Syntactic Indeterminacy and Semantic Ambiguity:
A Case Study for German Spatial Phrases

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Abstract

This chapter presents an operational grammar for German spatial language, in particular German locative phrases, as a case study for processing distributed information. It investigates the complex interplay of syntactic phenomena and spatial semantics, with a specific emphasis on efficient processing of syntactic indeterminacy and semantic ambiguity. Since FCG applies constructions in a sequence one after the other, the main challenge lies in mutual dependencies between constructions, that is, some constructions require pieces of information in order to make decisions that are only later on provided by other constructions. We present solutions and design patterns for dealing with these processing issues, which all have in common the strategy of postponing decisions as long as possible in processing until all the necessary information for making the decision is available.

1. Introduction

All languages of the world have a way of talking about space and spatial configurations of objects in one way or another making spatial language a central linguistic domain that, due to its ubiquitous nature, has received considerable attention.Its syntax and semantics have been treated in great detail in linguistics (see **???** among others), and its semantic complexity and necessarily following its complex syntactical features make it an interesting target for studies, especially, for computational models. It, therefore, can serve as a testbed for investigating the expressive power of FCG. This paper presents a complex unified grammar that allows for the production and parsing of German spatial language utterances, specifically, German locative phrases, that relate some object to a reference or landmark object using spatial relations, such as, "der Block links der Kiste" (the block to the left of the box).

Processing complex spatial phrases requires dealing with problems of intertwined information processing. In particular, we examine 1) how to handle indeterminacy in lexical class and 2) word form choice and 3) managing semantic ambiguity in German spatial language. All these examples have in common that constructions need to collaborate and accumulate information until the information is advanced enough to make decisions and, therefore, we developed techniques that allow us to 1) represent the current state of information, in particular, techniques that accurately represent the current state of uncertainty and ambiguity, 2) spread information in the transient structure and 3) postpone decisions as far as possible, building further on discussions in previous chapters especially (**?????**) We are particularly concerned with how to represent information such that decisions can be postponed and branching of search trees is avoided unless absolutely necessary. The techniques and examples discussed in this chapter are integral part of an operational grammar for German locative phrases, which is part of a larger robotic setup involving robots communicating about the position of objects in their environment (see Figure **??**) and thus poses the challenge of efficient processing of natural language in a real world scenario.

2. Semantic Ambiguity and Syntactic Indeterminacy

German locative phrases feature syntactic indeterminacy and semantic ambiguity, creating an interesting domain for testing design patterns and solutions available in FCG and developed in this book with a special eye on processing efficiency. In particular, German locative phrases can serve as an example of distributed information processing. For example, in order to process the complex syntactic and semantic structure underlying phrases like,

(1)	*der*	*Block*	*vor*	*der*	*linken*	*Kiste*
	the.NOM	block.NOM	front.PREP	the.DAT	left.ADJ.DAT	box.DAT.FEM

'The block in front of the left box'

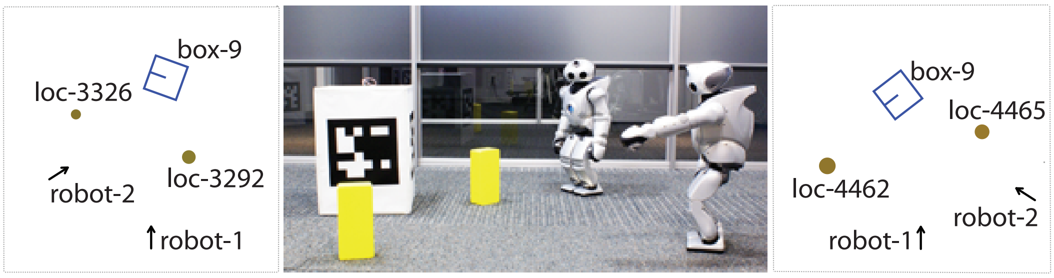

Figure 1. *Spatial setup in which two robots are communicating about objects in their environment. The spatial scene with the two robots is shown in the middle. The objects that populate the environment are tracked by visual processing systems (**?**). These systems distill a world model of the current spatial setup experienced by each robot. The left drawing shows the world model build by the robot to the left in the spatial setup. The drawing to the right shows the world model of the robot to the right. The world consists of three types of objects: robots (black arrows), blocks (yellow circles) and the box (blue square). Each robot is* `robot-1` *in its own world model. The interlocutor is always* `robot-2`*. There are two yellow blocks (e.g.* `loc-3292`*). Additionally, there is a box landmark* `box-9` *drawn as blue square. The box has a front side, marked by the extra blue line in the world models.*

(2) *der Block links von der Kiste von*
the.NOM block.NOM left.ADV of.PREP the.DAT box.DAT from.PREP
dir aus
your.DAT perspective

‘The block to the left of the box from your perspective’

a tight interaction of constructions is inevitable. For instance, Example **??** is semantically ambiguous with respect to how the landmark object, in this case *the left box* is conceptualized, that is, whether or not the perspective on the scene matters, a fact established only after parsing the complete phrase. To illustrate this dependency consider Example **??**, which is not semantically ambiguous because it features a perspective marker in the end.

Next to semantic ambiguity, problems of processing distributed information are salient when dealing with *indeterminacy* of syntactic decisions. Indeterminacy refers to the fact that the syntactic status of some part of an utterance cannot be determined or can only be determined when many mutually dependent constructions contribute enough constraints on the decision. In other words, just as in the case of semantic ambiguity, syntactic indeterminacy requires decision making to be spread over many constructions. There are two main examples of indeterminacy in German spatial phrases, one is the choice of lexical classes and the other, the related choice of word forms. It is important to understand the difference between ambiguity and indeterminacy in this chapter. Semantic ambiguity refers to the case that when parsing an utterance, even at the end of parsing and when considering all available information, the utterance has multiple interpretations. On the other hand, indeterminacy in this chapter refers to a stage in processing, where the status of a syntactic item, for instance the morphology of a word form cannot yet be established. Eventually, the indeterminacy is resolved by accumulating enough information. Semantic ambiguity, on the other hand, in some cases cannot be resolved.

Word class choice of projective spatial categories, i.e. `front`, `back`, `left` and `right` is an example of information processing spread across multiple subsequently applying constructions. Each projective spatial category can be expressed using different lexical classes, e.g. adjective, adverb or preposition and each of these lexical classes entail different morphological instantiations of the same projective category. For instance, adverbial use, as in,

(3) *der* *Block* *hinten*
the.NOM block.NOM back.ADV

'The block in the back',

entails the form "hinten". Whereas prepositional use, is expressed using the string "hinter' as in,

(4) *der* *Block* *hinter* *der* *Kiste*
the.NOM block.NOM back.PREP the.DAT box.DAT

'The block in back of the box',

Because both usages refer to the same category, the lexical construction cannot decide on the actual form of the word. Nevertheless, the lexical construction should be able to constrain the application of the functional constructions , because, given a particular lexical item, not all lexical classes are possible (see **?** for the idea of splitting lexical and functional constructions). For instance, projective categories cannot be expressed as verbs (see **?** for an overview of accepted lexical classes). Thus, it is lexical and functional constructions that need to work together in order to orchestrate the word choice for lexical items.

For adjectives the problem of handling distributed information is repeated, since the word form does not immediately follow from the lexical class but depends on the larger syntactic context. All adjectives in German have to agree, among other things, in case, number and gender with their surrounding nominal phrase, which leads to different morphological instantiations, such as in the following two examples:

(5) *die* *hintere* *Kiste*
the.NOM back.NOM.FEM.SING box.NOM.FEM.SING

'The back box',

(6) *der* *hinteren* *Kiste*
the.GEN back.GEN.FEM.SING box.GEN.FEM.SING

'The back box's',

Among other things, these two examples differ in the word form of the projective category `back`. Hence, for the case of adjectives, the information provided by lexical and functional constructions is not sufficient for deciding on the form of the word. While the set of possible word forms is constrained through the knowledge of the lexical class and the projective category to be expressed, the final decision can only be made after applying grammatical constructions that can settle the issue of case, gender and number agreement. Ultimately, the decision of word form for projective categories requires the assembling of information and constraints from different parts of grammar, namely, from lexical, functional and grammatical constructions.

Organizing efficient processing is challenging, as seen in all three examples, due to the mutual dependencies between constructions, where more locally operating constructions require information that is provided by more grammatical, hence more global, constructions. The crux is that grammatical constructions themselves require lexical constructions to apply first. In other words, constructions require bits and pieces of information from one another for the particular decision at hand. As a result, one faces the problem of distributed decision making when dealing with distributed information in highly dependent construction organizations.

In principle, there are three ways to handle problems of distributed decision making. One is to give up on the idea of compositional grammar organization, and hence of distributing information altogether, by engineering a holistic grammar, where, in the most extreme case, each construction maps a single utterance to a single meaning. The second solution is to *explicitly* represent the different possible outcomes of a particular decision in the search process through branching. The third solution is to postpone the decision for as long as possible in processing until all the information necessary for making the decision is available.

From the viewpoint of grammar design, the first solution is not desirable, because, after all, grammar designers are looking for elegant ways to capture similarities and distinctions in a unified way. In designing a grammar, the engineer looks for linguistic abstractions that allow for the modeling of the production and parsing processes without the need to code every utterance separately. The second solution to the problem of distributed information processing is to rely on the search process and track down every possible outcome of a particular decision in branches of the search tree. For the problem of word form choice, for instance, separate lexical constructions could exist for each of the different forms of a word, which would amount to many lexical items per projective category, such as one for each adverb, preposition and one for every adjectival form. This solution suffers from ill performance in processing, since every search branch needs to be followed until it can be abandoned. The performance of this solution in processing depends on how many possible forms of the word exist and how long branches need to be followed until the decision to abandon them can be made. For adjectives, for instance, the decision in many cases has to wait until the determined noun phrase construction applied. Depending on the complexity of the outcome of a particular decision, this approach can create hundreds of branches that need to be processed in full depth.

The third solution, and the one favored in this chapter, is to postpone the decision at hand as long as possible, namely, until all relevant information is present. This approach requires some machinery, in particular it requires:

- A representation that allows one to store the uncertainty of the state of information in a concise way
- Mechanisms for accumulating information so that the state of information becomes less and less uncertain
- Machinery for making the decision when there is enough accumulated information

The key insight is to have information stored in the transient structure itself, so that multiple constructions can contribute information and constraints independently of each other until the state of information is such that a decision can be made.

Consequently, uncertainty, partial information and ambiguity are not represented in branches of the search tree unless really necessary, reducing processing effort, since only few branches in the search tree need to be explored.

3. The Actual-Potential Design Pattern

The actual-potential design pattern gives grammar designers a way to distribute decision making by separating the specification of options from the actual decision process. Possible outcomes of a decision are explicitly stored in the form of disjunctive potentials. Constructions can use this representation in two ways. First it can be used to signal to subsequent constructions which choices are possible. Second, subsequent constructions can constrain their application using provided potentials.

An example for the actual-potential design pattern is the choice of lexical classes for projective terms. Projective terms (**?**) are a specific class of spatial terms particularly important for German locative phrases (**?**). A projective spatial term can be used to specify the static location of an object by indicating its spatial relation to a reference object [1]. Projective terms depend particularly on the direction of the object to the reference object. Examples of projective terms are “vor” (in front of), “links” (left).

Projective terms are intricately linked to projective categories. We denote the category a projective term denotes using their English equivalents, e.g. `front`, `back`, `left` and `right`. What is interesting is that each projective category can be expressed in different syntactic scenarios. For instance, the projective category `front` can be used as an adjective, as in the following example:

(7) *der* *vordere* *Block*
the.NOM front.ADJ.NOM block.NOM

‘The front block’,

It can also be used as an adverb, as shown here:

(8) *der Block* *vorne*
the block.NOM in the front.ADV

‘The front block’

Finally, it can be used as a preposition, as in the following:

1. In this chapter we are only concerned with the static spatial use of projective relations. This excludes dynamic or temporal readings.

(9) *der* *Block* *vor* *der* *Kiste*
the.NOM block.NOM front.PREP the.DAT box.DAT

'The block in front of the box'.

The actual-potential design pattern applied in this case allows lexical items to represent their possible lexical class categorizations as disjunctive potentials in the transient structure, leading to 1) a more concise grammar design, and 2) higher processing efficiency, which is simply due to avoiding split in search. In the case of lexical class choice the actual-potential design pattern allows to meet this objective by enabling grammar designers to separate the specification of lexical constructions, one for each projective category, from the specification of functional constructions, one for each syntactic usage scenario.

Examples **??**, **??** and **??** all have in common that they refer to the same projective category `front`, expressed using lexical constructions, which map the semantic fact that all refer to the same projective category to the syntactic fact that all feature a similar word stem. The skeleton for the projective category `front` expresses the following:

(10)
```
(def-lex-cxn
  (def-lex-skeleton front-cxn
   :meaning (== (bind frontal-category ?cat front))
   :args ((ref ?cat))
   :stem "vor"))
```

The skeleton maps the meaning, that is, the reference to the projective category `front`, to the stem ”vor”. In general, lexical constructions express the similarity of different syntactic usage scenarios of projective categories, namely, they feature the same stem and the same meaning insofar as they refer to the same projective category.

Functional constructions, on the other hand, map a particular lexical class to syntactic and semantic properties relevant for processing of the lexical class. For the projective category `front` the lexical classes differ semantically in that adjectives filter objects, adverbs refer to internal regions and prepositions refer to external regions (see **?** for the difference and a detailed discussion). We represent the different semantics of lexical classes through different semantic operations. Below is the skeleton for the functional constructions of spatial adjective:

(11)
```
(def-fun-cxn spatial-adjective
  :meaning (== (apply-spatial-category
```

projective term/usage	adjective	adverbial	prepositional
frontal	filter objects	internal region	external region
lateral		internal or external region	external region

Table 1. *Semantic distinctions for projective terms at a glance. The table shows how the different usage scenarios of projective terms differ in semantics. This is a very coarse view on many findings in cognitive linguistics regarding the semantics of projective terms. It only serves as a means to get an intuition into why the split into different functional constructions is necessary.*

```
                         ?target ?source ?category))
   :args ((ref ?target)(src ?source)(cat ?category))
   :sem-function modifier
   :syn-function adjectival)
```

which conveys that categories (e.g., `front`) used as adjectives are applied to filter objects, which is represented here by the operation `apply-spatial-category`. On the other hand, adjectives also have a distinctive syntactic behavior. One is their role in larger syntactic contexts, here denoted by the syntactic function `adjectival`. The second is their agreement in case, gender and number. The later will be picked up again in Section **??**.

Aside from the spatial adjective construction, there are a number of other important functional constructions. All reflect a hypothesized difference in processing both syntactically and semantically. In principle one can distinguish adverbial use and prepositional use on top of the adjectival use of projective terms. Both adverbs and prepositions are semantically different from adjectives as they are not used to filter objects, but rather denote spatial regions. In some cases they denote spatial regions in relation to a reference object or landmark (**?**). Yet, the split into categories goes even further. Frontal adverbs (adverbs that express frontal projective categories, i.e. `front` and `back`) behave differently from lateral adverbs (those that

projective term/usage	adjective	adverbial	prepositional
frontal	case, gender, number agreement	can be extended using an "in" headed prepositional phrase	governs dative
lateral		can be extended using "in" and "von" headed prepositional phrases	governs genitive

Table 2. *Syntactic distinctions for projective terms at a glance. The table shows how the different usage scenarios of projective terms differ in syntactic structure. It is by no means a conclusive or an exhaustive set of distinctions but should give the reader an intuition as to why the split into different functional constructions might be a valid modeling approach. Notice that the preposition "vor" (frontal preposition) can also govern the accusative case. However, for static phrases, i.e. phrases not describing dynamic events, dative is obligatory.*

express lateral categories), and frontal prepositions behave differently from lateral prepositions (see Table **??** for semantic distinctions and Table **??** for some syntactic intuitions). All of these differences are captured in functional constructions. Consequently, there are functional constructions for frontal adverbs, frontal prepositions, as well as for lateral adverbs and prepositions.

Given this wealth of functional distinctions how do lexical and functional constructions interact? In particular, how can the design pattern be used to constrain the possibilities of functional construction application? The design pattern is applied, here, to both the syntactic and semantic side of constructions. The lexical constructions provide semantic and syntactic potentials, which are used by the functional constructions to constrain their application. On the semantic side, constraints are rooted in types needed for semantic processing, whereas on the syntactic side, the potential for the application of functional constructions is directly represented. Since all projective categories can be used as adjectives, all lexical constructions

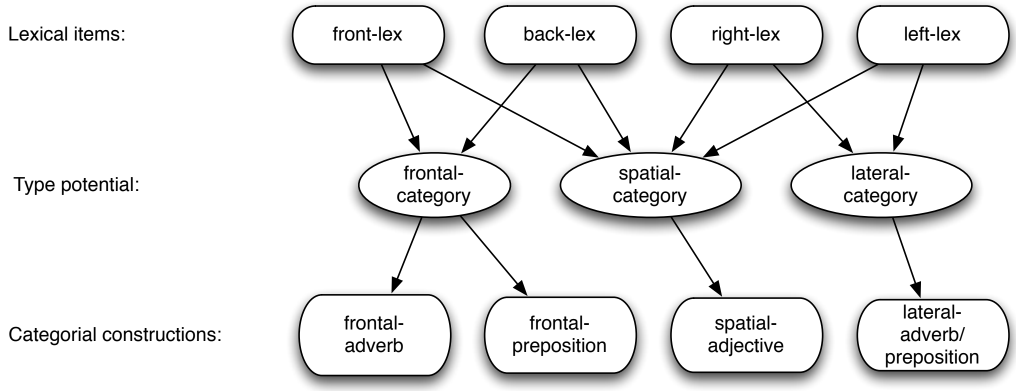

Figure 2. *Mapping of lexical items to functional constructions.*

for projective categories feature the `type` potential `projective-category`, as well as the syntactic `lex-cat` potential `spatial-adjective`. Fine-grained distinctions between lateral and frontal projective categories are made by supplying additional potentials. For instance, the lexical constructions for `front` and `back` both feature the type `frontal-category`, where lateral lexical constructions (i.e. for `left` and `right`) have the type potential `lateral-category`. Equally straightforward are the potentials on the syntactic side, which mirror the distinctions in functional constructions just discussed. Frontal projective lexical constructions have potentials for `spatial-adjective`, `frontal-adverb` and `frontal-prepositions`. Such distinctions are also applied to lateral projective lexical constructions. (Figure **??** shows the semantic potentials via the `type` attribute, Figure **??** shows the syntactic potentials, that is, the `lex-cat` attribute.

Let us look at the technical implementation. We extend the lexical construction specification in Example **??**

(12)
```
(def-add-potential front sem sem-cat type
  (projective-category frontal-category))
(def-add-potential front syn syn-cat lex-cat
  (spatial-adjective frontal-adverb
                     frontal-preposition))
```

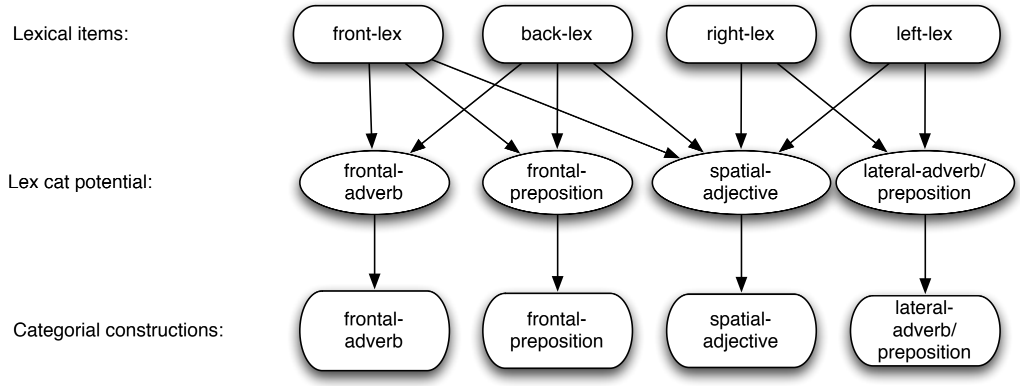

Figure 3. *Mapping of lexical items to functional constructions.*

These two templates specify the `type` and `lex-cat` potentials and directly translate into attributes in the following: construction:

(13)
```
(...
 (J ?front-unit ?top ()
  ...
  (sem-cat
   (==
    (type
     ((actual ?type-value)
      (potential
       projective-category frontal-category))))))
   ...)
...)
 <-->
(...
 (J ?front-unit ?top ()
  ...
  (syn-cat
   (==
    (lex-cat
     ((actual ?lex-cat-value)}
```

```
          (potential
           (spatial-adjective frontal-adverb
                              frontal-preposition))))
        ...))
    ...)
```

There is one notable feature of the technical implementation of the actual-potential design pattern. The template `def-add-potential` not only adds the `potential` attribute but also an attribute called `actual`. This attribute is automatically set to a variable in the lexical construction and is used to store which `type` attribute is used. If one of the potentials is picked up, for instance by a functional construction, the `actual` attribute is also set.

It is important to understand that lexical constructions store the information about potentials in the transient structure, in order to allow subsequent constructions to choose the potential in which they are interested and to constrain their own application. This process can be seen in an extended version of the spatial adjective functional construction:

(14)
```
(def-require-potential spatial-adjective ?cat-unit
  sem sem-cat type projective-category)
(def-require-potential spatial-adjective ?cat-unit
  syn syn-cat lex-cat spatial-adjective)
```

These templates express that, in order for the spatial adjective construction to apply, certain potentials need to be present in the transient structure. More precisely, the `type` potential `projective-category` and the `lex-cat` potential `spatial-adjective` need to be available.

The template for spatial adjectives translates into the following feature structure (for illustrative purposes, only the semantic side is shown here):

(15)
```
(...
 (?cat-unit
  (sem-cat
   (==
    (type
     ((actual projective-category)
      (potential
       (==! projective-category))))
    ...))
...)
```

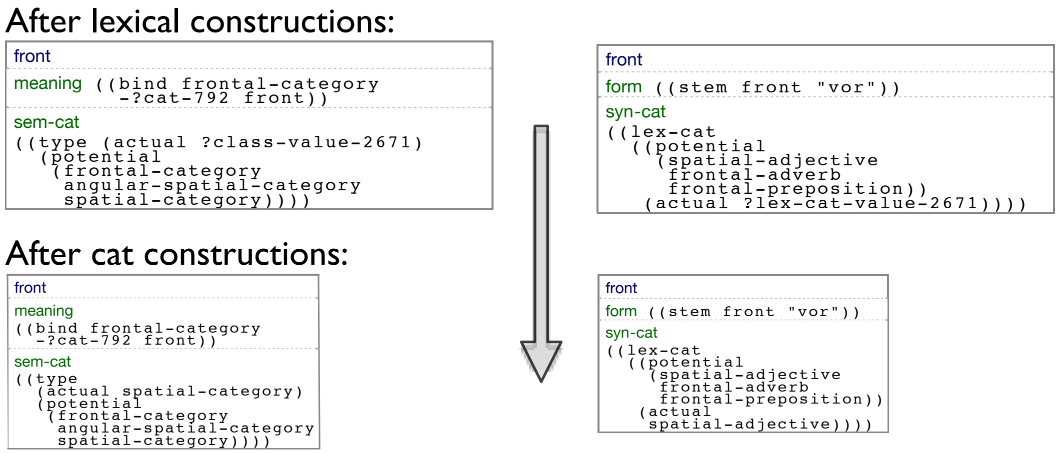

Figure 4. *Interaction of lexical construction constructions with functional constructions in production of "vordere" (front). The arrow signifies the order of application. Left, the* `vordere` *unit on the semantic side of the processed transient structure is shown. Right, the syntactic unit is shown. The transient structure actually contains more units, and the units themselves contain more features, but everything has been shortened for illustrative purposes. The top row shows the lexical unit after the application of lexical constructions, which have equipped the lexical unit with potentials for* `type` *on the semantic side, and* `lex-cat` *on the syntactic side. Both of these potentials have no value assigned to them yet. It is only after the application of the functional construction of spatial adjective that both have values assigned to them,* `spatial-category` *for* `type` *and* `spatial-adjective` *for* `lex-cat`.

This construction can only apply if the `type` potential of the lexical constituent in the transient structure imperatively includes `projective-category`. Additionally, it requires the `actual` attribute to be `projective-category` or a variable. Technically speaking, there are two things to note here: the use of the `==!` operator for potentials and the handling of the `actual` attribute.

The first interesting feature is the use of the `==!` operator for potentials. This operator only unifies and never merges, which means that neither in production nor parsing can a missing potential be merged. The specified potential always has to be

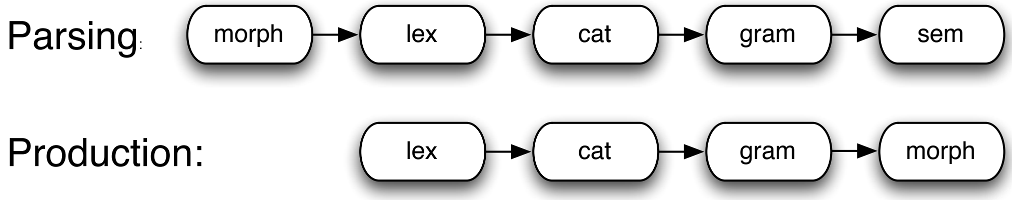

Figure 5. *Construction application in the German spatial language grammar discussed in this chapter. In parsing, morphological constructions apply first followed by lexical and grammatical constructions. Finally, there are special constructions important for handling semantic ambiguity. In production, constructions handling semantic ambiguity are not applied. On the other hand, morphological constructions apply in production at the very end in order to decide on the actual form used in the utterance.*

present, in this case on the semantic side, but for the `lex-cat` potentials, the case is vice versa on the syntactic side. Consequently, choosing a potential does not change the potential in the transient structure.

The second interesting feature is the `actual` attribute, which must be equal to `projective-category` or a variable, in order for the spatial adjective construction to apply. If the attribute is a variable, then that variable is bound to `projective-category`, and, hence, the application of the spatial adjective construction modifies the transient structure and sets the `value` attribute to the required potential. Of course, the corresponding potential also has to be present for the construction to apply in the first place (see Figure **??**)

This split into `value` and `potential` is not only nice for grammar designers who can track the application of constructions by tracing the actually chosen potential, but it plays an active role in processing. In parsing, the lexical class of a word is already decided by morphological constructions, which apply first when parsing an utterance. (See Figure **??** for an overview on construction application.) Morphological constructions are word recognizers that tightly interact with lexical and functional constructions in parsing. In production, they are used to map a particular lexical item and in particular a certain stem, which is expressed using a particular

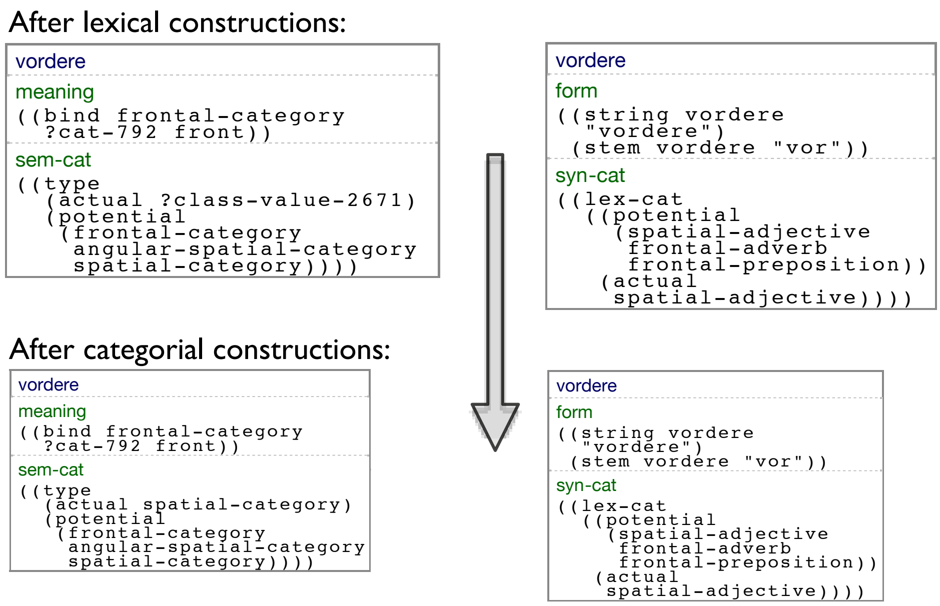

Figure 6. *Interaction of lexical construction constructions with functional constructions in parsing "vordere" (front). Lexical constructions apply before functional constructions. The* `vordere` *unit on the semantic side of the processed transient structure is shown on the left. The syntactic unit is shown on the right. The transient structure actually contains more units, and the units themselves contain more features, but everything has been shortened for illustrative purposes. The top row shows the lexical unit after the application of morphological and lexical constructions. The parsed string unambiguously allows for a decision to be made on the* `lex-cat` *value, and hence the value is set on the syntactic side. It is the functional construction that picks one of the* `potential types` *on the semantic side and fills its* `value` *attribute.*

lexical class to a form. In parsing this process is reversed and based on the string observed in an utterance. Because morphological constructions add information about the observed stem and the lexical class, they can provide a value for the `actual` attribute. For instance, when observing the form "vorne", the morphological construction responsible for the string "vorne" triggers and adds the information to the transient structure, namely that an adverb was observed in parsing. (See Figure **??** for a schematic overview.)

More can be said about the interaction with morphological constructions, with a complete discussion in Section **??**, which picks up the topic with further consideration of morphological features of the German language. Of central concern here is the `actual` attribute as an important feature in the design pattern for interacting with other constructions.

This section has provided an explication as to how the actual-potential design pattern can be used, on the one hand, to aid the grammar designer in formalizing intuitions about interactions of highly dependent constructions in an example of lexical and functional construction dependency, and, on the other hand, to maintain processing efficiency. Grammar designers are aided in the process of modeling a particular feature of natural language because the design pattern allows them to express their ideas without being constrained by processing issues. Splitting in search is avoided when the pattern is applicable, and the process of construction application stays manageable from the viewpoint of efficiency.

4. Handling Semantic Ambiguity

Semantic ambiguity arises when there are different possible interpretations for an utterance. This section examines a set of applicable techniques for dealing with semantic ambiguity in German locative phrases, a ubiquitous feature of such phrases. Specifically, this section is concerned with a particular kind of semantic ambiguity materializing in constructions, where different possible conceptualizations of a landmark or reference object are possible, resulting in different possible interpretations of the utterance involving that object. Interestingly, certain inferences about interpretations are possible when considering the larger syntactic structure (i.e. when considering all information present in the phrase), which makes the semantic ambiguity discussed in this section a problem of distributed information processing. In order to handle semantic ambiguity, a combined approach is proposed that integrates the following elements:

1. **logic variables**, for representing uncertainty,
2. **percolation**, for distributing information,
3. **the actual-potential design pattern**, for constraining the application of constructions and

4. **sem-sem constructions**, which are particular constructions that only apply on the semantic side of feature structures, for postponing decisions.

When applied together, this set of techniques allows to represent the inherent ambiguity in certain German locative phrases in a concise way, while allowing constructions to collectively resolve the ambiguity, where possible, or to otherwise interpret the phrase in all possible ways.

The semantic ambiguity discussed in this chapter focuses entirely on how a particular landmark is conceptualized. Consequently, this ambiguity only surfaces in phrases involving overtly or covertly expressed landmarks. Examples of such phrases are prepositional and adverbial phrases, such as the following (Example **??** is repeated in **??** for convenience):

(16) *der* *Block* *vorne*
the.NOM block.NOM front.ADV

'The block in front'

(17) *der* *Block* *links* *von* *der* *Kiste*
the.NOM block.NOM left.ADV of.PREP the.DAT box.DAT

'The block to the left of the box'

(18) *der* *Block* *hinter* *der* *Kiste*
the.NOM block.NOM hinter.PREP the.DAT box.DAT

'The block in back of the box',

Examples **??** and **??** explicitly refer to the landmark object, whereas Example **??** implicitly refers to a landmark. In all cases, however, a projective term is used in relation with some landmark, denoting the particular spatial relationship of the object in question, in this case *the block*, to the landmark. All of these phrases are semantically ambiguous because they do not explicate how the landmark is to be conceptualized.

4.1. One Source of Semantic Ambiguity

To conceptualize something as a landmark involves applying a particular coordinate system to it, to which spatial relations, such as projective categories, can then be applied. The combination of a particular coordinate system with a landmark is called a *reference system*. Coordinate systems for reference objects (i.e. landmarks)

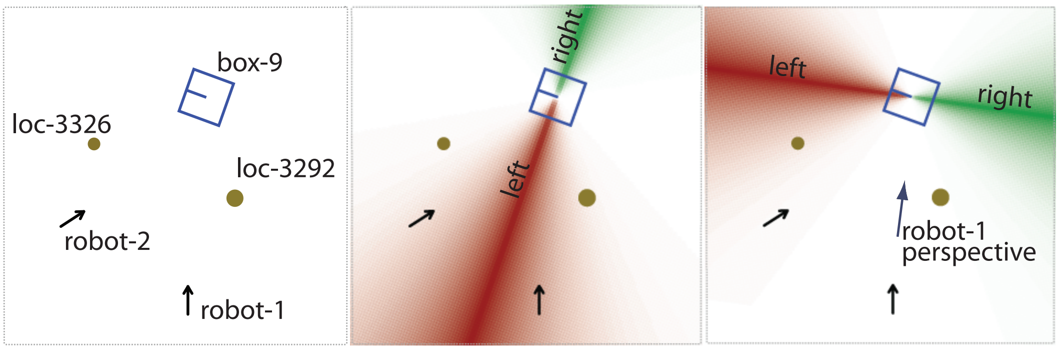

Figure 7. *Difference between intrinsic and relative frame of reference for* `left` *and* `right` *spatial distinctions illustrated using the box as example landmark. Left figure: original spatial scene (see Figure* **??***). The spatial scene features a potential landmark, the box (blue square). Middle figure: landmark construed with intrinsic frame of reference. The box in this world model has an inherent orientation (blue line in the box), which is used to construe the landmark using an intrinsic frame of reference. Consequently, the regions of* `left` *and* `right` *are aligned to the orientation of the box. Right figure: box construed using a relative frame of reference. Here,* `left` *and* `right` *are actively construed from the perspective of the cognizer* `robot-1` *and its perspective on the landmark. The intrinsic orientation of the box is ignored.*

have been dealt with in great detail in cognitive semantics and psycholinguistics under the concept *frame of reference*. **??** identifies three possible frames of reference: *intrinsic*, *relative* and *absolute*, all of which denote a particular way of construing a landmark for spatial relationships. In German all three frames of reference are possible, however, this chapter focuses only on intrinsic and relative frame of reference.

Intrinsic frame of reference The intrinsic frame of reference is an object centered coordinate system, meaning that projective categories are applied to the reference object based on particular sides of the object, which are construed as front, back, left and right. Hence, those objects that have something that can be considered as their front (with other sides, identifiable as well, e.g., left, right and back) are eligible to be used as landmarks with an intrinsic frame of reference. Examples of such objects are television sets, where the front is the screen, or houses, where the front is the main entrance or street access, and so forth.

Relative frame of reference The relative frame of reference is a perspective based coordinate system. (See Figure **??** for a graphical explanation.) Instead of relying on intrinsic features of the reference object for determining the particular layout of the coordinate system, the rotation of the coordinate system is determined by its angle to an explicitly or implicitly given perspective. Hence, the front of an object is induced by the particular perspective on the scene. For example, "vor dem Baum" (in front of the tree) implicitly refers to a perspective, because trees do not have an intrinsically determined front, and it is the position of the observer together with the position of the tree that designates the precise region denoted as front.[2]

These two frames of reference already provide an interesting source of semantic ambiguity, because in Examples **??**, **??** and **??**, the landmark can be construed using an intrinsic or relative frame of reference. Hence, all of the examples have at least two possible interpretations.

4.2. Perspective Marking

Semantic ambiguity alone is already an interesting phenomenon, but in German locative phrases there is even more going on. The syntactic structure can provide additional information that allows for the disambiguation of the conceptualization underlying a particular utterance. This is the case when the phrase also features a perspective marker, such as in the following:

(19) *der* *Block* *vor* *der* *Kiste* *von* *dir*
the.NOM block.NOM front.PREP the.DAT box.DAT from.PREP your.DAT
aus
from.PREP your.DAT perspective

2. For the grammar discussed in this chapter, we only look at a constrained set of landmarks. Every context consists of three possible landmarks usable in conceptualization, two interlocutors and one box. The box is a marker augmented carton box, which has an inherent orientation. Hence, boxes can be construed as landmarks using either an intrinsic or relative frame of reference and they behave in some sense like houses or television sets, which have an intrinsic front, but also like trees which do not. The choice of boxes for this purpose might feel uneasy to German native speakers. We use boxes as a placeholder for objects that have an intrinsic orientation.

'The block in front of the box from your perspective',

The component "von dir aus" (from your perspective) is a clear indicator of a construing of the landmark, namely the box, from a certain perspective. Consequently, this phrase has a relative reading only. After all, interpreting a relative landmark always entails construing the scene from a certain perspective. On the other hand, an intrinsic reading of the phrase is excluded, since construing a landmark using an intrinsic frame of reference is independent of the viewpoint of the scene.

The interaction with perspective marking makes the semantic ambiguity in German locative phrases an interesting problem for two reasons. First, the decision whether there is semantic ambiguity is distributed. Perspective marking is optional, and the perspective marker might follow or precede the locative phrase in question. Further complicating the matter is the fact that for adverbials even the landmark itself is optional, and hence large parts of the complete structure are optional. One, therefore, needs clever mechanisms to handle all these cases in a unified and elegant way. Second, the effects of the decision are also distributed. Section **??** already demonstrated how functional constructions add operations concerning how to process a particular projective category. As will be shown, it is at this level where the decision on the frame of reference needs to impact. Hence, methods must be found for propagating information so that the decision can have an effect at the right place in processing.

4.3. Processing Locative Phrases – Syntax and Semantics of Adverbs and Prepositions

In order to model the semantic interpretation, semantic ambiguity and semantic ambiguity resolution of phrases such as in Examples **??** to **??**, three elements are required: 1) the ability to represent the processing of semantic structure and the semantic ambiguity, 2) a way of distributing information so that constraints on the information can be applied and 3) the means to postpone the decision.

4.3.1. *Representing Spatial Semantics*

We use a procedural semantics (**???**) approach for representing the processing of spatial contexts and the link to language. The basic idea is that an utterance is communicating a specific set of instructions and cognitive operations that guides the hearer in deciphering the communicative goal. For instance, in the case of a referential expression that uses spatial relations the utterance encodes a set operations such as perspective reversal (**?**) and categorization operations that allow the hearer to identify the object in question. Our procedural semantic representation consists

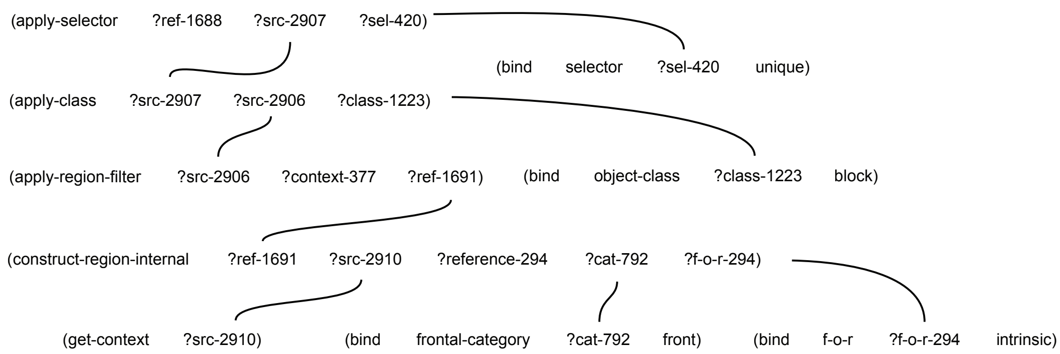

Figure 8. *Semantic structure of the utterance"der Block vorne" (intrinsic reading).*

of three parts: 1) operations, for which an example for filtering objects was already shown (see Section **??**), 2) the explicit introduction of conceptual entities (called *bind-statements*) and 3) links between operations and bind-statements.

Figure **??** shows such a procedural, network like, semantic structure for the utterance in "der Block vorne" (the block in front) from Example **??**. The structure features a number of operations, of which the most interesting, for purposes of this section, is the `construct-region-internal` operation. This operation has a number of input output arguments that are all signified by variables starting with a `?`, which are used for discussing the arguments below:

`?ref-6` is the region computed by this operation.

`?src-6` is the input context.

`?reference-6` is the landmark.

`?cat-6` is the projective category that is used to construe the region.

`?f-o-r-1` is the frame of reference used to construe the region.

As a result, the operation has all necessary input and output arguments to compute a spatial region. In this case, it is an internal spatial region (i.e. a region

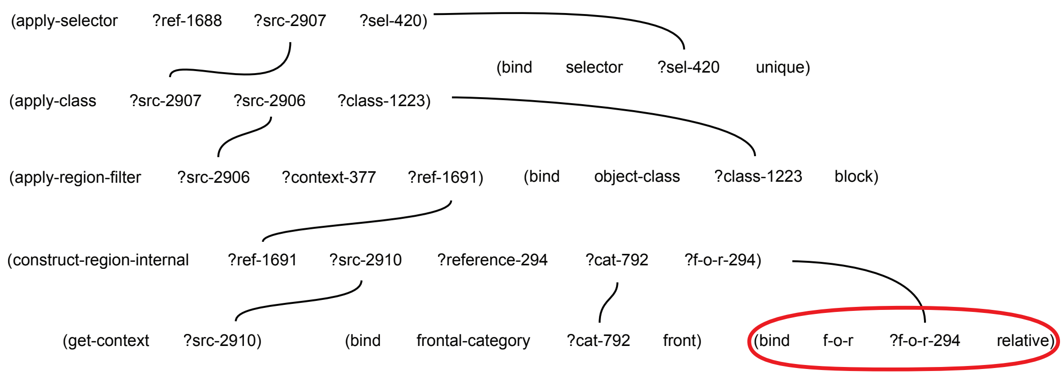

Figure 9. *Semantic structure "der Block vorne" relative reading. The difference from an intrinsic reading is only in the bind statement referring to the frame of reference used in computing the spatial region.*

that is inside the landmark), which takes into consideration the projective category, the landmark to which the category is applied and the frame of reference. In this particular structure the frame of reference argument is linked to a bind statement explicitly introducing the intrinsic frame of reference into the structure. Because the phrase in Example **??** is ambiguous, there exists also another interpretation of the phrase involving a relative frame of reference. (Compare Figure **??** which shows the relative interpretation with Figure **??** which shows the intrinsic interpretation). Consequently, procedural semantic structures can be used not only to represent the meaning of phrases but also to capture their semantic ambiguity.

4.3.2. *Tracking Ambiguity in the Transient Structure*

Given such a representation, the next question is concerned with how the semantic ambiguity can be represented in the transient structure. The solution is straight forward and has been applied many times in various contributions in this book. Uncertainty is represented using a variable. Since the procedural semantic representation has the same convention for variables, namely, that variables begin with a ?, parts of the semantic structure can be replaced using a variable. In order to allow FCG to contribute information to those parts in the semantic structure that are uncertain or ambiguous, the same variable is repeated in the construction. Below, then, as an example is the functional construction for frontal adverbs:

(20)
```
(def-fun-cxn frontal-adverb
 (def-fun-skeleton frontal-adverb
  :meaning
   (== (construct-region-internal ?target
        ?source ?landmark ?category ?f-o-r)
       (bind f-o-r ?f-o-r ?f-o-r-value))
  :args ((ref ?target)(src ?source)
          (cat ?category)(landmark ?landmark))
  :sem-function modifier
  :sem-class (region internal-region
                    relative-region)
  :syn-function adverbial
  :syn-class adverb)
  (add-sem-cat frontal-adverb
   (f-o-r-value ?f-o-r-value)))
```

Parts of the semantic structure in Figures **??** and **??** are represented by adding them to the meaning of this construction. In particular, the operation and the frame of reference are part of the specification of the functional construction. Moreover, the actual frame of reference is left unspecified but is represented using the variable `?f-o-r-value` instead, and it is this variable that is repeated as a semantic category attribute. Consequently, this specification expresses two things: firstly, when a frontal projective category is expressed using an adverb, its meaning is to construct a region, and, secondly, the frame of reference used to construct this region is unspecified Thus, to summarize, the use of the same variable allows for the representation of the uncertainty in a unified way in the semantic structure as well as in the construction and, consequently, in the transient structure.

4.3.3. *Processing Semantic Ambiguity*

With the knowledge of how to represent semantic structure as well as the ambiguity in the semantic interpretation, we can now turn to the processing of the utterance and, in particular, to the processing of semantic ambiguity. We focus first on the ambiguous case only, that is, the case where no perspective marker is present in the phrase. Consequently, we are trying to solve the problem of letting FCG compute all possible interpretations of a phrase like the one in Example **??**. The key property of the FCG search for an interpretation of such an utterance is

Figure 10. *Final part of the parsing search tree for the utterance "der block vorne".* `Sem-sem` *constructions apply at the very end and split the search tree and, hence, represent the possibility of two interpretations of the phrase.*

that each branch in the search tree corresponds precisely to one possible interpretation. As a result, in order to represent the different interpretations of the phrase, the search tree must be split, yet it should only split into different branches at the very end of parsing. From a processing point of view such a late split is desirable, since branching the search at the end reduces computational complexity. From the point of view of modeling, it is necessary, because it is only when considering the larger semantic structure that the phrase can be determined to be ambiguous. In other words, to be sure about whether or not the phrase is really ambiguous, processing must be complete with no perspective marker observed.

To achieve these objectives, two `sem-sem` constructions are used, that is, constructions which only work on the semantic side of the transient structure, one for representing intrinsic readings and one for representing relative readings. These constructions apply at the very end of parsing, and their job is to set the frame of reference variable. Here is one of the two `sem-sem` constructions:

(21)
```
(def-sem-sem-cxn
  :meaning  (== (bind f-o-r ?target intrinsic))
  :sem-cat (==1 (f-o-r-value intrinsic)))
```

The construction directly applies to the part of the transient structure that represents the meaning of the frontal adverb. Since the `f-o-r-value` was set to the variable `?f-o-r-value`, this part of the transient structure unifies with `intrinsic` and sets the attribute as well as the part of the bind statement in the meaning to the value `intrinsic`. A similar construction is used for applying a relative frame of reference. (Figure **??** shows the split at the end of parsing the phrase "der block vorne".) These constructions are necessarily very general and apply equally to all other required cases, in particular projective prepositions (i.e. frontal and lateral prepositions) but also to lateral adverbs.

The usage of logic variables allows for the representation of the uncertainty in interpretation directly in the transient structure. In interaction with semantic rules these variables are used in processing to provide the different semantic interpretations of ambiguous German locative phrases.

4.3.4. *Handling Perspective Markers*

Perspective markers pose a problem in terms of processing, since information about perspective marking is available on the phrasal level only. For instance, in Example **??**, the part "vor der Kiste von dir aus" (in front of the box from your perspective), the perspective marker is the additional phrase "von dir aus", which together with the prepositional phrase in the beginning makes up the complete phrase. As a consequence, the problem to be solved is to distribute the information about the used frame of reference so that a construction combining the two phrases can make the necessary semantic inference, namely, set the frame of reference. In particular the information needs to spread all the way to the part of the semantic structure processing the region, that is, the functional unit representing the preposition or adverb. The answer to this problem is the use of percolation for distributing the information, so that the information becomes available at the places necessary.

Before looking at percolation in more detail, below is a simpler case where a stand alone adverb is perspective marked (i.e. an adverb that has no landmark phrase attached to it).

(22) *der* *Block* *vorne* *von* *dir* *aus*
the.NOM block.NOM front.ADV from.PREP your.DAT from.PREP

your.DAT perspective

'The block in the front of the box from your perspective'

Basically, a construction is required that sets the frame of reference to relative, given a relative region or a region that has the potential to be interpreted as a relative region and also given a perspective marker that has the right syntactic relationship to the region. The following construction does exactly that.

(23)
```
(def-phrasal-cxn
    relative-region--perspective-marked
  (def-phrasal-skeleton
```

```
    relative-region--perspective-marked
  :phrase
  (?relative-region--perspective-marked
   :sem-function (modifier)
   :sem-class (region)
   :syn-function (adverbial)
   :cxn-form
   (== (meets ?relative-region-unit
              ?perspective-marker-unit)))
  :constituents
  ((?relative-region-unit
    :sem-function-potential (modifier)
    :sem-class-potential (relative-region))
   (?perspective-marker-unit
    :sem-function-potential (modifier)
    :sem-class-potential (perspective-marker))))
(def-set-cat ?relative-region-unit sem-cat
             f-o-r-value relative))
```

This construction captures all the constraints posed. For this construction to apply there need to be two constituents. One constituent needs to have the `sem-class` potential `relative-region`, that is to say, it needs to be able to be conceived as a relative region. The second constituent needs to be a perspective marker.[3] Above all, the construction sets the frame of reference value of the region unit to `relative`. Now, in the case of the phrase “vorne von dir aus” (in front from your perspective), the region unit in parsing corresponds to the adverb unit, namely to the unit setup by the adverb functional construction (see Example **??**). Figures **??** and **??** show the state of the transient structure before and after application of the construction.

The construction that handles the perspective marking of relative regions is necessarily very general, that is, it does not constrain the syntactic class of its constituents since it is used to handle not only cases of stand alone adverbs but also landmark augmented adverbs and prepositional phrases. The problem that remains is how the information, in particular the uncertainty about the frame of reference, is spread so that this construction can distribute its decision on the relative frame of reference to the place where this information is needed to compute the region, namely, the corresponding functional unit. The solution is to apply percolation

3. This construction only handles cases where the perspective marker directly follows the adverb. Other cases are handled by similar construction that differ in the syntactic constraints.

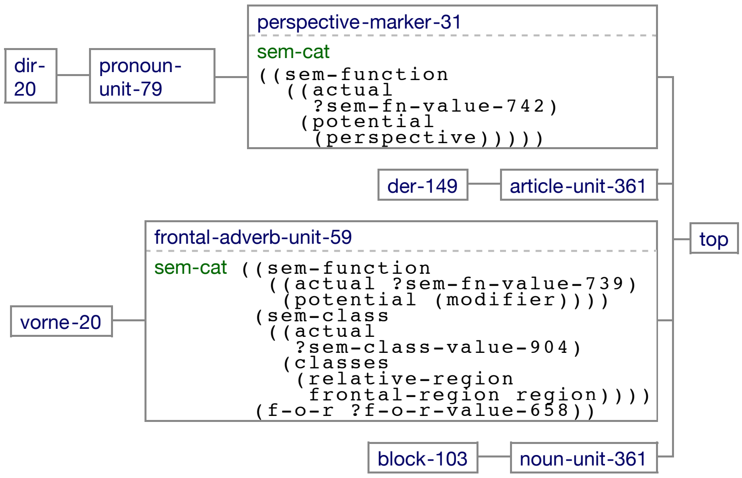

Figure 11. *Transient structure before the application of the* `relative-region--perspective-marked` *construction (when parsing "der Block vorne von dir aus"). The* `f-o-r` *(frame of reference)* `sem-cat` *attribute of the* `frontal-adverb-unit-59` *is set to a variable. Consequently, at this point in processing it is undetermined which frame of reference is used. For simplification, only the* `sem-cat` *features of relevant units are shown.*

through all intermediate processing steps. For instance, when parsing a frontal prepositional phrase, such as in "vor der Kiste von dir aus" (in front of the box from your perspective), the functional unit for "vor", first becomes a constituent of the frontal prepositional phrase "vor der Kiste", in which it is embedded, and then becomes a constituent of the perspective marked relative region phrase. Consequently, percolation is added to the `angular-prepositional-phrase` construction using the agreement macro introduced in Steels, this volume.

(24)
```
(def-add-phrasal-agreement
 angular-prepositional-phrase
 (?relative-region-unit
  :sem-cat (f-o-r-value ?f-o-r-value)
 (?angular-pp-unit
  :sem-cat (f-o-r-value ?f-o-r-value)))
```

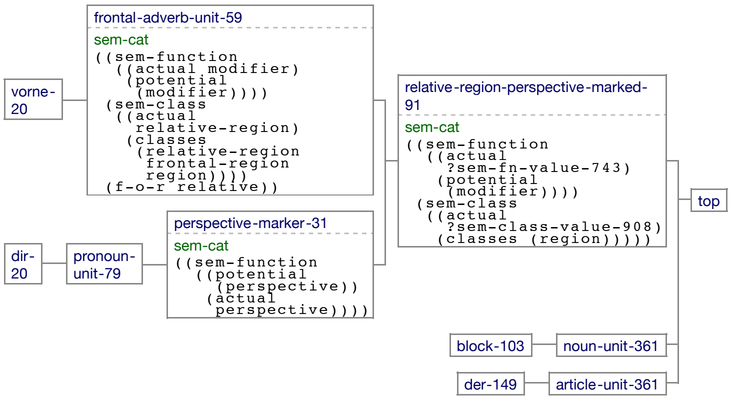

Figure 12. *Transient structure after the application of the* `relative-region--perspective-marked` *construction (when parsing "der Block vorne von dir aus"). The* `f-o-r` *(frame of reference)* `sem-cat` *attribute of the* `frontal-adverb-unit-59` *is set to* `relative` *and therefore determined.*

Similarly, this scheme has to be applied to landmark augmented adverbs in order for them to participate in these solutions.

Using a collection of techniques, each of which have been discussed separately throughout this book(i.e. logic variables, percolation and a particular kind of construction, that only operate on the semantic side), we are able to model the interaction of projective categories with perspective marking and their effects on semantic ambiguity pervasive in German locative phrases. This shows that the reusable solutions available in FCG are sufficient to tackle interesting natural language phenomena and to explore processing issues, like the processing of semantic ambiguity from a computational modeling point of view.

5. Feature Matrices

Case and gender agreement in German is an example of a highly distributed information processing task. The constraints on these syntactic features are contributed by many different constructions and thus have to be incrementally integrated in order to produce grammatical utterances in German. For instance, the grammatical gender of an adjective in a noun phrase is determined by the noun, as shown in the following example ("Block", masculine).

(25)	*hinter*	*dem*	*linken*	*Block*
	behind.PREP	the.DAT	left.DAT	block.DAT

'behind the left block'

Case on the other hand is governed by the preposition ("hinter", requires dative). The determiner ("der") and the adjective ("link") are case and gender marked according to the information provided from these different sources. Consequently, the determiner and the adjective are used in their masculine dative forms ("dem" and "linken"). In other words, the concrete form of a projective adjective is fixed by integrating information from different parts of the syntactic structure.

The organize such complex processes a number of mechanisms are necessary. This includes mechanisms for 1) representing the state of information including its uncertainty, 2) distributing information in order to facilitate decisions and spread their effect, and 3) ways to postpone decisions until enough information is accumulated. The solutions presented for these problems, naturally, mirror the techniques discussed in the previous section. We use logic variables, but this time embedded in feature matrices, to represent uncertainty, percolation for sharing information and constructions of a particular type in order to postpone decisions.

5.1. Representing the State of Information

Distinctive feature matrices (see **?**) are a means to represent the current, possibly indecisive state of information in processing. They allow different constructions to independently contribute constraints on values of the syntactic, case and gender features until enough information has been collected. Hence, feature matrices function similarly to the logic variable used for representing uncertainty in the previous section, as they are a technique for accumulating information contributed by different constructions. Distinctive feature matrices extend the concept of logic variables and allow for the representation of dependencies between features in processing.

The way lexical items interact with the case gender agreement system is determined in part by the lexical item and in part by the word class. Nouns, for instance, have a particular gender and always need to be marked for case, which is governed by prepositions. Adjectives and articles agree in case and number with the phrase in which they are embedded, specifically with the noun. Consequently, the state of information for some lexical classes is initially constrained. While adjectives and articles have no constraints on case and gender, nouns already provide information about their gender, and prepositions about the required case. Distinctive feature matrices allow for the representation of such different states of information in the transient structure in a unified way by explicitly representing all combinations of possible feature values in a matrix. For our German example, this information is captured in a two dimensional matrix, where columns reflect the four German cases, and rows reflect the three grammatical genders[4]. Every field in the matrix corresponds to a particular combination of case and gender, such as accusative-masculine, and every field can either be explicitly excluded (i.e. marked with a '-'), selected (i.e. marked by a '+') or in an unknown state of information, which is represented using variables i.e. marked with a '?').

Figure **??** shows the state of the transient structure after the application of lexical and functional constructions. It can be seen how the different states of information for articles, adjectives, prepositions and nouns are technically represented. The feature matrices for the spatial adjective (`spatial-adjective-unit-334`) and for the article (`article-unit-334`) are completely filled with variables. On the other hand, the feature matrix for the frontal preposition (`frontal-preposition-unit-93`) features a '-' everywhere but in the column representing the dative case, namely, the case it requires. On the other hand, the noun (`noun-unit-334`) is categorized based on its gender, and the feature matrix consequently has variables in the row for masculine and excludes all other fields.

5.2. Percolation and Agreement

Given the setup of initial information by lexical and functional constructions, all subsequently applied constructions have to be able to move information around and to further constrain the information. Movement of information is done using percolation, and unification of feature matrices for agreement automatically constrains the values in the feature matrices further and further.

Both percolation and unification are used together, for instance, by the `adjectival-nominal` construction. (See Figure **??**.) In our example, this construction handles the adjective (`spatial-adjective-unit-334`) and the noun (`noun-unit-334`) as constituents. Apart from introducing German word order, this construction unifies the feature matrix of the adjective and the noun, which automatically constrains the gender possibilities for the adjective, in this case, to mas-

4. In principle number and declension class are also important in German. However, these were omitted to keep it simple.

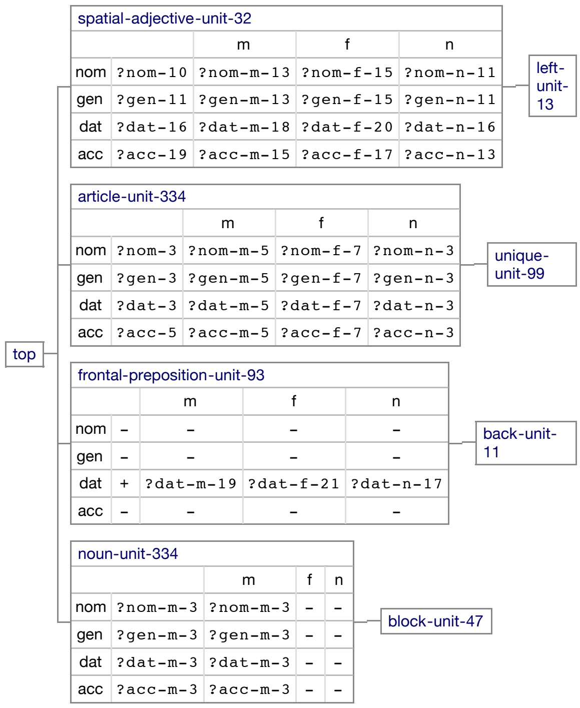

Figure 13. *Transient structure after the application of lexical and functional constructions for production of "hinter dem linken Block" ("behind the left block"). For simplification, each unit is only shown with its distinctive feature matrix for case/gender agreement, if present. Furthermore, the feature matrices of the lexical units are identical to those of their parent units and are thus also not shown.*

culine. In fact, through unification the two feature matrices are the same after the application of the `adjectival-nominal` constructions. Moreover, the newly created parent unit (`adjectival-nominal-phrase-43`) percolates this matrix up. This process is subsequently repeated, this time by the `determiner-nominal` construction, which has the same effect but this time with its constituents being the article and the adjectival-nominal phrase, which also constrains the article to be masculine. Percolation and unification have essentially established the agreement between the article, the adjective and the noun, while at the same time spreading the information about gender.

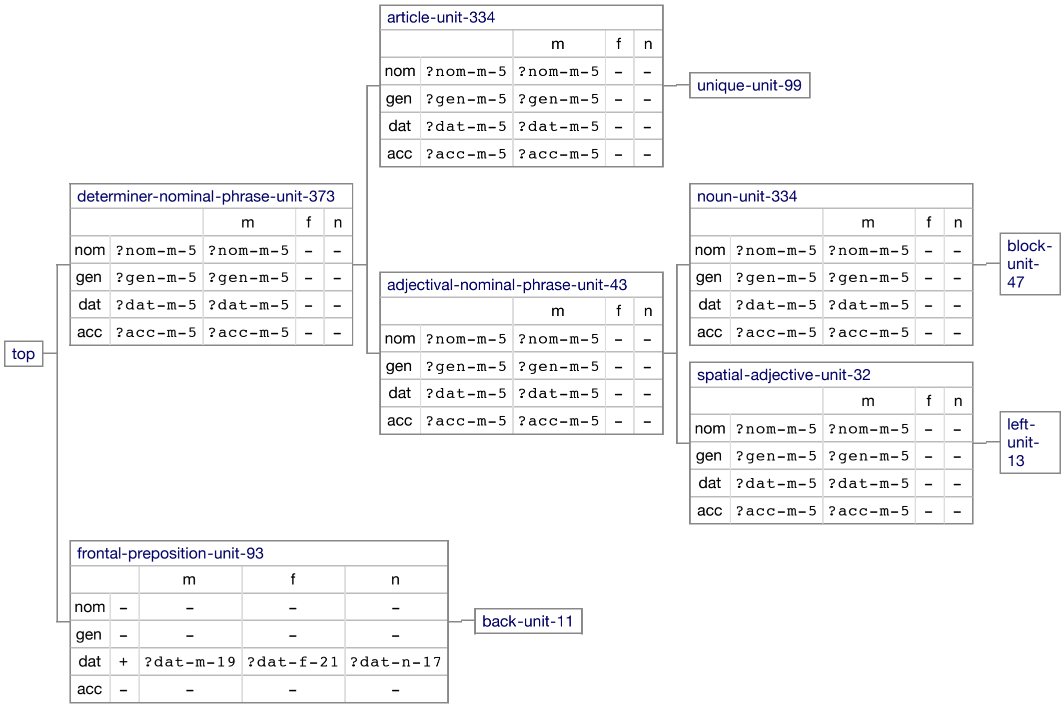

Figure 14. *Gender agreement between the article, adjective and noun are enforced by the adjectival-nominal and determiner-nominal-phrase constructions applied to the transient structure in Figure* **??**.

After the application of these two constructions, the decision on case is still missing. Case is provided by the angular preposition, and agreement between the preposition and the determined-nominal-phrase is established by the `angular-pp-phrase`. (See Figure **??**). The `angular-pp-phrase` technically behaves very similarly to the the `determiner-nominal` and the `adjectival-nominal` constructions: it unifies the feature matrices of its two constituents (`frontal-preposition-unit-93` and `determiner-nominal-phrase-unit-373`). However, the effect is quite different in that now the feature matrix of the article, the adjective and the noun is further constrained in terms of case. Consequently, case and gender of this particular phrase are ultimately decided.

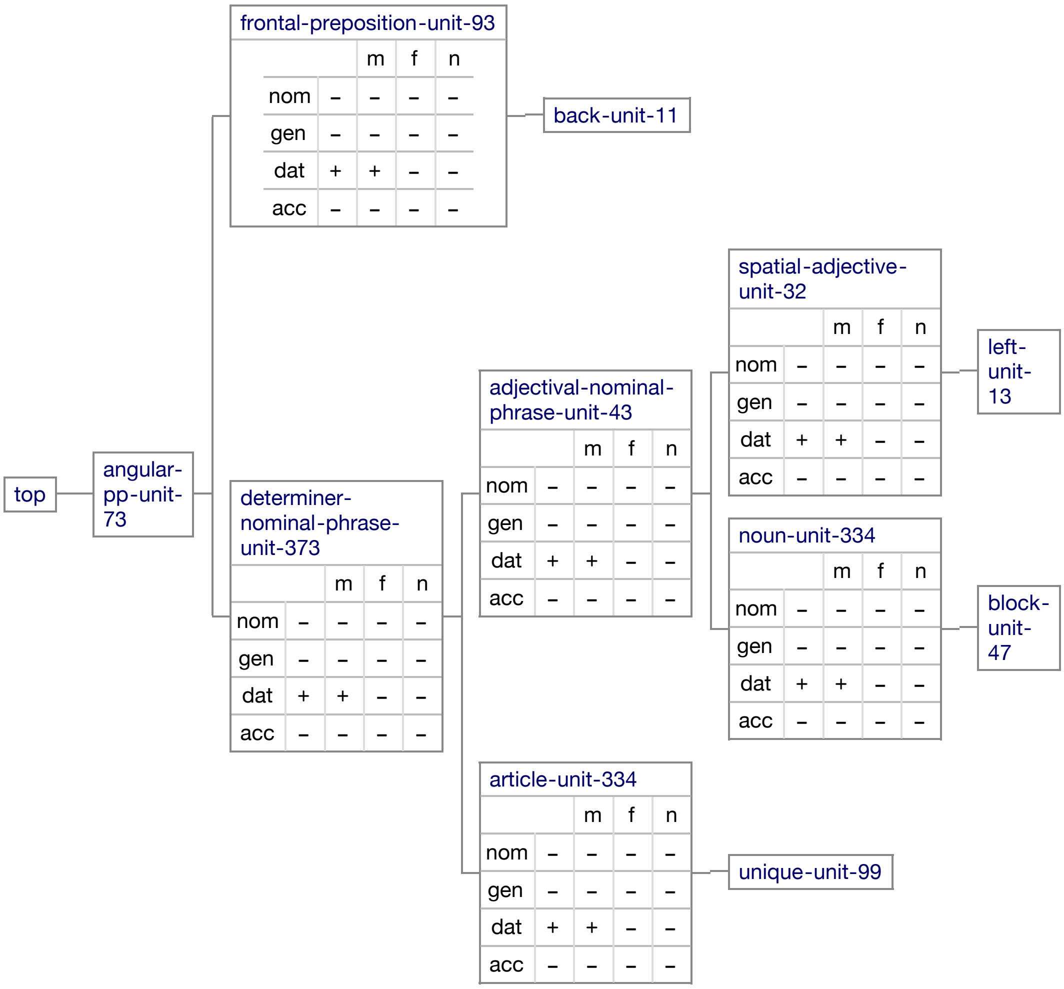

Figure 15. *Case agreement after applying the angular-pp-phrase construction to the transient structure from Figure* **??** *while producing "hinter dem linken block".*

For some phrases case is not established by prepositions. In such conditions we assume the nominative case[5] and the `referring-expression` construction (see

5. Strictly speaking, this is not always correct. For instance, answers to questions can be genitive, dative or accusative marked depending on the type of question. For the grammar discussed in this book we chose not to model these phenomena.

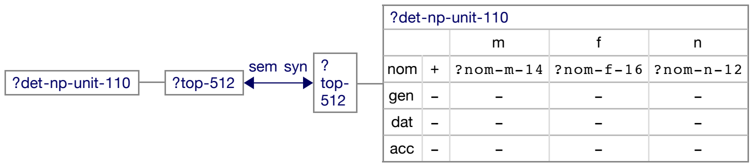

Figure 16. *The referring-expression construction sets the case of a single determined-noun-phrase unit to nominative.*

Figure **??**) introduces the nominative case by unifying the feature matrix of the determined-noun-phrase unit with a matrix constraining the case to nominative.

5.3. Postponing decisions

After the application of the `angular-pp-phrase` construction, all necessary information has been accumulated. Case and gender are decided, and, hence, all syntactic features for the particular lexical class in question are available to allow subsequent constructions to be able to decide the word form to be used. Morphological constructions are used here to represent this relationship between syntactic features and word forms. For example, for determiners, there are six different articles in German that unevenly cover the 12 possible case-gender combinations, as shown in the chart below:

	m	f	n
nom	*der*	*die*	*das*
gen	*des*	*der*	*des*
dat	***dem***	*der*	***dem***
acc	*den*	*die*	*das*

For each of these forms, a separate morphological construction exists which decides on the form used to express the article based on the lexical class and the case-gender feature matrix. An example of such a morphological construction is shown in Figure **??**. Since this construction has a variable in the dative masculine field, it matches with unit `unique-unit-99` in Figure **??**. Similarly, other morphological entries add the strings “linken” to the `block-unit-47`, “Block” to the `block-unit-47` and “hinter” to `back-unit-11`.

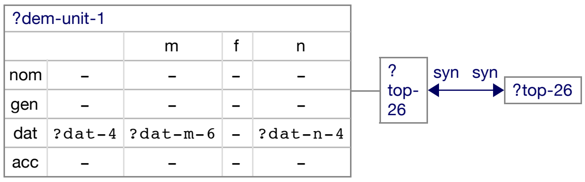

Figure 17. *Distinctive feature matrix of the morphological construction that maps the string “dem” to masculine or neuter and dative articles. Note that since this is a morphological construction, both poles of the construction apply to the syntactic pole of a transient structure.*

6. Conclusion

Problems of processing information distributed across multiple constructions and across different parts of transient structures often appear when dealing with complex, real world language. This chapter detailed how to tackle such problems using 1) adequate information representation techniques, such as logic variables, feature matrices and disjunctive potentials, 2) percolation for distributing information in the transient structure, and, 3) special constructions which are needed to help postpone decisions until the state of information is ready. The techniques have proven to be sufficient for handling problems of syntactic indeterminacy, e.g., morphology and lexical class choice and semantic ambiguity problems in German locative phrases. The discussed design patterns allow grammar designers to spread information processing across many constructions, leading to concise grammars, while facilitating efficient processing.

However, the techniques discussed in this chapter are also important for another reason: fluidity. Fluidity, ungrammaticality and error are the subject of the next chapter, but we can already hint at some of these issues by looking at the techniques discussed in this chapter. The actual-potential design pattern, for instance, can help when a word is not understood because the audio signal is too noisy. In such cases constructions can still merge information. In particular, using the actual-potential design pattern, constructions can also constrain the potentials normally provided by missing units. If a word is inapprehensible, the morphological construction for this word cannot apply, thus also preventing other constructions from applying that would have applied subsequently, because required information is missing. At the same time, FCG features additional mechanisms where such subsequent constructions can nevertheless contribute information. For instance, in the phrase "der block krrkks von mir" (the bock krrkks of me) grammatical constructions can provide information about the inapprehensible word, which is part of a spatial adverbial construction. Functional constructions can pick up on this information and provide additional lexical class constraints in the form of potentials. Ultimately this can lead to the identification of the most likely lexical class underlying the word "krrkks". The actual-potential design pattern, here, can help to provide this information.

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