. He proposes a lexical representation for climb, based on his ‘Semantics and Cognition’ framework (Jackendoff (1983, 1987, 1990)), where five operators model trajectories: Via / To / Towards / From and Away From (there are minor architectural changes in Jackendoff (1990), p.76, which matter only notationally):

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would create a severe difference between both verbs in a system like Landau and Jackendoff (1993) propose.
In the lexical entry for *climb*, there is one optional subcategorization of an object phrase, which is indexed in order to be later referred to in the semantic structure, denoted by \([ XP]_j\). The curly brackets denote a choice of semantic constituents: depending on the semantic category of the constituent \(XP_j\) (here: \(XP\) is either of type *Thing* or *Path*), one of the analyses is automatically chosen. Both ‘clambering’ and ‘upward’ are treated as default features (marked with a \(P(\cdot)\)) in the so called ‘preference rule system’: none of the features is necessary, but at least one must be present.\(^6\)

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

\[(19)\]
\[\begin{align*}
\text{a. } & \text{Bill is climbing (onto) the mountain.} \\
\text{b. } & \text{The train is climbing (onto) the mountain.}
\end{align*}\]

\[(20)\]
\[\begin{align*}
\text{a. } & \text{Bill is climbing down the mountain.}
\end{align*}\]

\(^6\text{A prefernece rule system 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 judgment. (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].}\]
b. \[
\text{Go}(\text{Bill}, [\text{Path} \downarrow \text{down the mountain}])
\]
\[
[\text{Manner CLAMBERING}]
\]
\[
[\text{Event}]
\]

c. *The train is climbing down the mountain.*

d. – NO MODEL –
(The preference choice rule requests that at least one element of the \(P(\cdot)\) elements is chosen. Here no element is found – this leads to a runtime error, and the modelling fails. That means: semantic constraints are technically modeled as failure in process.)

If more linguistic data is considered, and more nontrivial scenarios added, however, there appear some critical points concerning this framework. I want to mention four of them.

(Critique 1). The first point of critique concerns the behaviour of the lexical entry in the cases where no Path and no Object is explicitly present at all. Consider:

\[(21)\]

a. The train climbed.

b. Peter climbed.

The lexical entry offers a choice between ‘To Top Of \([\text{Thing } j]\)’ and just ‘\(j\)’, if \(j\) is of the type Path. But what, if there is no \(j\), as in example (21)? What is chosen then? Either, if the ‘algorithm’ behaves in a strict way, the modelling process fails due to missing data (since the XP\(j\) in the subcategorization frame is marked optional, but not the \(j\) itself). (21a) is then out, but also (21b).

An alternative view is to assume, instead of the constituent \(j\) itself, an underspecified slot which can be specified by a \(j\). Then one has to define how to deal with situations that remain underdetermined. One alternative is to assume \(\exists P\), then fill the \(j\) slot with this implicit path, and then to treat the UPWARD feature as a default. Then (22) would be the outcome, respectively\(^7\) – note especially, that The train climbed is not rejected:

\[(22)\]

\[
\begin{align*}
\text{Go}(\text{bill}, [\text{Path} \exists P, \text{UPWARD}])
\end{align*}
\]
\[
[\text{Manner CLAMBERING}]
\]
\[
[\text{Event}]
\]

Bill is climbing. / The train is climbing.

An alternative is to allow for a pure manner-verb without path specification. Then the whole path information must be treated as optional. Then the train variant in

\(^7\)The \(\exists P\) in the path slot has been inserted by the author of the current paper. It is a sketchy abbreviation and not necessarily an elegant solution.
(22) does not appear, since none of the features CLAMBERING and UPWARD is then left.

If a PP comes into play, another weak point of the model emerges: for non-animates, there is no representational difference left between go upward and climb upward (compare (23a) and (23b)), if I assume that Jackendoff’s ‘Clambering’ is reserved for animates:

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

One would like to claim that there are semantic differences, especially that there is more to the meaning of climb than only ‘upward movement’ (there is, for instance, slowliness of motion, difficulty in getting forward, effort). However, since ‘clambering’ is deleted with non-animate subjects, no difference to a simple go remains in Jackendoff’s architecture for non-animate subjects.\(^8\)

(Critique 2). The second point to be criticized here is the way default constituents are used: Which participant in modelling has the role to eliminate the ‘Upward’ feature, if not semantics does it? And, even more basically, what is the meaning of ‘Upward’? “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 only deleted in case “the PP is incompatible with ‘Upward’, and only if this information is explicitly semantically available. 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. This can be seen in (24):

(24) a. Bill climbed out of the hole.
    b. Bill climbed out of the hole until he reached its exit at its bottom end.

In (24b) the ‘Upward’-feature is not compatible with 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 this piece of information. In fact, Jackendoff’s default deletion does not work here, since the information needed does not come

\(^8\)And not only for non-animates – compare the snake-example above. It is a general observation that for animate subjects the difference can indeed get quite small. Compare:

(i) a. Peter climbed the ladder / the stairs.
    b. Peter went up the ladder / the stairs.
from Semantics but from reasoning with further information given by context. This failure occurs at least at the point of time of modeling; if the framework is embedded in an environment that supports collecting context information and backtracking, the information may be deleted later. The deletion mechanism is more like a passive ‘veto policy’ triggered by Syntax and Semantics, instead of an active search for a consistent solution.\(^9\)

(Critique 3: Possible Paths?) The question concerning the ‘Upward’ feature is even more general if one considers the possible conceptual realizations of the path. First: what is ‘Upward’, after all? If a path is represented more finegrainedly defined (which should be the case here; cf. van der Zee and Nikanne (forthcoming, this volume) on Path Shape Granularity) and thus as a sequence of locations, then each vector from a path point to a later path point may be able to define a direction, – it seems that it is conceptually not determined how globally or locally ‘direction’ is to be defined in a certain context.

Another source of conceptual mis-modeling is located in Jackendoff’s representation: ‘To Top Of’ in (18) implies contact to the r-object in each point of the motion path. This leads to conceptual contradictions, where (25) cannot be modelled correctly, since a modelling as in c. is not possible due to architecture, where both slots have to be filled with the same object \(j\) – either both are ladder, or both are tree:

\[
\text{(25)} \quad \begin{align*}
\text{a.} & \quad \text{Peter climbed the tree with a ladder.} \\
\text{b.} & \quad \text{wrong conceptual representation:} \\
& \quad \text{To Top Of [Thing Tree] Via [Place On [Thing Tree]]} \\
\text{c.} & \quad \text{better, but data mismatch error:} \\
& \quad \text{To Top Of [Thing Tree] Via [Place On [Thing *Ladder]]}
\end{align*}
\]

(Critique 4). The last point I 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 (26a) as (26b):

\[^9\]This discussion may lead to the general question about role and behaviour of defaults. In short, I suggest that defaults can be classified along two dimensions: first, how early they are assigned in the process of modelling (in some models, the lexical entries already contain defaults, and in other models, defaults are assigned at the end of the modelling process in order to ‘finish’ a representation), and second, how ‘intelligent’ is a default. A first step towards restricting a default’s domain of influence could be encapsulation: a default can only be overridden by a certain kind of additional information. A far more cooperative default would be one that autonomously and regularly checks for reasons of its own existence and disappears or changes its content, in case. This kind of architecture, however, would be quite untypical for a ‘default’, as theory normally uses it, it is rather to be located in ‘agent’ models – which, thus, can be a means to make default models more attractive.
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(26) a. +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. climb₁: [\ldots +UPWARD, +CLAMB\ldots ]
   climb₂: [\ldots +UPWARD, −CLAMB\ldots ]
   climb₃: [\ldots −UPWARD, +CLAMB\ldots ]

2.4 Conclusion

To conclude, there is a class of context and real-world knowledge factors which
Jackendoff’s account is not able to deal with (at least in the case of climb considered
here) – factors which, at least, seem to be helpful in fully determining the utterance
meaning in linguistically given situations which relate to complex physical real-world
settings. The role of conceptual knowledge in Jackendoff’s model remains restricted
to some predefined decision processes in semantic modelling.¹⁰ A pure preference
semantics seems not to be adequate here. In sum, the choice of ‘readings’ for climb
situations depends on conceptual and world knowledge. The framework proposed
in the following thus aims at involving more complex features that link to more
complex knowledge.

Reviewing the discussion, three questions have arisen 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, despite great diversity on
so many dimensions of knowledge involved, a sparse and sparing core meaning
architecture from which possible readings are derived from several kinds of knowledge
by algorithmic processes of search and information retrieval?

Just to mention a quite simple example: Given that only the Syntax-Semantics
interface is responsible for choosing Subjects, example (27) would be modelled as
if semantically ok. And — which mechanism, by the way, cares about the subject
choice effect in (28)?

(27) ???Peter is climbing onto the cloud

(28) a. The train climbed the mountain.
   b.???The train climbed the ladder.

Keeping in mind both these questions, and the type of problems Jackendoff’s frame-
work has to cope with, as a wish list which a new framework should be able to

¹⁰Zwarts and Verkuyl (1994) show how Conceptual Semantics can be redefined as traditional
model theory semantics.
cope with, I will now take a new route towards a different framework. I will ask what exactly is the conceptual and spatial knowledge involved in motion processes. I will propose a framework, give some formal definitions and end up with lexical and conceptual entries for the German counterpart of the climb test case. Along these lines, the 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, I will not discuss manner patterns in great detail (but see Dimitrova-Vulchanova et al. (forthcoming), this volume, and Weisgerber (2006) for an investigation, and further work). What I will focus on here is both the notion of Path – which has attracted some attention, there is a great variety of different definitions in literature – and the role of conceptual knowledge.

3 Conceptual vs. spatial knowledge

Conceptions of conceptual knowledge that have been proposed can be roughly divided in (1) theories that differentiate between a semantic and a conceptual component (cf. the treatment of motion in Kaufmann (1995), and cf. Bierwisch and Lang’s (1989) two-level semantics), often treating the latter as ‘all remaining information that is not semantics and therefore not formalized’ (as is done, for example, in model-theoretic semantics), (2) cognitivist theories that assign all the modelling work to an non-formal representation level, cf. Lakoff (1987), and (3) theories that focus on explicitly modelling the interplay between semantic and conceptual structure. Such frameworks are, among others, Jackendoff’s Conceptual Semantics (cf. Jackendoff 1983, 1987, 1990), who maintains the idea of an indirect linking of spatial cognition to language via conceptual structure which is seen as an interface between both), Pustejovsky’s (1995) Generative Lexicon, and Barsalou et al’s (1992, 1993) frame theory.

Theories of the second kind require 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’. I therefore argue for the need of involving both knowledge about and reasoning with a notion of ‘spatial representation’.

Jackendoff (1983, 1987, 1990) maintains the idea of an indirect linking of spatial cognition to language via conceptual structure which is seen as an interface between both: The central idea of his account is formalized in the ‘Thematic Relations Hypothesis’, based on Gruber (1976), hypothesizing that concepts of space and motion are basic for all other conceptual domains, and all semantic primitives can be derived from spatial cognition more or less directly.\(^\text{11}\)

Jackendoff defines Path as ‘the quantity of space traversed’. Conceptual constituents (like path) refer to entities in the projected world (and therefore not to

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\(^{11}\)Technically, this materializes in indices like Go\text{mental}. This is not further discussed here.
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 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 Landau and Jackendoff (1993), Spatial Representation is described as ‘a format or level of mental representation devoted to encoding the geometric properties of objects in the world and the relationships among them in space.’ What Landau and Jackendoff do not offer is more formal insight in how and where this encoded knowledge can be made use of in linguistic processes.\(^\text{12}\)

Nikanne (2003), in his concluding discussion, underlines the need for a framework with three levels, including interactions between them: the Linguistic Representation level, the Conceptual Representation level, and the Spatial Representation level. The Conceptual Level contains the *PATH* information that one of the features *Source*, *Route* (defined as a set of points) and *Goal* must be present. Each sentence on the Linguistic Representation level must have an interpretation in conceptual structure – and the interpretation of sentences cannot violate the well-formedness constraints of conceptual structure. The third level in Nikanne’s proposal, the Spatial Representation Level, has the job to derive spatial models for the possible situations arising from the information processing of Semantic- and Conceptual levels. In Nikanne’s example *twenty scientists went to Turku* the goal of the path is the place called Turku. In this example, a linguistic expression with a single (abstract) path requires *several separate paths* at the spatial level. One key point in Nikanne’s proposal is that due to the filtering function of the Conceptual Level, the Semantic and the Spatial level do not influence each other directly – in parallel to Jackendoff’s framework. Thus, the proposal 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 reduplication of information among the levels – we will see examples.\(^\text{13}\)

In the next section, these ideas are developed towards an implementation in a formal framework. First the information structure and information flow will be described and defined, a suitable architecture of lexical verb entries will be inferred and applied in a final case study on the *steigen / klettern* data described above, in order to test the new framework. I hypothesize:

\(^{12}\)In a footnote, Jackendoff (1991) 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, footnote 2).

\(^{13}\)Note however, that complexity does not disappear when only rearranging information – as soon as lexical entries get more minimalistic, the interface gets a greater load (cf. Jackendoff).
Hypothesis 1 There is an interaction between subject, manner, path, and a ground object. This interaction is located on all modelling levels: The movement patterns provided by the subject (i.e. a moving thing) put restrictions on a possible path, which is also restricted by the shape and material character of the ground object. Provided all this knowledge, all motion situations of the kind klettern / steigen / climb can then be lexically represented as “a subject moves along a path by performing suitable manner patterns, where the path is located relative to real world environment denoting positions that the subject is technically able to be at”.

The second working hypothesis, which is of technical nature, is:

Hypothesis 2 Lexical entries are algorithms.

This hypothesis will guide the process of technically designing the framework. In keywords, being algorithmic means the following: Above all the architecture has to be completely well-defined. This includes: (1) a well defined Input structure defining all the constituents dealt with in this algorithm; (2) determined Processes as functions, especially recursive calls, search routines and retrieval and including of further information; (3) access to a well defined formal data set; (4) and finally a well-defined format for possible output.

4 The algorithmic lexicon model, formalized

Assuming an interaction of linguistic knowledge, conceptual knowledge and (naïve physical) world knowledge as a basis of motion modelling, I now propose some basic architectural issues of a formal semantic-conceptual lexical representation of motion, where information unification and -enrichment is an outcome of algorithmic search and influence triggered ‘from inside’ by the lexical entries.

I will propose a lexical framework that serves as a starting point for reasoning towards a situation model. Even if this is not semantic’s main duty: semantic structure must provide a basis for further determination and specification.

4.1 Three Levels: Semantics, Concept, and Spatial Simulation

The current theory is based on a rich lexicon, on the one hand, and a distribution of information, on the other. Both semantic and conceptual information is stored in the lexicon – where lexical items are linguistic units that point to conceptual knowledge modules. In a broader technical sense, the lexicon is defined as including these formalized conceptual knowledge structures. (It is, obviously, not possible to draw a sharp distinction between which formal linguistic bits are of lexical or of conceptual nature, respectively. Due to finiteness of time and space, I cannot discuss the fundamental question of ‘what is in the lexicon’ at length here, but cf. Jackendoff (2002) for the correlation between storing and deducing lexical information).
This broad formal definition of *lexicon* allows us to deal with a rich inventory of both features and inference processes. Take, for example, the ‘presence of path’ – it can be seen as both a semantic feature as such, and as a source of conceptual/spatial information, that can be used to determine the sentence meaning. Finally, a formal theory has to become clear about questions like what happens or fails if something is (not) overtly realized? and, above all: how can ‘the world’ as an infinite knowledge base be efficiently accessed within a short finite processing time? 14

4.1.1 Information Levels in the lexicon.

On the *Semantic level*, relations among sentence participants are modelled compositionally (via structures accounted for by syntax): The verbal lexical entries select for arguments and assign 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, which is built up compositionally from the meanings of its parts. In sum: semantics obtains the role of the interface between grammar and concept.

On the *Conceptual Level*, conceptual knowledge about the relations and the referents is encoded. For example, the conceptual knowledge of a *Path* comprises that it has a *Goal*, a *Via* and a *Source* information, and the conceptual knowledge about the *Object* will be features like if the m-object is animate, if it has a defined shape and a hard surface, if it can be moved, and so forth. In 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*.

In an interpretation process where semantic structure triggers composition and conceptual knowledge about the parts is bitwise included, new facts about world settings arise from this – this is the point where many semantic theories add more selectional restrictions to the lexicon. Note however that, since world knowledge is infinite, a technique of piecewise excluding readings can never reach the status of a full model. My framework is therefore based on a two-step architecture: first compose and propose an utterance meaning, allowing for underdetermined information slots, and then search for missing information by further accessing available knowledge sources (i.e. conceptual knowledge about all participants, further “world knowledge”, and contextually given facts), and check for consistency. Using the right algorithmic modelling, this search can always be kept finite.

14 Zwarts and Verkuyl (1994) show how far one can get with modelling Jackendoff’s CS in terms model-theoretic semantics. How can we, thus, incorporate mechanisms elaborated in model-theoretic semantics? What is the architecture of the syntax-semantics-interface? Keeping a separate semantic level means keeping the model open for insights elaborated in several neighbouring theories. It will be a significant amount of further work to incorporate more and more semantic modelling insight into the current model. What I model here is the general architecture of three levels and their communication.
4.1.2 Interlevel Communication and Information Flow.

Interface structures mediate between the levels. On the semantic level, only the information about the existence of a path and an object is present, and the information that the object is moving from a source to a goal, respectively. Figure 1 illustrates the information flow in the modeling process.

The division of work may, in the end, answer the general question about the relation between event and path in a threefold way: Is the object really mapped onto successive points? What is the end of moving? Is the figure moving consecutively on the path? To answer this, note that both Path and Event appear in different shades on the different levels. On the semantic level, the Event is just the whole process of moving and reaching (or not reaching) a goal. On the Conceptual Level, both Path and moving along that path are ‘filled with life’: the Path consists of Source and Goal, and the whole scene where an object moves to a goal is together – but still abstract – the Event. Only the $\sigma$-world-view models a direct mapping to a model of space: at points of time, points of the object are located at points of the path. Only now, determined knowledge of speed, direction and reaching the goal can be modelled (which is, indeed, another domain where the $\sigma$-world can be of some help, consider modification like climb slowly).

Let me give more examples. On the one hand, there are cases where not too much conceptual information is needed in the modelling process: consider, for examples, cases of pure feature assignment, like Peter is blond. Also in The plane is flying from Stuttgart to Trondheim, assigning Source and Goal points is sufficient to get a unique interpretation. On the other hand, there are cases where after semantic and conceptual processing the model is still underdetermined: these are, on the
one hand, all physically impossible settings (consider PP adjunction, where the information added via the PP makes it possible for the σ-world to find a model. Peter steigt auf die Wolke (Peter climbs onto the cloud)), and cases where physical modelling ‘saves’ a candidate from being odd-marked by proposing a context setting – consider cases like (29) below, where including more world knowledge finally leads to a valid model (assume a scenario involving something offering support, like a ladder for (29).

(29) Peter steigt im Wasser nach unten.
Peter is clamber-climbing in-the Water to down.
(Peter is climbing down in the water)

Since high computational effort and a huge amount of world knowledge is needed here, the sentence will be indexed as ‘quite marked’ – which meets our intuition about such sentences.

In order to explain both the levels’ architecture and interlevel communication, I will now build a fragment of the three-level model which will be able to deal with klettern and steigen situations.

5 Modelling

5.1 The case of motion

The Conceptual Motion Encoding Scheme (1) defines how motion of an object as such is conceptually encoded:

Definition 1 (Conceptual Motion Encoding Scheme) An object of type THING, \( x_{\text{THING}} \) is localized related to a supporting reference object \( z \), this supported localization is of type PLACE. If \( x \) provides a Motion Method (i. e. “it is able to move”) of type EVENTPATTERN it may change its place.

Note that from such a motion a sequence of different localizations results; yields “the path”, which will below be defined more formally.

The Conceptual Motion Encoding Scheme, which is of purely conceptual nature, sketches the lines along which linguistic encoding of object motion should be modeled in the lexicon. The current model assumes a lexical Core Motion Model which is the lexicalization of the Conceptual Motion Encoding Scheme as a two-place relation in the lexicon.\(^{15}\)

(30) \( \text{Go}(x, \text{along a } P \text{ in a certain manner}) \) (subject \( x \), path \( P \))

\(^{15}\)Note that Jackendoff’s GO, which I adopt here, is compatible to what in the Bierwisch and Wunderlich tradition has been called MOV.
The new contribution of the current framework, which aims at being both semantically compositional and conceptually oriented, is the fact that the path, semantically subcategorized via the variable $P$, does not directly enter the two-place relation, but only in its adapted variant. The question of how much – and which – fine grained information must be included in a semantic-conceptual model in order to provide a semantically and conceptually valid situation representation leads to assuming a mechanism called *Path Shape Adaptation*: it models the spatio-physical correlation between the moving subject with its motion patterns, and the physical character of the supporting object. A path-shape adapted path should thus be seen as ‘a new entity of the same path’ which has been changed such that it describes a motion trace which fits the current situation in the current setting in a more fine-grained way than the path primarily given by pure semantics:

\[(31) \quad \text{Go}(x, \text{!ADAPT}(P; \bullet)) \quad (\bullet: \text{to be defined})\]

The mechanism of Path Shape Adaptation according to the objects and available motion methods will get the key role in rejecting examples which are impossible due to physical settings.

### 5.2 Motion and the algorithmic lexicon

The basic idea of the *algorithmic lexicon* is, in a nutshell, to consider lexical items as algorithms. Central points to be discussed are at least the question what happens to the path – processes like Path Shape Adaptation; what happens in the object – theory and date behind motion methods; what happens in case of ‘no-match’ – processes of further search, backtracking, and rejecting; and finally: What is the algorithmic / semantic lexical rule for *steigen* and *klettern*?

**Lexical encoding.** In order to lexically encode the semantic-conceptual meaning of certain motion verbs, the algorithmic lexicon architecture adds some information on types of participants, maybe restrictions, and the general structure of force- and causation relations. This leads to the general architecture of a lexical (meta-) entry for a path motion verb like given in (32) (which is a quite empty concept which is maybe not even lexicalized in a single word):
Each entry starts with a name (e.g. *steigen*, here in the undetermined entry for “any path motion verb”: □EVENT\_PATH\_MOTION) and a type out of a (conceptually given) type ontology (e.g. EVENT or EVENT\_PATTERN). In parallel to the general architecture of algorithms, entries in the algorithmic lexicon are divided into a head part and a core part: the head part includes all the information about information in- and output, i.e. subcategorization information about the participants of the situation to be modelled. Constituents which can (or must) be subcategorized are listed in the head part, each denoted with the subcategorization sign ‘⊿’.

Note that in the current architecture, it is possible to include (and even reason with) undetermined information. In such a case, the empty slot □, which is not yet determined, is treated as constituent; which means instead of either inserting some default information or excluding the unknown part from reasoning, the fact that this constituent is undetermined is calculated with (according the maxim “we always know what we do not know”). To simplify notation of later reasoning steps, empty slot constructions may get a label, e.g. y in ‘− ◦ y’.

All constituents are of a conceptual type; this type information offers the interface to further conceptual information about objects, in that it links to a type ontology where all the types and subtypes are further specified. Here, objects are ‘filtered’: the first restriction is the type / sortal information, given in a type ontology (here: xTHING\_MOVABLE and PPATH); and the second restriction are semantic-conceptual features (here, ground(□.y□) denotes a still unknown object of unknown type which must satisfy ground(·); as soon as found in the modelling process, this object will get the name y, before that, y refers to the underdetermined ground object). Note that type information can be replaced by specialization: the most obvious example are underdetermined objects ‘□’ that themselves bring their type information as soon as they have been found in the course of the modelling / searching process.

In the core part the “semantic load” is collected: here, the relation and interaction of the participants depending on a certain verb’s meaning is defined. It entails the semantic rule how to include information into a resulting meaning model. Here, pr

The default algorithmic setting of the current framework is Lazy evaluation: if, for example, no y is given, then y-related rules are simply ignored (In more algorithmic...
words: the algorithm is ready to skip steps in case of failure (‘no $y$? then do not care about . . . ’). The ‘!’ in the second argument of Go denotes Forced evaluation: It is a switch which disables lazy evaluation and forces the evaluation to take place.

The $\text{motionMethod}$ is the conceptual description about the way how a moving object $x$ interacts with a ground object $y$ (i.e., more traditionally, manner information). It is given as a two-place relation, the first one linking to the moving subject, already known to the verb as $x$, and the second one linking to the ground object$^{17}$:

\begin{equation}
\text{motionMethod}(x, \square \rightarrow o z)_{\text{EVENTPATTERN}},
\end{equation}

Unlike the subject, the ground object need not be semantically given in an utterance (– lambda semantics would either leave it out of semantics, which is done in most accounts, or satisfy the request with an $\exists$ operation.). Thus, the ground object as well as its type is modeled as underdetermined, denoted by ‘$\square$’, and bind this unknown object to $y$, denoted by ‘$\square \rightarrow o z$’.

How a concrete motion verb is derived from this meta entry will be discussed in the following for the example $\text{klettern} / \text{steigen}$ ($\text{climb}$). To do this, we will have to discuss questions like (1) what is, in more detail, the structure of a motion event? (2) which additional information is available in the concepts of objects (as m(oving)-objects and r-objects)?, and (3) how does it all interact in a specific physical setting?

5.3 The Path

On the semantic level, a verb subcategorizes for a path-PP (variable: $P$, e.g. $\text{onto the mountain}$), or a path-adverb (e.g. $\text{upward}$). Alternatively, the verb subcategorizes for a single object and expresses Path-motion related to this object (e.g. $\text{enter}$, $\text{leave}$). The decision if a PP or an adverb is of type PATH is met with the help of conceptual knowledge about its participants. Similarly, a preposition subcategorizes for an object to yield a path.

The definition of PATH is based on the Conceptual Motion Encoding Scheme (given above in 1).

**Definition 2 (Path)** A PATH $P$ is defined as a sequence of different localizations that result from the motion of an m-object according to the Conceptual Motion Encoding Scheme. of a moving object; motion of an object $x$ on a Path $P$ is represented as ‘$x$ changes its position related to locations given by the path’. Semantically, the presence of such path motion is formally expressed in $\text{GO}(x, P)$. Conceptually, the Path is represented as a sequence of SOURCE, VIA$_1$, . . . , VIA$_n$ (where 1 . . . $n$ is an index function) and GOAL, at least one of which has to be explicitly instantiated.

$^{17}$I chose the term ‘ground object’ because this term is emblematic for the realization of this physically given object as sometimes unknown and most of times underdetermined. It is not to be confused with Talmy’s more general use of the term.
with a location. The number of specified locations is a flexible parameter of conceptual nature: specifying and thus localising more path locations means looking more fine-grainedly at the path and, thus, further specifying the situation description.

Further down, when discussing the interaction of m-object and r-object along the PATH, it will become clear that exactly those path points where a support-relation is located will be of type PLACE. Thus, the PATH is only definable in correlation with the (yet unknown) objects \(\Box_{\text{THING}} \rightarrow x\) and \(z\), such that supports\((z, y)\) holds at these path points. That means formally: a Path is a chain of located places, two of which are designated as starting place and end place:

\[
\text{PATH} = \{ p_i : \text{PLACE}(p_i, \Box_{\text{THING}} \rightarrow x), i \in [0..n] : \\
p_0 = \text{‘starting place’} \land x_1 = \text{‘end place’} \land \\
\text{the points make up a chain, and there are no more specified points}\}.
\]

Note 2. This definition of Path as a sequence of location-relations between a moving theme and a background object on the \(\sigma\)-world is similar to the definition of Zwarts (forthcoming), who suggests a path algebra defining path as “a starting point, an end point, and points inbetween on which the path imposes an ordering [...] defined as continuous functions from the real unit interval \([0, 1]\) to positions in some model of space”, the path is defined. This definition offers the advantage that inserting and deleting path points – as is done when increasing and decreasing granularity, respectively – only means rewriting two neighbour pairs, which is of little algorithmic complexity. Additionally, one can assume replacement functions ‘starting point → source’ and ‘end point → goal’ dependent on the decision if the path is telic (as in arrive) or atelic (as in approach). I do not elaborate on that – see, for instance, Zwarts (forthcoming), Verkuyl (1993) and Verkuyl and Zwarts (1992) for an elaboration of aspect and (a)telic path.

As already mentioned, it is not trivial to define direction: its basic definition would be a vector. However, 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. 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 it defined globally as ‘from \(a\) to \(b\)’, not mentioning the detours?\(^{18}\) All these facts are undetermined while modelling: the framework allows for including and even reasoning with empty slots. Only later, when knowledge from all available sources has been involved, some of the slots are filled, i.e. the situation is “a bit more determined”. – A path can have even more features. A curved path, for example, may have a radius and a middle point. This kind of information is another example where semantics (as in to curve), concept

\(^{18}\)The one first case is the local path shape and the other the global path shape in van der Zee and Nikanne’s system – cf. van der Zee and Nikanne (2005), Zee (2000), and van der Zee and Nikanne (this volume).
(rotation, middle point, radius, speed) and \( \sigma \)-world (physical facts about rotation and forces) basically interact.\(^{19}\)

Consider, as an example, the lexical entry for \( \text{auf}_{[+\text{dir}]} \)

\[
\begin{bmatrix}
\text{auf}_{\text{dir}} \\
\text{PATH} \\
\triangleright \text{xTHING} \\
\text{SOURCE} = \Box \text{PLACE} \\
\text{VIA} = \{\Box \text{PLACE}, \ldots, \Box \text{PLACE}\} \\
\text{GOAL} = \Box \text{PLACE} \rightarrow R : R \subset \text{Surface}(x)
\end{bmatrix}
\]

Observations and explanations: The \( \text{auf} \)-path is a sequence of locations of a moving object, but as such undetermined for Source and Via points. Even the Goal is unspecific. This fact is inherited from spatial \( \text{auf}^{-\text{dir}} \): This is another point where knowledge about an object and its function in a specific situation interact: the highest point of a ladder, referred to by \textit{on top of the ladder} is never conceptualized as the absolute highest point of the wooden object “ladder”, but as the highest \text{PLACE} where and object finds support (cf. also \( ? \) for the notion of \text{PLACE} as expressed by prepositions).

5.3.1 Path Shape Adaptation.

The \text{DIRECTION} depends on the moving object’s support request. The path does not directly enter the relation, but only in an adapted variant: We saw before that in cases like (36) (repeated here) the \text{UPWARD} feature can be overridden:

(36) a. via oriented:
   dem Felsen entlang \{steigen / klettern\}
   (climb along the rock)

b. source / goal oriented:
   aus der Tonne / in die Tonne \{steigen / klettern\}
   (climb out of / into the bin)

c. environment-marked:
   aus dem gesunkenen Schiff / in das gesunkene Schiff \{steigen / klettern\}
   (climb out of / into the sunken ship)

It is a core point in the model proposed here that moving object, ground object and path interact and mutually contribute to situation modelling.

An explanation of this phenomenon can now be given more formally along the following lines: As soon as a *Path* is explicitly introduced, an interdependence of *Path* and *Direction* can be found: If the moving object needs contact to the ground (which is a conceptual feature) and if the ground object has a solid surface, then the path adapts to the ground object’s shape along the direction of the moving object’s motion. In other words: two conceptual competitors are involved here: the object, and the path. The process of further specifying makes the path visible in a more fine-grained fashion, since presence and shape of the r-object and based on that localisation of the m-object along places lead to conceptually taking more and more via-points into focus. Thus, object concept and path concept are integrated (co-composed) into a common situation model. I call this the *Path Shape Adaptation Rule*, defined like follows and illustrated in figure 2: thus ‘Path Shape Adaptation’: “the path adapts to the shape of the ground object along the direction of the motion of the moving object.”

**Definition 3 (Path Shape Adaptation)** A *Shape Adapted Path* $\text{adapted}(P)$ results from superimposing the support request of a moving object on each point of a *Path* $P$, given a ground object $g$. The points of $\text{adapted}(P)$ are such that $x$ finds support at a position of $g$, topologically denoted by the preposition.

![Figure 2: Path Shape Adaptation example on the mountain where gravity is present, the ground object has a hard surface, and the moving object is of type human: before specification the path onto the mountain is represented as a global vector from a position near a bounding box to position on its top; after specification, the path’s VIA points are all Places that offer support to the object.](image)

In the lexicon:

(37) \[ \text{Go}(x, \text{!adapted}(P; \bullet)) \quad (\bullet: \text{to be defined}) \]

Consider once again the case of German *steigen* and English *climb*:

(38) a. Peter steigt auf einen Baum / vom Baum.
    (Peter is climbing onto a tree / from-the tree)
b. Der Luftballon steigt (nach oben / ?? nach unten).
   (The balloon is climbing (upward / ?? downward))
c. Der Pilot steigt aus dem Wrack.
   (The pilot is climbing out-of the wreck)

As a consequence, steigen should denote – in its conceptual core – an upward motion. This implies a force antagonism: the motion pattern in steigen has to actively provide a force to overcome gravitation. This force can be rooted in one of two possible forces: first, the object actively moves and thus produces an upward force in interaction with a supporting ground object or ground medium; second, the object is conceptualised as having an upward impetus and thus is able to overcome gravitation.

As an example, in the sentence Peter climbed onto the cloud, the conceptual feature of no consistency of the cloud interferes Path Shape Adaptation and creates a contradiction. Given this contradiction, the information that it is not possible to fix a path on a cloud such that an object can stand on it finding support is passed back via the conceptual level to the semantic level and creates the semantic oddness marks (‘??’) as output. The semantic oddness marks do not intend to mark the sentence (and thus the situation) as impossible in any case: If evidence is given that the sentence is used in a situation as a description of a fact, then the semantic level can initiate a new interpretation process where the σ-world searches for settings which make the sentence true. The algorithmic complexity of this search is mapped onto a ‘markedness’ measure of the sentence, and the additional information is provided to the output.

The paths in the lexicon Let us now come to the lexical-conceptual definition of PATH. The paths given in steigen (heightDifferencePath) and klettern (rarePlacesPath) differ in detail. The global direction of the path depends on the m-object’s support request and on the granularity level of situation description (cf. v. d. Zee & Nikanne); thus the shape of the path makes up several classes of paths. These are given in Conceptual Knowledge Modules:

\[
\text{heightDifferencePath:}
\]
At least one of the path points is significantly higher (in gravitation-oriented metrics). By default, a heightDifferencePath is +Upward unless adapted.

---

\(^{20}\)Note that there is no transitivity in that mapping, which means that each step of information transfer has to be performed separately.
rarePlacesPath:
The path is such that an object located at a point of this path is not able to reach the next PLACE using only its standard motion method. Effort and planning has to be added, and other motion methods have to be employed.

(40)

Let me illustrate this. In the case of steigen, due to the motionMethod and Path Shape Adaptation the motion comes to be a “stepwise change of $x$’s position in the order given by $P$”. Each position taken by $x$ is then a PLACE (with PLACE=“where an object can stand in its normal standing position getting support from a ground”). Semantically, heightDifferencePath only models the information that in the course of the path height differences occur. Things are different in klettern: here, rarePlacesPath models the information that the motion along this path is not trivial (i.e. both effort and planning is involved). Thus, the paths now look like this:

(41) a. $\triangleright P_{\text{Path.heightDifferencePath}}$
    b. $\triangleright P_{\text{Path.rarePlacesPath}}$

I will give examples in the applications subsection.

5.4 The Objects

In parallel to the path, the object(s) involved must be modelled including a basic inventory of conceptual features. (At least) two objects are involved: the m(oving)-object and the r(eference)-object. (Cf. Langacker and Talmy and others for other names as ‘Landmark’ and ‘Trajector’).

On the semantic level, the verb subcategorizes for both m-object and r-object (in most cases syntactically given as ‘subject’ and ‘object’ of a verb). Both objects must fulfill some requests in order to be suitable for certain situations: the m-object must provide the motionMethods requested in the verb’s semantics; and the r-object must provide the support requested by the m-object, and therefore a suitable material makeup. Often, we do not know much about the r-object, since its (necessary) presence is kept in the unfocused background of a situation and it is not mentioned explicitly.

In the lexicon, objects are selected in the head part of the verb’s lexical entry, where the participant structure of a lexical item is made explicit. Lexical entries then link to Conceptual Knowledge Modules. These contain conceptual / ontological knowledge about events and objects (for example: Motion Methods). Consider the head part of the steigen lexical entry:
In sum, due to the definition developed above where in climb situations “the object provides a force to overcome gravitation”, the following test is sufficient as a filter for objects for steigen: $x$ must belong to the major conceptual category (Jackendoff) THING, and must fulfill the boolean test

\[(43) \text{ PROVIDESMETHOD} (VerticallyOvercomeGravityMethod, x).\]

(Finally, this test is redundant if we decide for an error catching procedure architecture in the core part of the semantic description, where the method is necessarily required. However, it is more convenient for the human reader to reduplicate this semantic requirement as an ‘entrance test’.) For reasons of efficiency, tests like the one given in (44a) are encoded as in (44b), which is typographically shorter, but (by definition) identical in meaning:

\[(44)\]
\[a. \quad \triangleright x_{\text{THING}} \text{ such that } \text{PROVIDESMETHOD}(\text{VerticallyOvercomeGravityMethod}, x)\]
\[b. \quad \triangleright x_{\text{THING}}. \text{providesVerticallyOvercomeGravityMethod}\]

**Motion Methods.** The motionMethods are conceptual information about objects, given as a Conceptual Knowledge Modules (CKM) in the lexicon. In a CKM, arbitrarily many\(^{21}\) knowledge units can be listed: unlike the more stable semantic lexical items, CKMs are the units in the lexicon where learning may add (and in case deletes) more and more details. Cognitively, we imagine motion methods in CKMs to be closely linked to human architecture of physical motion control.

For the current model world, I give two motionMethods – the VerticallyOvercomeGravityMethod and the clamberMotionMethod:

---

\(^{21}\)Modulo memory capacity
Here, ‘standardMotionMethod’ is a subtype of ‘motionMethod’ and inherits from this. Since humans need support from a ground object, the standardMotionMethod of humans determines the type of the ground object □ − ◦ y as THING: □THING − ◦ y – this information is directly feeded into the Path Shape Adaptation process. A balloon, in contrast, has an other standardMotionMethod: due to its architecture (filled with gas or hot air, for example), it moves upward as until a status of force equality is reached. Based on the old but ongoing discussion on naïve physics, we argue in Weisgerber and Geuder (2006) that this highly abstract physical fact is implicitly conceptualized as *impetus*. Furthermore, the standardMotionMethod of balloons determines the type of the ground object as *Matter*.

**Note.** Such a representation of knowledge about objects resembles *affordances*, or *qualia* as introduced by Pustejovsky (1995). Both, however, are parts of static semantic entries and thus lists of fixed length. The current approach, opposed to this, links to extendable and growing-with-learning units of conceptual knowledge about things.

### 5.5 Processes: Towards the algorithmic lexicon

Figure 3 summarizes the different processes of searching, unifying and cocomposing information about m-object and r-object and the motion patterns as such along a path, described above.
5.5.1 Lexical entries.

After having defined the levels and some interfaces, we are able to define information units, namely the concrete bits of information stored in the lexicon for our toy scenario for *klettern / steigen*. There are two kinds of information units stored in the lexicon: *lexical entries*, and *conceptual knowledge modules*. Both lexical entries for *steigen* and *klettern* are a specialization of the lexical entry for the meta entry for translational motion defined above in cf. (32) in section 5.2 above. Since both *steigen* and *klettern* specify a manner of motion, the lexical entries have more specific motionMethods and more specific paths than their mother $\Box_{\text{EVENT PATH MOTION}}$ – in the course of modelling, both leads to a further restriction of possible ground objects.

(47)

\[
\begin{align*}
\text{steigen}_{\text{EVENT PATH MOTION}} & \\
\forall \, x & \text{THING \ provides VerticallyOvercomeGravityMethod} \\
\forall \, P & \text{PATH \ heightDifferencePath} \\
\forall \, r & \text{supports}(r, x) \\
\text{Go}(x, \text{!ADAPTED}(P, \text{VerticallyOvercomeGravityMethod}(x, r)_{\text{EVENT PATTERN}}))
\end{align*}
\]
In the case of \textit{klettern}, the ground object is further specified to type \`THING:\n
\[
\begin{align*}
\text{klettern}_{\text{EVENT.PathMotion}} \\
\quad \triangleright x_{\text{THING.Movable}} \\
\triangleright ! P_{\text{PATH.RAREPlacePath}} \\
\triangleright ! \Box_{\text{THING} \preceq y} : \text{supports}(r, x) \\
\quad \triangleright \text{GO}(x, !\text{ADAPTED}(P, \text{clamberMotionMethod}(x, r)_{\text{EVENT_PATTERN}}))
\end{align*}
\]

At this point the division of work between semantics and concept can be explicitly seen: while semantics declares that such path features have to be involved, concept specifies these paths.

\subsection{Examples}

Consider first the case with no path given:

\begin{enumerate}
\item a. Das Flugzeug / der Ballon \{steigt / ??? klettert\}.
   (The plane / the balloon is Ving.)
\item b. Der Affe \{klettert / ??? steigt\}.
   (The monkey is Ving.)
\end{enumerate}

Example (49) is straightforward: since the plane has a the standardMotionMethod of creating force to move along a path in gaseous matter (i.e. air), it fully fits to the subcategorization requests of \textit{steigen}. With \textit{klettern}, no clamberMotionMethod is found for plane, also Path Shape Adaptation cannot propose a shift to a replacement – thus, (49a) is rejected. (49b) is rejected via the difference in support request in the motionMethods: different to the balloon / plane case, where \`air\' is conceptually present as \textit{MATTER} and thus as a ground object, there is no ground object of type \textit{THING} given in the monkey scenario – and, in \textit{steigen} there is no mark \`!\’ given in the head list which could enforce implicit existence. (This is due to the semantic fact that \textit{steigen} cannot be used as a pure manner verb, unlike \textit{klettern}.) In sum, Path Shape Adaptation is enforced but does not find a ground object, which leads to a runtime-error which causes rejection.

Consider now the case \textit{Paul steigt / klettert auf den Berg} (\textit{Peter V’s onto the mountain}). We must first add some units to our lexicon to make the process transparent:\footnote{\textcircled{22}cf. Weisgerber and Geuder (2006) for similar entries.}
(50) \[
\begin{align*}
&\text{auf}^+\text{dir} \\
&\phantom{\text{auf}^+\text{dir}}\downarrow \quad \text{PATH} \\
&\phantom{\text{auf}^+\text{dir}}\downarrow \quad \text{xTHING} \\
&\quad \text{SOURCE} = \Box \text{PLACE} \\
&\quad \text{VIA} = \{\Box \text{PLACE}, \ldots, \Box \text{PLACE}\} \\
&\quad \text{GOAL} = \Box \text{PLACE} \rightarrow R : R \subset \text{Surface}(x)
\end{align*}
\]

(51) a. \[\text{Paul}_{\text{THING.HUMAN}}\] b. \[\text{Berg}_{\text{THING.MOUNTAIN}}\]

Semantic composition now yields \textit{auf den Berg} and finally \textit{Peter steigt / klettert auf den Berg}.

(52) \[
\begin{align*}
&\text{auf den Berg}_{\text{PATH}} \\
&\phantom{\text{auf den Berg}}\downarrow \quad \text{SOURCE} = \Box \text{PLACE} \\
&\phantom{\text{auf den Berg}}\phantom{\downarrow} \quad \text{VIA} = \{\Box \text{PLACE}, \ldots, \Box \text{PLACE}\} \\
&\phantom{\text{auf den Berg}}\phantom{\downarrow} \quad \text{GOAL} = \Box \text{PLACE} \rightarrow R : R \subset \text{Surface}(x)
\end{align*}
\]

(53) a. \[\text{auf den Berg steigen}_{\text{EVENT}}\]

\[
\begin{align*}
&\phantom{\text{auf den Berg steigen}}\downarrow \quad \text{SOURCE} = \Box \text{PLACE} \\
&\phantom{\text{auf den Berg steigen}}\phantom{\downarrow} \quad \text{VIA} = \{\Box \text{PLACE}, \ldots, \Box \text{PLACE}\} \\
&\phantom{\text{auf den Berg steigen}}\phantom{\downarrow} \quad \text{GOAL} = \Box \text{PLACE} \rightarrow R : R \subset \text{Surface}(\text{derBerg}) \\
&\quad \text{VerticallyOvercomeGravityMethod}(x, \Box \Box, y)_{\text{EVENTPATTERN}})
\end{align*}
\]

b. \[\text{auf den Berg klettern}_{\text{EVENT}}\]

\[
\begin{align*}
&\phantom{\text{auf den Berg klettern}}\downarrow \quad \text{SOURCE} = \Box \text{PLACE} \\
&\phantom{\text{auf den Berg klettern}}\phantom{\downarrow} \quad \text{VIA} = \{\Box \text{PLACE}, \ldots, \Box \text{PLACE}\} \\
&\phantom{\text{auf den Berg klettern}}\phantom{\downarrow} \quad \text{GOAL} = \Box \text{PLACE} \rightarrow R : R \subset \text{Surface}(\text{derBerg}) \\
&\quad \text{clamberMotionMethod}(x, \Box \Box, y)_{\text{EVENTPATTERN}})
\end{align*}
\]
Note that the motionMethods have been specialized into explicit descriptions of motion events of type EventPattern.

5.5.3 The case of ‘no-match’

Example Transport Readings. Most (if not all) Path Motion events (Type event.PathMotion) have in common that there is a transport-reading:

(55) Das Paket ?steigt / ?fährt / ?fliegt / ?... (the package is going up / being transported in a car / plane / ...)
\[ \begin{align*}
\Box_{\text{EVENT.PATH.MOTION}} & \Rightarrow E \\
\Delta x & \Box_{\text{THING.MOVABLE}} \\
\Box_{\text{THINC}} & \Rightarrow t : \text{LOCATEINREGIOBOX}(t, x) \\
\end{align*} \]

where \text{LOCATEINREGIOBOX}(t, x) is a function that operates on the spatial configuration, and \text{MOVABLE} ensures the minimal requirement for x to be a thing that can be moved.

### 5.6 Applications

**Embedding environment information: Nontrivial Path Adaptation Cases.**

(57) Peter steigt im Wasser nach oben.
Peter passive-goes-up in-the water to up

Since GO(x, ADAPTED(P)) is underspecified for passive vs. active motion, (i.e. underspecified for the means of transport or the kind of motion producing the motion), sentence (57) gets two readings. In the first reading, Peter is located in the water, and is climbing along an underwater mountain wall, or something like a ladder. In the second reading, Peter is located in the water, too, but motion results from bouyoncy: the upward forces on Peter are stronger than the downward force (i.e. gravity). That leads to a active interpretation in the first reading of (57), and an impetus-physical in the second (parallel to the balloon case).

(58) von oben auf ein Pferd steigen
from above onto a horse go-climb

Another confirmation why Path Adaptation is in fact needed even in steigen are situations like (58): here the GOAL is the highest PLACE of the goal object, but in a lower absolute location than the SOURCE place.

Finally, consider

(59) ???Peter steigt / klettert auf die Wolke
(Peter climbs onto the cloud)

Utterances like (59) get only rejected when the \(\sigma\)-level comes into play: due to conceptual knowledge about the structure of a cloud, Path Shape Adaptation gives ‘physical mismatch’ and the sentence is rejected, unless the situation is ‘repaired’ by adding further context knowledge.
When adding PPs makes metonymies: The RarePlacesPath.

(60) Peter steigt über das Matschloch
Peter is stepping over the hole of mud

(61) durch einen Fluss steigen / klettern
through a river go-climb / clamber-climb
 [von Stein zu Stein]
 [stepping and hopping from stone to stone]

The ‘stepwise’ in the definition of the human standardMotionMethod allows for the step over reading, which can, thus marked, be formulated as steigen über constructions in German: example (60) is a good sentence in exactly these cases where one motion pattern of $x$ (i.e. $x$’s maximal step length) is enough to reach a place ‘path-behind’ the starting place. Since Path Shape Adaptation only concerns such points where $x$ has been, the intermediate interval of the path does not need to have contact to the mud on the ground – which is implied by (60). (61) is another good example for the application of a RarePlacesPath in the definition of klettern.

Dimitrova-Vulchanova et al. (forthcoming), this volume, find empirical evidence that a Koala ‘climbing jumpwise up a tree’ is judged as as a good instance of climbing. This can be taken as an example for an extreme instantiation of RarePlacesPath. The example with a snake climbing is on the other extreme of the same phenomenon: here the ‘steplength’ of a snake which only winds, never leaving ground support, is approximately zero, so each chain of points along a ground object would instantiate a climb situation – which seems to meet intuition about traveling snakes.

Consider now

(62) Das Flugzeug klettert durch die Gewitterwolke
The airplane is clamber-climbing through the thunderstorm cloud

In (62), only the information added via the path makes it possible for the $\sigma$-world to find an output. Processing works as follows: Conceptual Knowledge proposes to mark the sentence odd, since the plane’s motion patterns do not fit into a klettern scenario that would be suitable here. However, after backtracking $\sigma$-world proposes a solution by modelling the sequence of locations that offer support to the plane as discontinuous (due to inferable physical settings in thunderstorm clouds). Hence, the Path can be modelled as a nontrivialPath (or even a rarePlacesPath), which the sentence a marked but possibly true utterance.

Consider now (63), which are both not too bad in certain readings:

(63) a. Die Lokomotive der Zahnradbahn klettert bergwärts.
The locomotive of-the rack railway V’s up-the-mountain.
(The locomotive of the rack railway is climbing up the mountain.)

b. Die Lokomotive der Zahnradbahn klettert talwärts.
The locomotive of-the rack railway V’s towards-valley.
(The locomotive of the rack railway is climbing towards the valley.)

Since a locomotive does not supply a clamberMotionMethod, the sentences would be rejected by Conceptual Level. Here, the $\sigma$-level finally suggests a ‘metaphorical map’ since the effortful rolling on wheels shows great similarity to clambering on limbs. (One could as well argue that a rack railway locomotive indeed does supply a clamberMotionMethod.) In sum, (63) comes out as ‘quite marked, but possible’ in the end.

6 Outlook: Open questions and challenges

The model I propose and sketch is by far not ready in its development – this has never been the intention of the current paper. My aim has been to generally mark some lines along which such a modelling should proceed. What remains, except giving and discussing more examples, more settings, and more verbs in the end, is a huge amount of insights out of different theories, that must be tested for applicability in the current model. ‘The story has just begun’!

Modification. I did not discuss cases of modification like (64) and (65). Including modification in a framework means answering a whole set of new questions – like ‘What meaning changes are brought in by slowly – and how can this process be formally modelled?’ I will leave this to further research. A central add-on to the model will then be a notion of points of time, made necessary by modifications concerning speed, as in (65).

(64) Der Affe steigt mit Händen und Füßen
The mokey is go-up-climbing with hands and feet

(65) langsam steigen / klettern
slowly climb-go / clib-clamber

Aspect. Finally, consider aspect. Example (66) suggests that, again with no path added, steigen can made denoting bounded events by adding the German bounded-ness prefix be- together with a direct object, while klettern cannot.

(66) a. Peter bestieg den Aconcagua [i. e. a mountain].
Peter be-climbed (go) the Aconcagua
b. ??Peter bekletterte den Aconcagua.
Peter be-climbed (kletter) the Aconcagua
(Ex. (b.) can be imagineable in a very constrained context, where climbing has been introduced as a sprotive activity, for example, then denoting an unbounded event). Note however that, again, a bounded ground object can superimpose its boundedness onto the situation, as shown in ??: In (67) the ‘reach the top’ feature of besteigen is made necessary part via the unification of the Path’s goal with \( y.\textsc{outstandingPlace} \), which is the uppermost place of the object \( y \) offering support for \( x \):

\[
\begin{align*}
\text{besteigen}_{\text{EVENT}} & \\
\quad & \uparrow \text{\(x.\textsc{thing.movable} \)} \\
\quad & \uparrow \text{\(y.\textsc{thing.solid} \)} \\
\quad & \text{\textsc{go}}(x, \text{\textsc{adapted}}(\text{\textsc{heightDifferencePath}}, \text{\textsc{standardMotionMethod}}(x, y)_{\text{\textsc{eventPattern}}})) \\
\quad & \land \\
\quad & P.\text{goal} = y.\textsc{outstandingPlace}
\end{align*}
\]

This effect is typical of the Slavic ‘pairs’ with PP promotion to direct object. (e.g. Dimitrova-Vulchanova et al. (forthcoming), this volume, for Bulgarian examples).

It would be ‘much nicer’ and ‘more generative’ to start out from an extra lexical entry for the German prefix \( be- \), which semantic contribution is (atleast) to make situations bounded.

Due to finiteness of time and space, this cannot be discussed here. Even if I will not go deeper into aspect in this paper, architecturally the lexical entries offer the place to do so in future research. Another case I cannot deal with here are cases like (68) – but cf. the work of Mila Dimitrova-Vulchanova, Joost Zwarts, and Henk Verkuyl concerning this field.

(68) a. Peter stieg \( in \text{\textit{einer Stunde}} \) auf den Berg.
    Peter go-climbed \( in \text{\textit{one hour}} \) onto the mountain

b. Peter kletterte \( in \text{\textit{einer Stunde}} \) auf den Berg.
    Peter kletter-climbed \( in \text{\textit{one hour}} \) onto the mountain

7 Conclusion

Analyzing the MANNER-PATH-verbs klettern and steigen in a case study, I showed that there are situations in which knowledge available on the semantic and conceptual level is not enough to judge sentences describing situations. Therefore, I proposed a three-level division of representational knowledge into semantical, conceptual, and \( \sigma \) (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 \( \sigma \)-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 I 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, the theory proposed here avoids family resemblance structure; and I avoid ‘passive defaults’ as they are normally used. Technically, my framework uses formalizations of spatial representation, and in particular, the notion of PATH.

In concrete, I showed (for situations where an object moves along a path in a manner) that relevant information is hidden in the interaction of verb, subject, objects, and directional PP. This interplay of information can be challenged via lexical entries of algorithmic nature. I proposed a toy toolkit with lexical entries for lexical entry for German steigen and klettern (both: climb) and the related knowledge structures. One further main message of this enterprise may be: it is indeed possible to seriously use ‘world knowledge’ in a semantic framework. The key to such kind of knowledge is ‘accessing the infinite unsorted set of knowledge of all kinds.’ The methods to do this are introducing formal bits of knowledge, searching and asking, including undetermined slots into reasoning, and assuming algorithms in the lexicon.

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