Modeling meaning

A spatial theory of the semantics of polysemous prepositions

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Preface

Probably, for many students the process of writing a final thesis is an especially instructive part of their study. It seems to me that this pre-eminently holds for Cognitive Artificial Intelligence students. After years of following courses on divergent subjects, in diverse disciplines, that give a broad overview of various aspects of CAI, one single topic should be chosen that can be studied in depth.

I have experienced the process of writing this thesis to be very instructive and interesting. This graduation project has given me an idea of what it is to conduct research. Moreover, the process has been long and sometimes difficult, and it has been a, mostly pleasant, challenge to find the right way through, leading to some final product: this thesis.

A number of people have contributed to the realization of this work. First of all, I would like to thank my supervisor Joost Zwarts for his advice, feedback and encouragement during the process. I thank Thomas Müller and Yoad Winter for reviewing this thesis. Their comments have been of great value.

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I am grateful to my fellow CAI students. They have been vital for the great study atmosphere I have experienced during the years of studying CAI and have always been open to discuss any CAI related topic.

Finally, I would like to thank my friends and my family for giving me great support.

Contents

1 Introduction and research question

1.1 General introduction

What is the difference in meaning between “We walked *across* the field.” and “We walked *through* the field.”? How does this occurrence of *through* differ from the occurrence in “He stuck a pen *through* a piece of paper.”? What are the relations between these, apparently different, meanings of prepositions?

In this thesis, questions like these will answered. Five prepositions, *along*, *across*, *through*, *around*, and *over*, are object of study. These are words that are frequently used in every-day language and with which we all are familiar. Prepositions furthermore typically are polysemous (i.e. have multiple meanings). The differences and commonalities between the various meanings of a preposition, and of different prepositions, and the (derivational) relations between the meanings, can be studied. Prepositions also are spatial terms. Their meanings therefore can be designated by some spatial structure, for example represented in an image.

Geographic Information Science (GISc) is a field of research that has the properties of space as its focus. Spatial structures and relationships are studied and modeled in a formal way. In this thesis, ideas and modeling tools from the field of GISc are transferred to linguistics. A model that has its roots in GISc is applied to the five spatial prepositions and provides insight into the meanings of these prepositions, and in the relations and differences between these meanings. The model that will be used is a topological model: topological aspects of the meanings of the prepositions will be represented.

The advantage of the use of this formal model is that a systematic and schematic analysis and comparison of the spatial meanings of prepositions becomes possible. Relevant aspects of meaning will be distilled and formalized; meanings, consequently, can be analyzed in a precise way. Moreover, the modelings of the prepositions will literally provide insight into meanings, because the meanings will become visible, represented in images.

1.2 Research question

The primary goal of this thesis is to provide insight into the spatial meanings of (five) prepositions. This will be done by making use of the 3D-9-intersection model, a variant of a model originating from GISc, designed for the purposes of this thesis. Modelings of the meanings of five prepositions will be built and analyzed.

In general, models have as a function to simplify a certain phenomenon, to focus on some relevant aspects of the phenomenon and to unlock and highlight these aspects, leaving out others. The 3D-9-intersection model, specifically, highlights some aspects of the phenomenon under consideration - the meanings of prepositions - namely the topological aspects of meaning. The expectation is that the modelings of the prepositions, by being formal models that represent some relevant aspects of meaning, make systematic analysis and comparisons of the meanings possible.

The research presented in this thesis shows that the 3D-9-intersection model indeed can be helpful by providing insight into the (relations between the various) meanings of polysemous prepositions.

The main questions of this thesis thus will be the following.

> To what extent can the 3D-9-intersection model be helpful in the study of the meaning of spatial prepositions? Does this model provide us with an adequate description of the meaning of spatial prepositions, and of the relations and resemblances between different prepositions and between different meanings? And what is it that can be learned from the models; what are the diverse meanings of *along*, *across*, *through*, *around*, and *over*, and how do the various meanings relate?

1.3 Relevance to CAI

How does the research presented in this thesis relate to Cognitive Artificial Intelligence (CAI)? How does it contribute to linguistics, and to cognitive science, and maybe also to other fields?

First of all, the research presented here shows that a broad perspective on semantics is valuable. The semantic analysis of prepositions that is presented in this thesis, fits in the framework of Cognitive Linguistics. Within this movement, language is studied as a part of human cognition and linguistics is thus placed within the broader field of cognitive science. Also the (philosophical) paradigm of Embodied and Embedded Cognition (EEC) - the theory that human cognition is dependent on the form of the human body and the environment - is related to and supportive of Cognitive Linguistics. CAI combines various disciplines that all can contribute to a broad perspective on language and meaning, and thus is a suitable background for the present research, in which the combination of ideas and methodologies from various disciplines will turn out to be valuable.

The research presented in this thesis also fits within the field of CAI. The main objective of Cognitive Artificial Intelligence is the study of human cognition. Language is one of the (and possibly: *the*) most important and interesting human cognitive phenomena. The study of language thus takes an important place within the field of CAI. Especially semantics is a core part of cognitive science and (thus) of CAI, for it is concerned with concepts, which are central in our thinking and which are crucial for us to make sense of the world.

Also the fact that a formal modeling tool is used to provide insight into some aspect of cognition, makes the research that is presented in this thesis fall within the field of CAI. In CAI, an important method to gain insights in human cognition and intelligence is cognitive modeling. Also the formal and mathematical aspects of the model that is used fit well within CAI. Finally, the fact that methods, ideas and insights from different fields are combined in this thesis (philosophical ideas about cognition being embodied and about the nature of meaning, modeling tools from mathematics (via GISc) and an object of study from linguistics, to mention a few), gives this research a high degree of 'CAI-ness'.

What thus can my research contribute to the fields of research it is embedded in? It can contribute to the goal of gaining insight into the nature of human cognition, by providing insight into the nature of the semantics of spatial prepositions. Furthermore, my research can contribute to ideas about the methodology of the study of language. When the application of such a formal model in (spatial) semantics, also following the line of thinking of Cognitive Linguistics, indeed is successful, this thesis can be seen as a plea for an approach to semantics that is both cognitive and formal.

2 Theoretical background

2.1 Introduction

Before spatial modelings of the meanings of prepositions will be created and analyzed, first a framework should be sketched within which my research takes place. In the following sections, section 2.2 and 2.3, this will be done. Relevant literature will be discussed to make it possible to place the present study in a line of research. Terminology and semantic analyses that are used will be introduced. Also an introduction in the field of Geographic Information Science and topology will be given, and the 9-intersection model, that has served as a basis for my own modeling tool, is presented.

Furthermore, the following sections are used to account for the choices that were made regarding my research. Why at all would it be interesting to study the meanings of spatial prepositions, and why should the focus be on topological aspects of meaning? What evidence can be found in the literature that supports the relevance of spatial language, of prepositions and of topology? What perspective on language and cognition should be kept in mind? What methodology would be suitable?

In the next section, the linguistic background that is needed to understand and appreciate my research, and that was used as a basis for my own analyses, will be provided. Afterwards, the required topological background will be exposed.

2.2 Linguistic background

2.2.1 The relevance of prepositions

Prepositions constitute a popular subject of semantic analysis; researchers from diverse disciplines have studied the meanings of words such as *around*, *over*, and *along*. What makes prepositions such an interesting object of study? First of all, prepositions are frequently used words in our everyday language, with which every native speaker of a language is familiar. The urge to understand the semantics of prepositions is thus relatively large. Furthermore, prepositions have some specific properties that make a semantic investigation especially interesting and relevant.

First, the fact that prepositions express spatial relations makes them a suitable object of semantic investigation. Such relations are relatively concrete, and objectively measurable. This increases the possibility of a successful semantic investigation of spatial terms. More abstract and 'vague' words such as "beautiful" or "democracy" would be much less suitable as a subject of systematic semantic inquiry. Semantic investigation indeed is complex, so the less potential misunderstandings and vagueness exist around the meaning of a word, the better suited it is as the object of semantic study.

Secondly, prepositions are interesting because of their polysemy. Polysemy is the phenomenon that a word (or phrase) has multiple related senses. Many prepositions are strongly polysemous. This makes an investigation of the meanings of such prepositions especially interesting, because the resemblances and relations between different senses of a word can be analyzed. Also related senses of different prepositions can be compared. This offers the opportunity to distinguish aspects of meaning - that are part of some sense of a word but not of others. When such aspects are distinguished, moreover, a systematic analysis and comparison of meanings is made possible.

Furthermore, prepositions are an especially interesting object of study because of the linguistic primacy of the spatial relations they express. For Regier ([24]), among others, this is a main reason for studying the semantics of (spatial) prepositions. Two different and strong indications exist for the fact that space has a privileged status as a domain of language.

The first indication stems from the fact that spatial relations often are expressed by closed-class forms. A closed class is a relatively small set of linguistic forms to which members are added only rarely. Most of the forms that express spatial relations are closed-class forms; indeed prepositions are. Closed-class forms have certain semantic properties that make them function as a skeleton of language.

Only a restricted number of conceptual categories is represented by closed-class forms, and, importantly, these forms do represent only specific kinds of aspects within those domains. As Talmy puts it: "[closed-class forms] are not free to express just anything within these conceptual domains but are limited to quite particular aspects and combinations of aspects, ones that can be thought to constitute the 'structure' of those domains." ([26], p. 179). This indicates that closed-class forms are the fundamentals of a certain semantic domain - the structure they constitute functions as a framework that can carry more broader conceptual material.

The second indication for the primacy of space is the fact that spatial terms are often used in non-spatial domains. Prepositions, and other spatial terms, are used to refer to more abstract concepts as well. Prepositions are transferred to domains other than the spatial one and are used metaphorically. One can speak of "working *through* an enormous amount of books and papers" or "preferring Utrecht *over* Amsterdam". In such cases, structure is borrowed from the spatial domain and transferred to other domains to express more abstract meaning. The structure that the domain of space possesses, helps us to make sense of abstract concepts. In a lot of different, and maybe in all domains, prepositions and other spatial terms can be found. This indicates that forms expressing spatial concepts are core linguistic elements that have influence all through language.

The idea that conceptual structure is transferred to other domains through metaphor, originates from Lakoff and Johnson ([16]). These authors argue that metaphor is integral in language and understanding, and that the spatial domain is primary: its structure helps us to make sense of concepts in more abstract domains. Lakoff and Johnson also sketch how the 'translation' of spatial terms to other domains works. More evidence for the claim that the spatial domain is the most fundamental one, is provided by Lera Boroditsky and others. In [1], [19], [2] and [3], it was shown that transferring spatial terms and concepts to non-spatial domains is possible, but that the opposite is not. This holds both for language and for thought and understanding. Spatial terms are used, for example, in the temporal domain: the more concrete spatial domain provides structure to a more abstract domain.

Studying the meanings of (spatial) prepositions thus has a relatively large chance to succeed, and, moreover, can provide insights not only into the semantics of some frequently used words, but also into much broader aspects of language.

2.2.2 Overview of relevant literature

The semantics of prepositions are studied by a lot of researchers. In this section, only a few of them will be discussed. Some of the authors whose work has been of great importance to the Cognitive Linguistics movement will be mentioned. Furthermore, the authors whose analyses of the meanings of prepositions are used as a basis for my own analyses are discussed.

Talmy

Leonard Talmy pioneered in the Cognitive Linguistics movement. Cognitive Linguistics is a branch of linguistics that started in the 1970's and that is still growing up till now, in which the concepts that underlie the meaning of linguistic expressions are made central. Cognitive linguists study language as a part of human cognition. Meaning is not understood in terms of truth-conditional models of the world, but in conceptual models instead. Furthermore, language is seen as both embodied and embedded in an environment.

This idea - that language should be seen as embodied and embedded - is part of what the movement of Embodied and Embedded Cognition (EEC) stands for. Followers of EEC believe that human cognition is, at least partly, determined by the form of the human body, and by the way humans interact with their environment. As philosopher Andy Clark puts it, "[Our brains] are *essentially* the brains of embodied agents capable of creating and exploiting structure in the world." ([4], p. 220) Also language, which is part of human cognition, is embodied: the concepts that are expressed by linguistic expressions are shaped by bodily aspects and by our interacting with the world.

In [26], Talmy studies the structuring of space that is present in language. Among other things, he shows that the linguistic representation of space can be seen as representative for the linguistic representation of meaning in general.

What, for the purposes of this thesis, is borrowed from Talmy, is on the one hand the general idea of Cognitive Linguistics, and on the other hand some specific terminology. Considering spatial relations between two objects, as expressed by prepositions (e.g., "the bike is behind the house"), Talmy uses the terms *figure* and *ground*, that have their origin in Gestalt psychology. The figure is the first object, mostly the smaller one, the more movable, the one that is more relevant and that is generally treated as geometrically simpler. The ground is the second object, that acts as a reference object, that can be geometrically more complex and is in most cases bigger than the first object. In the syntax of an expression, the first object (*the bike*) is the one that is mentioned in front of a preposition (in the case of the example: "behind"), and the second object (*the house*) is always mentioned directly behind a preposition. Instead of "figure" and "ground", other authors use the terms "trajector" and "landmark". These latter terms are used in this thesis.

Also worth mentioning from Talmy is what he states about topology. In the meanings of words, Talmy observes, non-topological aspects like shape, size, angle, and distance are also relevant. Distinctions of this sort, however, "are mostly indicated in languages by full lexical elements - for example, *square*, *straight*, *equal*, plus the numerals. But at the fine-structural level of conceptual organization, language shows greater affinity with topology." ([26], p. 223). Prepositions, such as *through* and *in*, are examples of such fine-structural linguistic elements. The meaning of such word is highly independent of shape and other non-topological aspects. *In*, for example, is applicable in diverse cases ("The man was in the building", "Amsterdam is in the Netherlands", "How much money is in your wallet?"), yet indicating one and the same kind of spatial structure.

Hawkins

Bruce Hawkins, whose work ([11]) constitutes an important part of the foundation for the linguistic analyses in this thesis, is also a cognitive linguist. Being a pupil of Ronald Langacker, whose main enterprise was to define a cognitive, semantic grammar, Hawkins has developed a descriptive system for the semantics of prepositions, for which Langacker's Cognitive Grammar ([17]) functions as a framework.

Hawkins' descriptive system offers a way to analyze spatial configurations consisting of a trajector and a landmark. Such a configuration represents a meaning of a (spatial) preposition. The system specifies the nature of the trajector, the nature of the landmark, and the nature of the relation between trajector and landmark. The combination of those aspects then specifies the meaning. For my analyses of the prepositions (*across*, *along*, *around*, *over*, and *through*), Hawkins' analyses have functioned as a basis.

Lakoff and Johnson

George Lakoff, like Talmy, is one of the founders of Cognitive Linguistics. Mark Johnson also has made significant contributions to this movement. One important joint contribution of these authors is [16], in which the idea of conceptual metaphor was put forward. The main thesis of this work is that metaphors are not purely linguistic, but are conceptual instead. Metaphors, as was said before, play a key role in the way humans make sense of reality; most concepts are understood by use of metaphors.

Two main insights from [16] are relevant for the purposes of this thesis. The first is that language can and should not be studied apart from cognition and thought, and that thought and language are embodied and embedded. The second is that spatial concepts are primary in language, and that concepts in other domains are, through metaphor, derived from the concepts of the spatial domain.

In another important work ([15]), Lakoff brings together evidence for the theory that human thought - and language - is not only imaginative but also embodied. This evidence mainly stems from studies on the way people categorize. Lakoff defends experiential realism. This is the theory that 'the external world' is the world *as we experience it (through our bodily interaction with it)*. Given this, semantics should be cognitive, because meanings exist in the human experience of the outer world. A theory of meaning, consequently, should not try to define meaning in terms of mind-independent truth-conditional models, but in terms of experiential, mental models. Meaning is to be found in the embedded and embodied human being, and in its experiences of and interaction with the world.

Structure of meaning also stems directly from the structure of our experiences, and "experience is structured [...] prior to, and independent of, any concepts" ([15], p. 271). Johnson introduces the idea of *image schemas*, basic spatial configurations that frequently occur in our everyday experiences. Image schemas are a model of the way we humans make sense of reality, of both our own body and of the outer world we live in.

A linguistic elaboration of the idea of image schemas is provided by Lakoff ([15]) in a case study in which the meaning of the, strongly polysemous, preposition *over* is analyzed. This case study shows that Lakoff's approach of searching for meaning in pre-conceptual structures provides a better account of certain phenomena - polysemy, among others - than a model-theoretic search for meaning can do. The case study also has contributed to my own analysis of the preposition *over* in section 4.8.

Cuyckens

The next linguist that deserves to be mentioned here, is Hubert Cuyckens. Relevant for the present purposes is his paper on the Dutch prepositions *door* ("through") and *langs* ("along") ([6]). In this work the various senses of both of the prepositions and the resemblances and derivational relations between the senses are discussed. Cuyckens' analyses have contributed to my own analyses of the English variants of these two prepositions, which can be found in sections 4.4 and 4.6.

Regier

Attention should be paid to the work of Terry Regier too. In [24] he studies the semantics of spatial terms in a very innovative way. Regier has built a connectionistic model, with which he shows what the human semantic potential is - given the embodiment of the human being, that provides possibilities and restrictions.

Connectionism is the branch of cognitive science that seeks insight into human mental and behavioral phenomena through the modeling of such phenomena in interconnected networks consisting of simple units. Such networks can gain knowledge through a learning process. Regier's connectionistic models are *constrained*, which means that the models have some structure from the start, which can be used in the process of learning.

Inspiration for Regier's modeling is gained from the domain of color. It was showed in that domain ([13]) that perceptually grounded models of the human semantic potential are possible. Semantics indeed can be restrained by perception. In the domain of color, semantic universals were found: aspects of meaning that are represented in all languages. This provides hope for the search for perceptually grounded semantic universals in the spatial domain, for this is also a relatively concrete domain, that seems strongly related with our embodiedness in the world.

Regier uses connectionistic models to gain insight into the human semantic potential. He is not specifically interested in the meanings of individual words, but foremost in the semantic possibilities of the human mind. What kind of concepts can be learned? Do universal semantic 'building blocks' from which the meanings of spatial terms are constructed exist? What universal constraints, for example stemming from the nature of the human body, exist? Regier's model has as a goal to explain how the acquisition of the semantics of spatial terms works. "The model's task as a whole is learning how to perceive simple spatial relations, both static and dynamic, so as to name them as a speaker of a particular language would." ([24], p. 7)

What is borrowed from Regier for the purposes of this thesis, is especially what his approach makes clear about the way human beings conceptualize and learn language, and what the human semantic potential is.

The model presented in [24] shows that the meanings of spatial terms - semantic categories, including family resemblances and prototype effects - can be learned by some basic learning network, without explicit negative evidence[1], but given some structural restrictions. It becomes plausible that human language acquisition works in a similar way. No explicit negative evidence is available, but some restrictions exist, that would be caused by our human embodiment, on what aspects of meaning are possible.

Cognitive Linguistics is thus supported by Regier's modeling. Language should be understood in relation to human cognition, and as dependent on the embodiedness of human beings.

Dewell

Finally, Dewell has to be mentioned here. In [8], aspects and properties of *over*, and of prepositions in general, are distinguished. Dewell argues that *over* should not be considered to be a locational preposition, as it is according to, e.g., Tyler and Evans ([27]), but a route preposition. Multiple properties of *over* indicate that it is a route preposition. First, *over* typically is used to express some path that has no profiled end point. If "a plane flies over the ocean", it is not explicated where exactly the plane is going to. In this respect, *over* is similar to other route prepositions, such as *around* ("He drove around the lake.") and *across* ("He reached across the table"). Locational prepositions, on the other hand, *do* indicate a specific location ("He put the cup on the table.").

Over furthermore has in common with other route prepositions that it can be combined with "all" ("Mud was all over the floor."). Compare, for example, the route preposition *through*: "Mud was all through the house.". Locational prepositions, in contrast, cannot be combined with "all" (*"Papers were all on the table."[2]). Locational prepositions, however, might be combined with "somewhere" ("Papers were somewhere on the table"), whereas this construction is not possible in the case of route prepositions (*"Papers were somewhere over the table".). Also in this respect, *over* is the same as other route prepositions.

The insight that *over* is a route preposition is borrowed from Dewell. Consequently, in this thesis *over* is treated in the same way as the other four prepositions - *along*, *across*, *through*, *around*: all route prepositions - that are studied.

Even more relevant for this thesis, is Dewell's paper on *around* ([7]). In this paper Dewell provides an analysis of this preposition, which has supported my own analysis of *around*. Dewell also makes some interesting remarks on the role of the conceptual viewpoint or perspective. He shows that the totality of distinguishable senses of *around* indicates that meaning does not exist in an objective, mind-independent reality. The view that human experience determines meaning provides a better explanation of the meanings of *around* than a theory of

[1]In linguistics, "negative evidence" refers to evidence that is available to the language learner about what is not grammatical.

[2]The * before a sentence indicates that that sentence is ungrammatical.

objective meaning does. This case consequently supports the experiential view on meaning: the meaning of a preposition does not exist in an objective relation between a trajector and a landmark, but in a cognitive pattern, a construal of such a relationship.

2.2.3 Cognitive Linguistics as a framework

Now, all literature relevant for this thesis has been discussed (although briefly). This list of authors is quite diverse, but the authors still have a lot in common. All participate in the Cognitive Linguistics movement; their research is performed following the idea that language is part of human cognition, that cognition is embodied, and that the meaning of language stems from the experiences of the embodied human being in the world.

The research that is the subject of this thesis is performed largely within this framework of the Cognitive Linguistics movement - largely, but not completely. Regarding some aspect, my approach opposes the approach of the cognitive linguists.

What is borrowed from the Cognitive Linguistic movement, is, first, the main idea of this movement: its perspective and vision on cognition. Cognition is viewed as embodied, and the concepts we express are viewed as being determined by our bodily interaction with our environment. Below, this view will be supported and argued for, both from a philosophical and from a linguistic perspective.

Secondly, what is borrowed from the movement are linguistic analyses of the meanings of prepositions, performed by cognitive linguists and grounded in the framework. The data that my analyses and models are based on stem from Cognitive Linguistics. Because of this, it is the most convenient choice to place my own research within this framework too. The line of thinking of the authors whose work is used, is cognitive linguistic, and so is the design of their research. By borrowing not only the analyses and data from the Cognitive Linguistics literature, but also the framework itself, coherence is achieved in the present work.

The Cognitive Linguistic movement, however, has a certain aspect that I do not want to borrow. This specific aspect is not part of the main idea of Cognitive Linguistics, and is not a consequence of its perspective on cognition and language either, but indeed is part of the routine and way of thinking of a lot of cognitive linguists. This specific aspect concerns the fact that cognitive linguists typically apply an informal approach of language and meaning. Historically, cognitive linguists have resisted and opposed generative grammarians and truth-conditional semanticists and, moreover, have shown an antipathy to a formal approach of language.

Instead of defining meaning in terms of models of the world, cognitive linguists try to define meaning as a cognitive pattern. In the view of Cognitive Linguistics, meaning does not exist in the correspondence of a linguistic expression with some situation in the outer world, but in a relation between the linguistic expression and a human, cognitive pattern that corresponds to some situation in the world.

The fact that the meaning of an expression is a cognitive pattern, a human concept, does not, however, exclude a formal theory of meaning. The ideas of Cognitive Linguistics are not anti-formal at all! The Cognitive Linguistic perspective on meaning and cognition is compatible with a formal approach to meaning. Formal models of meaning can be built that justify the idea that meaning stems from human experience in the world. These models, then, would not be mind-independent models, as the models of the truth-conditional semanticists typically are. Formal, cognitive models will be models of cognitive patterns and conceptual structures.

In this thesis, an approach is chosen that indeed combines the idea of Cognitive Linguistics with a formal approach to semantics. The ideas of Cognitive Linguistics - on meaning as stemming from human embodied experience - thus are borrowed, but not the preference for informal methodologies.

Now, the question will be considered why the cognitive linguistic conception of language and meaning would be the right one. First this question will be considered from a philosophical perspective and secondly linguistic support for the Cognitive Linguistics framework will be provided. A complete philosophical argument in defense of Cognitive Linguistics and Embodied and Embedded Cognition is far beyond the scope of this work. Instead, an attempt will be made to render plausible the ideas of the framework, by roughly sketching some of the lines of reasoning that have led to it.

Cognitive Linguistics is linked to and supported by Embodied and Embedded Cognition and experiential realism. Philosophical foundation for experiential realism can be found, among others, in the work of Putnam ([23]). Putnam doesn't argue against realism; an objective world might exist. We human beings, however, don't have privileged, objective access to the world. This is because we are part of the world. Objective understanding and knowledge of the world would only be possible if one could stand outside reality and observe the world from outside. Stating this, Putnam argues against an externalist perspective on reality. His alternative is called internal realism.

Experiential realism, or experientialism (defended by Lakoff in [15]) is a kind of internal realism. As was said in section 2.2.2, experiential realism is the theory that the 'external world' should be understood to be the world *as we experience it*. We experience the world through our bodily interaction with it. Furthermore, we make sense of the world by being in the world. Therefore, not only perception and movement depend on our embodiment, but also concepts and meaning. Meaning, consequently, should be understood and studied as being part of our embodied cognition. This is what Cognitive Linguists do.

Foundation for the theory that cognition is embodied can also be found in the philosophy of Merleau-Ponty. Merleau-Ponty ([20]) has provided the foundations for a framework in which embodied experience can be accounted for. He has demonstrated that two main traditional philosophical paradigms, rationalism and naturalism, are not able to account for the way human beings perceive, think about, make sense of and acquire knowledge of reality. The rationalist (or idealist) tradition doesn't suffice, because it ignores the role of our bodily nature and ascribes meaningfulness only to (body-independent) thought. Naturalism (or behaviorism) doesn't suffice either, because this paradigm, in explaining perception, ignores the connection between the object and the act of perceiving.

For Merleau-Ponty, perceiving an object is not only the functioning of sense organs and brains, but also an act in which a human individual perceives. Only by recognizing that the perceiving object is also the subject that perceives, it can be explained how perception can be meaningful. It is precisely through the body that we have access to the world; we make sense of the world by simply being in that world. Meaning, therefore, should be understood a stemming from our bodily interaction with the world we are in.

As was said, also in linguistics, evidence can be found that supports the Cognitive Linguistics framework. This framework would be more suitable to account for certain linguistic phenomena that other theories are. First, the appearance of prototypes, family resemblances, and polysemy seems to be problematic for the old theories. Traditional, model-theoretic semantics cannot easily account for these phenomena. To explain why we understand a word to have different meanings in different context, it will not be sufficient to just try to describe what these context are and to explicate which meaning matches which state of affairs in the world. It might help to involve a human perspective, and other aspects of human cognition. How do we experience a certain state of affairs? What are the aspects of that situation that determine the meaning of the linguistic expression we apply to it?

Cognitive Linguistics indeed involves such a human perspective. Prototype effects can be explained (see, for example, [15]) by taking into account the way human beings make sense of reality. Situations in the world are understood and recognized by use of idealizations of those situations - and actual situations may fit such an ideal situation to a certain extent. Cognitive Linguistics generally consider polysemy as being caused by the existence of prototypes. The various meanings of a polysemous linguistic expression match different situations that all can be understood as being instantiations of one 'ideal' situation.

To take stock, it is clear that choosing the Cognitive Linguistics framework for the purposes of this thesis is convenient, and that, furthermore, evidence and foundation supporting this framework - and opposing others - exist. The choice thus was made to perform my research within the framework of Cognitive Linguistics. The conceptions of this framework are borrowed, and data originating from researchers who participate in the framework were used.

My research, however, is not restricted to interpretation within this framework; it also has relevance when viewed from other perspectives. Not only for cognitive linguists my research is meaningful. The models, that will be elaborated on in the remainder of this work, can provide insights into the semantics of prepositions also when maintaining another framework. If one does believe in an objective account of meaning, for example, the models can be interpreted as representing real-world situations, instead of cognitive patterns.

2.2.4 On methodology

Above, the framework in which the present research is performed was accounted for. Now the question will be answered which methodology was chosen for the present research, and why this is a suitable methodology for the purposes of this thesis.

In linguistics, a diversity of methodologies occur. First of all, data can be collected in a number of ways. The most 'classical' method is to just 'observe' language. A researcher observes (spoken, written or imagined) language, and searches for structure and regularities, following his own ideas about correctness of linguistic expressions. This method of data collection is empirical: the linguistic behavior of a subject (the researcher himself, in this case) is observed. Often, not actual behavior, but potential behavior will be observed, when a researcher thinks about what linguistic expression he *would* use to express a certain meaning, or what linguistic structure he considers (un)grammatical.

This method of data collection can be extended to 'real' experimental research. In an experimental setting, participants are observed that use or interpret language. They can be asked, for example, to match certain linguistic expressions to certain representations of situations. Also subjects could be asked whether they consider a certain linguistic expression to be correct or not. In this way, actual language use is observed and registered. Another way of data collection is to search through texts or corpora. In the case of this approach, a large and structured amount of language is observed and analyzed.

When data are collected, these can be used in several ways to develop a scientific theory. Regularities that are found in language can, for example, be written down to form a grammar. When the meaning of expressions is the object of study, a theory of meaning can be the result.

Building a model is also a possibility. A model is a special kind of theory, in which certain aspects of the phenomenon it is a model of are represented. A good model always is in some sense simpler than what it represents, and often is a formalization of the phenomenon under consideration. A model, in this way, can help to understand a complex phenomenon. A model of the meaning of certain linguistic expressions, for example, can help to gain insight into the semantics of these expressions. Regier ([24]), among others, uses this modeling methodology. His model represents, in a formal way, the human acquisition of meaning.

The diverse methods of data collection and of the development of theory can be combined in several ways, and complement each other. Empirical research is necessary to gain knowledge about actual language use. To perform empirical research, hypotheses are needed. Modeling, for example, can provide those. A model of meaning can be tested in an experiment. Often, a model is based on ideas that originate from observations of language.

In this thesis, an important part of the methodology is modeling. A model concerning the meaning of prepositions is built. The structure of this model is spatial, and shows similarities with image-schematic structure. The model thus is compatible with the idea that meaning stems from our experiences as embodied humans embedded in an environment. Furthermore, the model is based on linguistic analyses; on insight into semantics gained by 'observing' language.

2.2.5 The primacy of topology

Up to now, it has been demonstrated why it is interesting to study and analyze spatial language, and how such research can be done. In this thesis, spatial language indeed is the subject of study, and spatial models are built to gain insight into the meanings of spatial terms. In these models, more specifically, certain aspects of meaning are focused on: the models represent *topological* aspects of meaning. Topological properties (of some (spatial) object, or configuration of objects) are, briefly stated, those properties that are preserved when the object or configuration is twisted, stretched, displaced or rotated.

What would be a reason to choose to model precisely these aspects of meaning? Why not model other, or all, aspects? First of all, representing all aspects of meaning would be less attractive - even if it were possible -, for then the model would be just as complex as what it represents. A model is more valuable when it is simpler than what it represents. Then the model indeed can help to gain insight into the phenomenon or object it is a model of. Of course, also the reverse might hold: a model can be more valuable when it is more complete, that is: when as few aspects (of meaning) are left out as is possible. Even if this was the case, one can imagine that it might work well to build a simple model first, in which only certain aspects are represented and that is very clear and easy to understand, and then to add more and more aspects, to make the model a more complete theory of what it represents. In this thesis, models will be built that focus on one type of aspect of meaning - topological aspects - but it will be possible to extend the models by representing additional aspects of meaning as well.

Focussing on topological aspects of meaning is valuable because of a number of reasons. First, representing just those aspects will result in clear, schematic models. Other aspects of meaning, of which some might be 'fuzzy' (shape, for example), will be left out, and thus less vagueness will exist in the model. Furthermore it is the case that some non-topological aspects are less suitable to be included in a model because they cannot be part of a structural, picture-like representation. This holds for aspects such as cardinal directions.

Secondly, topological aspects of meaning seem to be core aspects. Evidence exists supporting the view that topology is the primary tool for humans when making sense of spatial reality. Piaget and Inhelder ([21]) studied how children learn to make sense of space. Their research shows that Euclidian and projective relations develop from topological relations. A child first only uses topology to understand and reconstruct space.

Other authors have shown that this asymmetry not only occurs in our non-linguistic conceptualization. The 'structure' of our non-linguistic set of concepts is preserved in our linguistic concepts (see, for example, [5]).

Talmy also provides support for the thesis that topological aspects are core aspects of meaning. He observes that specific properties, such as shape, size, angle, and distance, can be expressed in language. Like a cited earlier, however, " at the fine-structural level of conceptual organization, language shows greater affinity with topology." ([26], p. 223). At this fine-structural level of language, closed-class forms can be found, among which the prepositions.

Regier's work ([24]) can be seen as supportive for the idea of the primacy of topology too. In the model Regier has built, topological features and relations, and the names they are given, can be recognized and learned more easily than non-topological ones. Because this model learns in a way humans learn language, this might indicate that topology indeed is more basic.

More backing for the idea that shape is of minor importance, can be found in Herskovits' idea of *schematization* ([12]). Herskovits argues that schematization is of fundamental importance for human understanding. To be able to make sense of the world, it is necessary for us to abstract away from specific aspects of the world; the incoming information is reduced to what is relevant. To understand spatial structures, specific aspects of a certain configuration, such as shape, are mostly irrelevant. Configurations are understood in a more schematic way; the abstract structure of a configuration we encounter is recognized, when it fits our abstraction of similar configurations we have seen before.

As is clear now, a lot of support exists for the idea that topological aspects of space are more fundamental than, for example, shape - both in cognition and in language. If indeed topological aspects are crucial for humans to make sense of space, these aspects thus cannot be left out from any model representing the meaning of spatial expressions. The choice was made, therefore, to represent the meanings of spatial prepositions in topological models of space. In the next section, an introduction to topology and an explanation of the way topology is used for the purposes of this thesis, shall be provided.

2.3 Topological background

2.3.1 Topology: an introduction

Topology is the area of mathematics concerned with spatial properties that are preserved under continuous deformations of objects. Topology is related to geometry, but, as opposed to geometry, topology is not concerned with metric properties such as the distance between two points. Topology only concerns topological properties, such as connectedness. This kind of properties will be preserved when continuous transformations like stretching and rotating are performed on an object.

In mathematics, topological properties are of course defined formally. These mathematical definitions, however, are not necessary for the current purposes, and therefore will not be discussed here in detail. The notion of topology as is used in this thesis is taken from the field of Geographic Information Science (GISc). In the next section, an introduction to GISc will be provided, and the relation of topology to GISc will be explained. Also, relevant topological notions and definitions from GISc will be discussed.

2.3.2 Geographic Information Science

Geographic Information Science is the academic theory behind the development of geographic information systems (GIS). These systems are applied in diverse branches of science and society. They are useful, for example, for archaeologists, to help them model and predict historic sites in landscapes, from crime analysts in mapping crime incident patterns, and for water management purposes. A GIS is a system that is able to recognize and analyze relationships that exist within spatial data. A large part of such relationships are topological. A GIS should, for example, be able to deal with adjacency (what adjoins what) and containment (what encloses what).

To be able to process such topological spatial information, a notion of topology is developed within GISc and made applicable in geographic information systems. First of all, it is important to define what topological relations are, and how this kind of relations is related to other kinds of spatial relations. In the following quotation this is described.

> "Based on different mathematical concepts, the GIS literature distinguishes three major types of spatial relations (Pullar and Egenhofer 1988 ([22]); Worboys 1992 ([28])): topological relations require the concept of neighborhood and are invariant under consistent topological transformations, such as rotation, translation, scaling; cardinal direction relations are based on the existence of a vector space and are subject to change under rotation, while they are invariant under translation and scaling of the reference frame; and distance relations express spatial properties that reflect the concept of a metric and,

therefore, change under scaling, but are invariant under translation and rotation" ([25])

These 'topological transformation' are continuous transformations. Such transformations can be defined as changes, applied on an object, that could be described by means of a continuous function: a function for which small changes in the input result in small changes in the output. Topological properties are those properties of objects that do not change when the object is changed continuously. Also the relation between two objects can be studied. A relation between two objects is topological if the relation remains the same when continuous changes occur to the configuration of the objects.

Above definitions provide tools to distinguish and study topological properties and topological relations. To be able not only to study such properties, but also to apply the theoretical GISc in working systems, certain building blocks are needed that represent spatial structures. Such building blocks can function as elements between which topological relations can be defined and to which topological properties can be attributed.

In GISc, three types of geometry are chosen to model a diversity of spatial features. Small, point-like objects, or objects of which only the location and not the shape is important, are modeled as *points*. The point is a zero-dimensional object. Line-like geographical objects such as rivers, roads and trails, are represented as *lines*. The line has topological dimension 1. Note that this does not exclude the possibility that the line - when it is not a straight line - extends in more than one dimension. The last geometrical shape is the *polygon* (or: *region*). This type can represent any two-dimensional spatial feature, for example a lake, a park, or a country.

These three kinds of geometric shapes that are defined within GISc will be the building blocks of the models in this thesis. The point, line, and region are the kinds of shapes to which topological properties will be attributed, and between which topological relations will be defined.

To choose only these three types fits the ideas of the modeling enterprise. Shape is of minor importance and the model should be a topological one. Some geometric objects are needed to attribute the topological relations to, but a restricted set of objects (shapes) is sufficient. To choose only three of such geometrical shapes also, and pre-eminently, is in line with the idea of schematization ([12]) that was mentioned before. The line, for example, can represent all 'line-like' objects, because humans understand such shapes *as* a line, abstracting away from the precise details. When talking about "a path along a river", we conceptualize this situation as a configuration of two lines running in parallel, and in this abstract way such a configuration will be modeled.

2.3.3 GISc: bridging the gap

Topology in itself, as a field of mathematics, could provide useful notions to build spatial models of the meanings of preposition. As was said above, however, the choice was made to not borrow topological notions and definitions directly from mathematics. Instead, the field of GISc was involved here and is used as a source for the requisite topology. This choice was made because of the following two main advantageous of GISc, considered the purposes of this thesis.

First, in the GISc literature topology is defined in a way that is easy to understand and that is still strict and formal enough for the present purposes. Especially qualitative (in contrast with quantitative) topology is developed well within GISc, and this is the kind of topology that is relevant here: models should be built from geometric structures, and not from numbers. Qualitative topological notions are defined sufficiently formally in GISc. GISc thus defeats mathematics on this: the GISc notion of topology can be seen through and used more easily, and because the mathematical amount of formality is not necessary.

Secondly, and more important, in the field of Geographic Information Science efforts are taken to bridge the gap between a formal description of spatial relations on the one hand and human thinking and natural language on the other. Within GISc, the movement that attempts to synchronize the semantics used in geographic information systems with natural language semantics is gaining popularity. Empirical research has been performed in which the formal distinctions that can be made between spatial situations are linked to the way human subjects conceptualize and describe space.

To conclude, topology as applied in the field of GISc is both formal enough to make a systematic analysis of meaning possible, and can be used to learn about the human conceptualization of space. GISc, therefore, is to prefer as field to borrow our modeling tools and notions from. GISc is advantageous compared to both the 'typical' branch of Cognitive Linguistics, in which spatial relations as expressed by humans are described informally, and to mathematics, in which field topology is defined formally, but that does not take into account knowledge of human conceptualization.

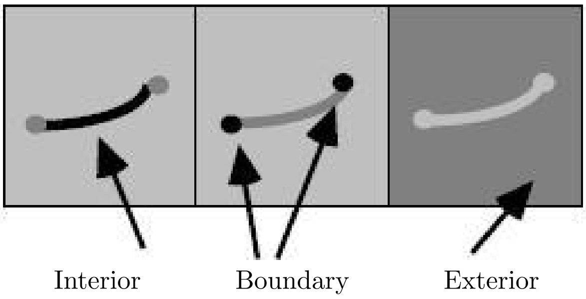
2.3.4 The 9-intersection model

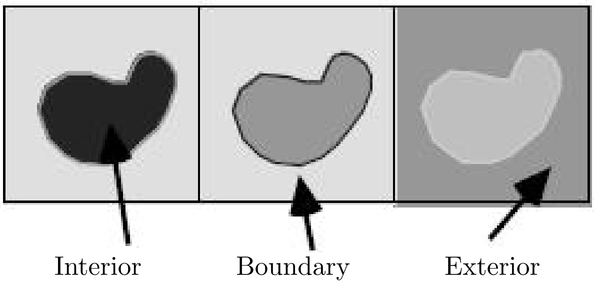
One way to formally define topological spatial relations between pairs of objects, chosen from the set of points, lines and regions, is contained in the 9-intersection model ([9]). This model, originating from GISc, offers a method to formally categorize these topological relations. The most frequently described and applied variant of the 9-intersection model concerns relations between a line (actually: a line segment) and a region, in a two-dimensional space. Definitions relevant for this line-region 9-intersection model will now be formulated.

First the atomic elements need to be defined, from which the geometrical objects are built. The atomic elements are called *cells*, and three different kinds of them are distinguished. A 0-cell is the smallest unit, a node - and corresponds to the mathematical zero-dimensional object: the point. A 1-cell is defined as the connection between two distinct 0-cells. A 2-cell is the area described by a closed sequence of three non-intersecting 1-cells.

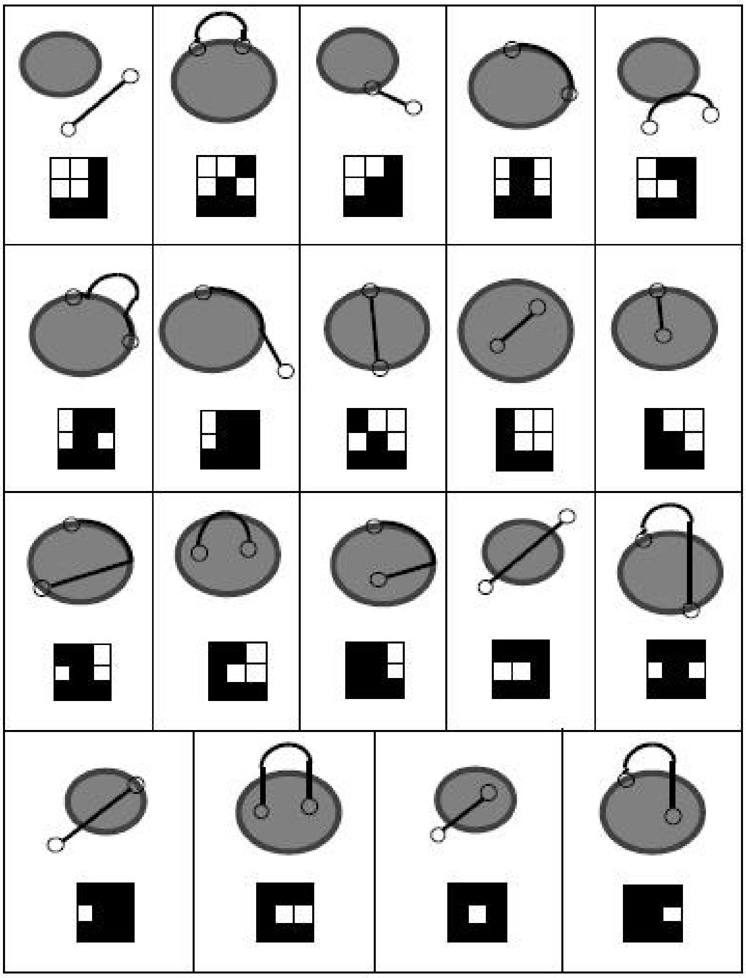
The line and region are complexes built out of cells. Both are joint, homogeneous complexes, which means: they are not partitioned in non-empty disjoint parts. A *line* is defined as "a sequence of 1...n connected 1-cells [...] such that they neither cross themselves nor form cycles." ([18], p. 198). A *region* is defined as "a connected, homogeneously 2-dimensional 2-cell" (ibid.).

Both the line and the region are considered to consist of three parts: an interior, a boundary and an exterior. In the case of a line, the boundary consists of the nodes at which exactly one 1-cell ends. (A simple (unbranched) line thus has exactly two boundaries.) The interior of a line consists of all the nodes that are an end point of more than one 1-cell, and the connections between those nodes. The exterior of a line is the complement of the union of interior and boundary. Interior, boundary and exterior of a region are defined in a similar way: the boundary of a region is a Jordan curve, which can be seen as an unbranched and curved line of which the two endpoints coincide. Naturally, the Jordan curve divides a plane into an 'inside' region and an 'outside' region. The part of the plane that is inside the curve is defined as the interior of the region. (To be precise: only in the case of a *region without holes* the inside of the Jordan curve coincides with the interior of the region.) The complement of the union of interior and boundary is the exterior of the region.





When the intersection relations between a line and a region are studied, these distinguishable parts of the line and the region are taken into account. Interior, boundary and exterior of the line all are in a certain intersection relation with interior, boundary and exterior of the region. The relation between a line and a region therefore can be described by means of nine intersections. Each one of those intersections can be empty or non-empty, meaning that the concerned parts do or do not overlap. The result is 512 (2^9) theoretically possible relations between the line and the region. When a configuration of a line and a region in a two-dimensional space is considered, and the constraints are added that the line is unbranched and that the region has no holes, only 19 of these possibilities remain. In the following picture, interpretations of these 19 possible intersection relations between a line and a region are provided.



Not only for the relation between a line and a region, but also for other combinations an intersection model can be built. The first of the two objects can be either a region or a line or a point, and the second object can also be one out of these three options. A *point* is defined as a single 0-cell, and thus is the same as the mathematical point. A point does not have any distinguishable interior, boundary and exterior, and thus when a point is involved, less than 9 intersections have to be considered.

Now that the building blocks are defined, models can be constructed. The routine way of displaying the intersections of a given topological relation between two objects is to simply place these intersections in a matrix. This method of notation, also used in this thesis, will be explicated here with an example.

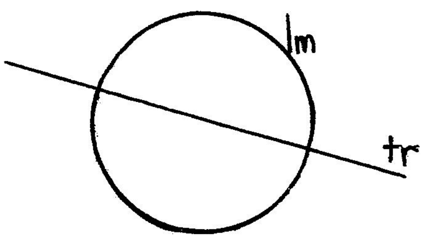
In the following matrix, the “L” stands for the first object, and this object is a line. The “R” represents the second object, which is a region. The topological relation between these two objects is modeled. The result is a 9-intersection model, that is displayed in the following matrix, in which the intersections between the three parts (interior, boundary, and exterior) of both of the objects are written down.

$$\begin{pmatrix} L^\circ \cap R^\circ \neq \emptyset & L^\circ \cap \delta R \neq \emptyset & L^\circ \cap R^- \neq \emptyset \\ \delta L \cap R^\circ = \emptyset & \delta L \cap \delta R = \emptyset & \delta L \cap R^- \neq \emptyset \\ L^- \cap R^\circ \neq \emptyset & L^- \cap \delta R \neq \emptyset & L^- \cap R^- \neq \emptyset \end{pmatrix}$$

The $^\circ$ stands for "interior", the δ for "boundary", and the $^-$ for "exterior". The matrix can be read as follows (starting in the upper row and in the left column): the intersection between the interior of the line and the interior of the region is not empty, i.e. the interiors of both objects do, at least partly, overlap; the interior of the line does also intersect with the boundary of the region; and with the exterior of the region. The boundary of the line does not intersect with the interior of the region; and also the intersection with the boundary of the region is empty; but the boundary of the line does intersect with the exterior of the region. The end points of the line thus are both outside the region. The exterior of the line intersects with the interior of the region; and with the boundary of the region; and also with the exterior of the region.

The (interior of the) line thus is inside as well as outside the region, and (thus) crosses the border of the region. From the fact that the boundary of the line only intersects with the exterior of the region, it can be inferred that the line starts and ends outside the region. The line thus travels (at least one time) into the region and out again. The fact that the exterior of the line intersects with interior, boundary *and* exterior of the region is not surprising; the line naturally does not cover the entire region, thus its exterior (the complement of the union of interior and boundary) intersects with all parts of the region as well.

Because such a matrix might be difficult to read - especially it may not be simple to imagine the picture(s) that is (are) represented by the matrix -, pictures will be added, here and there in this thesis, to the representation of the models. The following (in which "tr" indicates the trajector and "lm" the landmark) is a pictorial representation of the above model.



It is important to note that the picture can not be seen as *the* representation. The matrix displaying is the only actual way of displaying of the models. Pictures are never equivalent to the information that is contained in such a matrix: a picture actually contains more information than an intersections matrix does. A matrix only contains information about the 9 (or less, when a point is concerned) intersections (empty or non-empty) and about the kind of geometry (point, line, region) landmark and trajector are. When a matrix is 'translated' into a picture, it is inevitable that information is added. Choices have to be made about the shape of the region (is it a circle as in the picture above, or is it, for example, elephant-shaped?) and the line (straight, curved, zigzagging?), about the orientation of line and region, and about the precise composition of the configuration (Does the line run through the centre of the region, or only through some peripheral part? Does the line, for example, cross the border of the region only twice, or more times? Etc.). This kind of information is not part of my modelings, so it is a disadvantage of pictures that they *do* include such information: pictorial representations of the models are over-informative (i.e. too specific).

As was said, pictures will occasionally accompany the matrices, to help the reader to imagine what the models represent. In the pictures that are added, the choice was made to represent regions as a circle, and lines as a straight line. Furthermore, of course, some orientation and relative size had to be chosen for the lines and regions. Keep in mind that these choices are made arbitrarily, and were not enforced by the models.

3 A model for the meanings of prepositions

3.1 Introduction

In the previous section, the 9-intersection model is presented and explained. As will be shown, this model has certain important shortcomings. In the following sections, therefore, a new variant of the model will be presented, as an alternative that is more suitable to model the spatial meanings of prepositions. This model of my own is inspired and based on what is discussed above. Before this new model will be exposed, first it will be explicated why the 'standard' 9-intersection model does not suffice.

3.2 Shortcomings of the 9-intersection model

The 9-intersection model is a suitable tool for the modeling of the meaning of (spatial) prepositions. Prepositions, after all, express a relation between two entities (trajector and landmark), and the 9-intersection model indeed represents the (topological) relation between two objects. To model the meaning of a preposition, the trajector and landmark should be mapped onto, respectively, the first and the second object of the pair of objects. The trajector can, for example, be represented by a line, and the landmark by a region. The topological aspects of a configuration that matches (one of) the meaning(s) of a certain spatial preposition thus indeed can be represented by the 9-intersection model.

The model does, however, have a number of limitations. Not all kinds of aspects of meaning can be represented. Of course, the model is restricted to topology, and thus, for example, metric aspects cannot be represented. (The model, besides, might be extended by adding metrical details, that specify for example the relative length of the connection between a trajector and a landmark, or the degree that two lines run in parallel. For work in this direction, see for example [10]. Then, of course, the possibility exists to represent certain metrical aspects of meaning. The default 9-intersection model, however, does not represent any non-topological aspect.) This kind of limitations, however, was not unexpected; the choice to study topological aspects of meaning was indeed made consciously, and a model was chosen deliberately that can represent precisely such aspects.

Considered the fact that the goal was to represent (only) topological aspects of meaning the model, however, still is in some aspect restricted. The model can only represent two-dimensional configurations. The point, line and region are all at most two-dimensional, and only configurations - of two such objects - that reside within two-dimensional space are considered. This restriction of the 9-intersection model is a very important one when the goal is to model the meanings of prepositions. The meanings of prepositions indeed are not restricted to a two-dimensional space; prepositions are used to refer to configurations in the real, three-dimensional world.

3.3 An alternative: a 3D 9-intersection model

To take away this dimensionality constraint of the 9-intersection model, and thus to be able to represent meanings of spatial prepositions, I introduce a new, adapted version of this model, a version that does offer the opportunity to represent three-dimensional configurations.

This new model borrows several properties of the regular 9-intersection model - the version for which the combination of a line and a region results in 19 possible configurations, but also allowing all other combinations of a point, line, and region - that is specified above. The most relevant resemblances of the regular model and my version are the fact that trajector and landmark can be chosen from the set of point, line, and region, and the way in which these objects, and their interior, boundary, and exterior, are defined. Furthermore, as in the standard, two-dimensional model, the restrictions hold that a line is unbranched and that a region has no holes. Also the line and region, and the configuration in which these are combined, should have extension only within a plane.

Then, of course, some differences exist between the regular 9-intersection model and my new version. Instead of expressing a meaning of a certain configuration of two objects (trajector and landmark) by just a single 'image' of the configuration (consisting of, for example, a line and a region), now a meaning will be expressed by a combination of three such models. To be precise: three orthogonal views of a configuration will together construct the model of a meaning of a preposition.

This combination of three views - three two-dimensional 9-intersection modelings - makes the model three-dimensional. Each of the three views is a flattened version of the 'real' three-dimensional configuration. The configuration is flattened in three different directions, that all are mutually orthogonal. This flattening is necessary to represent a three-dimensional real-world configuration in a two-dimensional picture. Combining three flattened configurations, that are orthogonal to each other, makes the representation three-dimensional again. In this way, a three-dimensional model is constructed, using the properties and building blocks of the 'standard', two-dimensional 9-intersection model.

Another property that the 'standard' 9-intersection model lacks, but that is added in this three-dimensional variant, is the possibility to specify, to a certain extent, the direction of a view. One of the three orthogonal views of a model might be marked as, for example, being the top view; the other views of this model consequently will be side views. In this way, the 3D-9-intersection model is equipped with the possibility to represent some non-topological aspects of meaning: directions.

It should be noted that the so-called 'views' of the presented three-dimensional model are not exactly *views*. The choice was made to construct each of the orthogonal views of the model out of separate views of the landmark and of the trajector, instead of of the view of the *configuration* of landmark and trajector. This has as a result that both trajector and landmark are always visible in each view (unless views of trajector and landmark completely coincide), even if in the configuration one of them is behind the other and thus restrained from sight, viewed from the perspective corresponding to that particular view.

This way of composing the views is chosen, because it can be more informative than the alternative. When, for example, a trajector is completely hidden by the landmark, if the model was built out of 'real' views of a configuration, no information could be represented about the nature of the trajector . By making the trajector visible, although it actually is restrained from sight, information is added and the model becomes more valuable.

A possible disadvantage of this modeling method is that it isn't in line with the way we human beings perceive reality. When an object is restrained from sight, then indeed we don't see it. Although the intention of the present modeling enterprise is to stay as close as possible to the idea of Cognitive Linguistics that language is a human, cognitive phenomenon, with respect to this property of the model the choice was made - to give the models more expressive power - to deviate from the most 'human' way of modeling.

Now, an explanation will be given of my three-dimensional variant of the 9-intersection model, and of the way it is notated and displayed, by presenting an example and explicating how its meaning can be derived. The following is the 3D-9-intersection model representing a certain spatial relation between a trajector and a landmark:

$$\begin{pmatrix} \mathrm{L}^\circ \cap \mathrm{R}^\circ \neq \emptyset & \mathrm{L}^\circ \cap \delta\mathrm{R} \neq \emptyset & \mathrm{L}^\circ \cap \mathrm{R}^- \neq \emptyset \\ \delta\mathrm{L} \cap \mathrm{R}^\circ = \emptyset & \delta\mathrm{L} \cap \delta\mathrm{R} = \emptyset & \delta\mathrm{L} \cap \mathrm{R}^- \neq \emptyset \\ \mathrm{L}^- \cap \mathrm{R}^\circ \neq \emptyset & \mathrm{L}^- \cap \delta\mathrm{R} \neq \emptyset & \mathrm{L}^- \cap \mathrm{R}^- \neq \emptyset \end{pmatrix} \mathrm{v1}$$

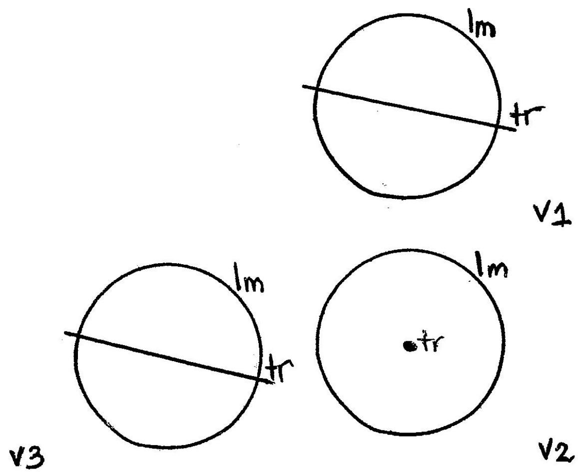
$$\begin{pmatrix} \mathrm{P} \cap \mathrm{R}^\circ \neq \emptyset & \mathrm{P} \cap \delta\mathrm{R} = \emptyset & \mathrm{P} \cap \mathrm{R}^- = \emptyset \end{pmatrix}_{\mathrm{v2}}$$

$$\begin{pmatrix} \mathrm{L}^\circ \cap \mathrm{R}^\circ \neq \emptyset & \mathrm{L}^\circ \cap \delta\mathrm{R} \neq \emptyset & \mathrm{L}^\circ \cap \mathrm{R}^- \neq \emptyset \\ \delta\mathrm{L} \cap \mathrm{R}^\circ = \emptyset & \delta\mathrm{L} \cap \delta\mathrm{R} = \emptyset & \delta\mathrm{L} \cap \mathrm{R}^- \neq \emptyset \\ \mathrm{L}^- \cap \mathrm{R}^\circ \neq \emptyset & \mathrm{L}^- \cap \delta\mathrm{R} \neq \emptyset & \mathrm{L}^- \cap \mathrm{R}^- \neq \emptyset \end{pmatrix} \mathrm{v3}$$

The model consists of three view, that are denoted "v1" (view 1), "v2" (view 2), and "v3" (view 3). These three views are orthogonal to each other. Each view is a model like the two-dimensional 9-intersection model: the intersections between two objects are displayed in a matrix. The first mentioned object in the matrix (denoted "L" in the first and third view and "P" in the second) always is the trajector. The second object in each matrix is the landmark. "P", "L", and "R" indicate that the trajector or landmark is a point, line, or region. When both the trajector and the landmark are represented by, for example, a line, than these are denoted "L1" and "L2", respectively. When one of the views has some specific perspective (for example, it is a top view), then this also is indicated.

This above model represents a straight line that runs through a three-dimensional landmark. The fact that the trajector is a straight line can be derived from the fact that the trajector is represented by a line in two of the views, and as a point in one view: because a view exist in which the trajector is visible as a point, it is determined that the trajector does not have extension in more than one dimension. The fact that the landmark is represented by a region in all three views, determines that the landmark is three-dimensional. As can be derived from the matrices of view 2 and view 3, the interior of the trajector intersects with interior, boundary *and* exterior of the landmark, and the boundary of the trajector intersects with only the exterior of the landmark. This means that the trajector starts and ends outside the landmark and runs through the interior of the landmark (at least once).

The model can be represented in a picture. One possible pictorial representation of the above model is presented below. (In all pictures that are included in this thesis, "v1", "v2", and "v3" indicate respectively view 1, view 2, and view 3.) This picture is indeed a representation of the above model: a straight line that runs (one time) through a region is compatible with the model of view 1 and view 3 (which are identical), a point that is in the centre of a region is compatible with view 2.



The presented variant of the 9-intersection model, the 3D-9-intersection model, is significantly more suitable to represent the meanings of spatial prepositions, than is the default 9-intersection model. The combination of three orthogonal views makes the model three-dimensional. Of each configuration in the real, three-dimensional world, the totality of dimensions can thus be represented. To compare: when the default 9-intersection model would be used, three-dimensional configurations would first have to be reduced to two-dimensional one, before these would fit in the model. This extra 'translation step', in which a lot of information gets lost, becomes superfluous when my new version of the model is used.

One might wonder, however, whether the above presented model is the only possible three-dimensional variant of the 9-intersection model. Instead of a three-dimensional model that consists of two-dimensional views, one can imagine a 'real' three-dimensional intersection model. In such a model, not only points, lines, and regions would be possible building blocks, but also three-dimensional entities, volumes, would occur. For example, the intersections between a volume and a line could be represented, or between a region and a volume. Also the combination of, for example, two regions is possible, and, of course, in the three-dimensional model these regions may extend into three-dimensional space.

A volume, as the line and region, would have an interior, boundary, and exterior. The boundary would separate the interior from the exterior, just as the boundary of the region does. Whereas the boundary of a region is a (curved and closed) line, the boundary of a volume is a (curved and closed) region.

For what reasons the views approach is chosen to model the meanings of prepositions, instead of developing such a 'native' three-dimensional intersection model? The presented 'views variant' of the 9-intersection model has as an advantage that, although it is new, little work had to be done to develop and define this modeling tool. Building blocks and notions could be borrowed from the two-dimensional model straightaway. No additional building blocks, such as the volume, needed to be defined. No intersection possibilities between all the possible building blocks in a three-dimensional space had to be explored either. In choosing the above presented variant of the 9-intersection model, a model thus is chosen that is suitable to represent three-dimensional configurations, *and* for which little new notions and definitions were needed.

Apart from these considerations, the question should be asked whether the presented model and the 'native' three-dimensional variant are equally suitable to model the meanings of prepositions, or that perhaps one of the two has more expressive power. A formal proof of the (lack of) equivalence of the two model variants is beyond the scope of this work. Intuitively, the models seem to be able to express the same information. The fact that a landmark is three-dimensional, for example, or that a trajector is two-dimensional, can be represented in both the model variants. In the case of **through 1**, to mention one, the 'native' model cannot represent more information than can the views variant: both models can express that the trajector is a line of which the interior intersects with all parts (interior, boundary, exterior) of the three-dimensional landmark. Also in the case of **over 6** and **over 8** the models seem to have the same expressive power. Both variants cannot distinguish between these two occurrences of *over*. The properties of these meanings that can be represented in the 'native' model variant can also be represented in the views model. In this case, the views model even seems to have more expressive power than has the 'native' model: the views variant can, when one of the views is labeled as being the top view, contain the information that landmark and trajector are above each other, whereas the 'native' model cannot.

Of course, these considerations are not nearly a proof of the relative possibilities of the two model variants. At most the above examples can render plausible that the presented three-dimensional variant of the 9-intersection model doesn't have far less expressive power than the 'native' model would have. Hopefully, in the remainder of this thesis it will become clear that this indeed is the case.

A last consideration regarding the choice between these two ways of modeling concerns the role of perspective. Possibly, the 'native' three-dimensional model is more in line with the ideas of Cognitive Linguistics and Embodied and Embedded Cognition than is the views variant. Human beings, after all, interact with the world not only by perceiving, but also by moving in the world. The world we encounter is three-dimensional, and therefore, one might say, the spatial structures that match the meanings of prepositions should be modeled in a natively three-dimensional way. One might object to this that human beings always view the world in a certain way. It might be the case that people understand the spatial structure of the world by viewing the world from different perspectives, and by recognizing structures that are present in those views. If this is the case, then the presented views model still might be in line with the way human cognition works.

Because it is unknown how exactly human beings make sense of the spatial structure of reality, the choice between modeling the meanings of prepositions in a 'native' three-dimensional way on the one hand, and by making use of view models on the other is, in this respect, arbitrary. No strong reasons exist to prefer the one modeling method or the other.

In the following section the 3D-9-intersection model, that is presented and explained above, will be used to model the meanings of five spatial prepositions.

The modeling tool, in this way, will be put to the test: is the 3D-9-intersection model indeed suitable to represent spatial meanings? Moreover, as we will see, the model straightaway will fulfill the goal for which it was designed, which is to help to provide insight into the semantics of the chosen prepositions.

4 3D-9-intersection models of five prepositions

4.1 Introduction

The focus of the sections 4.4 to 4.8 is on five spatial prepositions: *along*, *across*, *through*, *around*, and *over*. For each of these prepositions, first a linguistic analysis will be given. Based on linguistic literature, I will give my own analyses of the semantics of the prepositions. The diverse occurrences of each of the preposition will be enumerated, and the meaning of each occurrence will be accounted for. Differences and similarities between meanings of a preposition will also be explicated.

When the linguistic analysis is given, secondly, a translation is made of the distinguished meanings to models of the 3D-9-intersection model. For each occurrence of each of the prepositions, the meaning is modeled according to the constraints of this model.

Thirdly, for each preposition, the modelings will be analyzed: what can be learned from them about the meanings of each of the prepositions, and about the relations between them, their resemblances, shared aspects of meaning and differences? Also, attention will be payed to the question to what extent 3D-9-intersection modelings of each of the occurrences of each of the prepositions are possible, and what are the shortcomings of the 3D-9-intersection model in the modeling of that preposition.

In section 4.9, finally, all models will be compared. What similarities can be found across models of different prepositions? First now, in the sections 4.2 and 4.3, some choices will be accounted for. Why are these five prepositions chosen to be modeled and analyzed, and what foundation can be provided for the distinguishing of the diverse meanings of each of these prepositions?

4.2 Accounting for the choice of the prepositions

The prepositions that are chosen to be discussed in this thesis, are *along*, *across*, *through*, *around* and *over*. These prepositions all are route preposition, although one might argue that *over* is not. (For arguments on this last point, see, for example [8], and section 2.2.2.) Above it was argued why (spatial) prepositions, in general, are an interesting object of study. Now reasons will be given why especially route prepositions are interesting.

Route prepositions are to be opposed to locational prepositions. Locational prepositions designate a relation between a stationary object (trajector) and a landmark, whereas in the case of route prepositions the trajector is a route. A route can be defined as "a particular type of schematic path defined in terms of its internal structure and location rather than by its endpoints" ([8], p. 272).

It should be noted that, in addition to locational and route prepositions, a third category of prepositions can be distinguished, consisting of source and goal prepositions, such as *out of* and *into*. Source and goal prepositions have in common with route prepositions that they can express a movement, whereas locational prepositions can only express stationary location. In the case of source and goal prepositions, however, the shape and internal structure of the path (trajector) are not relevant; only the location of its end-points determines the meaning. Route prepositions, furthermore, can express both movement and extended location (linear extension), whereas source and goal preposition can only express movement.

Route prepositions are more relevant for the purposes of this thesis than locational and source/goal prepositions, because of the nature and properties of the trajector. The trajector of a route preposition represents a path, and can express both movement and extended location. Therefore, it has more interesting properties than just its location; also the shape and structure of the trajector are relevant, and the relation between different parts of it and the landmark can be investigated. Furthermore many different kinds of path trajectors can exist, whereas only one type of locational trajector is possible. (A locational trajector indeed is a trajector of which the shape is irrelevant; it always is represented by a point.)

Moreover, route prepositions are more interesting for the purposes of this thesis because of their suitability to be modeled in the 9-intersection model. The most discussed and well-known version of this model is the line-region variant and route preposition do fit into this model pre-eminently. (The path trajector then is modeled by a line and the landmark by a region.) Of course, also for prepositions that have a locational trajector a suitable 9-intersection model exists (in which the trajector is modeled by a point), but this variant of the model has far less interesting properties than has the line-region variant.

The category of route prepositions thus is chosen deliberately to be object of study in this thesis. Because investigating all route prepositions is beyond the scope of this work, five of them were elected: *along*, *across*, *through*, *around* and *over*. These five prepositions form an interesting selection of the category of route prepositions. The selection is diverse in multiple respects. To begin with, the prepositions differ in complexity of meaning: the number of meanings a prepositions has, the number of distinguishable aspects of meaning that are relevant, and the degree in which non-topological aspects of meaning determine the meaning are different among the five prepositions. Furthermore, the chosen prepositions differ with respect to the nature of the trajector and of the landmark.

With respect to the number of distinguishable meanings, as will be clear in the next sections *along* is the simplest of the five prepositions. In the cases of *across* and *through*, a few more meanings will be distinguished, and *around* and *over* are yet more complex in this respect. *Along* also is relatively simple regarding the number of relevant aspects of meaning. Only the nature of trajector and landmark (both should be line-shaped), and the relative location and direction of these two (the lines have to run in parallel) are relevant. Cardinal directions, among other aspects, are irrelevant. *Across*, to mention one, has more distinguishable aspects of meaning than has *along*: apart from the nature and relative position of trajector and landmark, also cardinal directions (absolute positioning of the configuration) play a role.

Furthermore, the degree in which non-topological aspects determine the meaning differs across the five preposition. As was just mentioned, in the case of *across* cardinal directions are relevant. In the case of most of the occurrences of *over*, this aspect of meaning - the trajector should be above the landmark - even is crucial. The other three prepositions, to compare, are direction-independent. Also the degree of relevance of shape and distance differs. In some cases, topological models will be quite complete, but in other cases, the models lack non-topological information that indeed is relevant for the meaning.

The trajectors and landmarks of the five prepositions, finally, also are diverse.

In the case of *along*, only line trajectors occur, whereas *over* has lines as well as points and regions as trajectors. The landmark of *around*, for example, can be both zero-, and two- and three-dimensional, whereas all landmarks of *across* are at most two-dimensional.

Another reason to choose these five prepositions is that these are discussed sufficiently in the literature. The (linguistic) literature on the meanings of these prepositions has provided a basis for my own analyses, and, indirectly, for my modelings of the meanings. (It might be the case, moreover, that these prepositions have gained a relatively large amount of attention in the literature *because* these five prepositions are more interesting than others - providing an extra reason to choose these.)

4.3 Accounting for the distinguishing of meanings

Each of the five prepositions that will be discussed below has multiple, related senses. Not in all cases it is obvious what exactly the distinguishable meanings of that preposition are. Boundaries between one meaning of a preposition and another may be vague, and also it is not fixed at what level of precision meanings should be distinguished (or grouped together). Indeed, I think, no single 'right' division in meanings exists for each of the prepositions. The polysemy of a preposition may be seen as a conceptual space in which 'meanings' are regions that do not have sharp boundaries and between which various family resemblances, (derivative) relations, differences and commonalities can be noted.

Drawing boundaries in such a space, and thus distinguishing separate meanings may be considered, to some extent, an arbitrary division of the space. The distinguished occurrences of the prepositions that are presented in the next sections are the result of *some* classification; this is not the only possible classification, or the single 'correct' one. If indeed boundaries in the polysemous space are arbitrary, then the classification can not be false either. The classification presented here, however, is not made arbitrarily. The division of meanings for each of the prepositions is based on the linguistic literature.

In some cases, the meanings I have distinguished are exactly the ones that are distinguished in the literature. In the case of *across*, for example, the five occurrences that are distinguished are the five occurrences from Hawkins' ([11]) analysis. When a preposition is discussed by multiple authors, their classifications are combined. This is done in such a way that, first, as little information is lost as possible. The case of *through* might illustrate this. The first four of the meanings of *through* I have distinguished, occur in the analyses of both Hawkins ([11]) and of Cuyckens ([6]). The fifth meaning I have added is only mentioned by Cuyckens and the sixth only occurs in the analysis of Hawkins. Both these two meanings are included in my analysis, because both indeed are different from the first four occurrences of this preposition, and cannot be shared together with any of the other occurrences.

Secondly, in combining analyses from the literature, it was tried to be as consistent as possible, in relation to the devision in meanings of the other prepositions. In the case of some of the meanings of *around*, for example, this strategy was applied. The distinguishing of **around 1** and **around 2** has been the result of a consideration of the methods of distinguishing meanings of Hawkins ([11]), and of Dewell ([7]). In Dewell's analysis, whether the trajector is in contact with the landmark or not is not a distinguishing feature: in one single distinguished meaning of Dewell, the trajector may or may not contact the landmark. Hawkins, on the other hand, considers the contact/non-contact feature as distinguishing: two separate meanings of *around* are distinguished that only differ with respect to this contact/non-contact property. The choice was made to follow Hawkins in this, because then the classification of *around* is more in line with the classifications in the cases of the other prepositions. Also in the case of *over*, for example, contact/non-contact is a distinguishing feature - because it is not only in Hawkins' analysis of *over*, but also in the analysis of Lakoff ([15]).

Dewell ([7]) does consider another aspect of meaning as distinguishing: movement vs. linear extension. In line with Hawkins the choice was made to not consider this aspect as distinguishing. The result is that both my **around 1** (non-contact, movement or linear extension) and my **around 2** (contact, movement or linear extension) match two separate occurrences of Dewell's *around* each. The reason to not consider movement/linear extension as a distinguishing feature is, again, that this is the most consistent choice. Not only Hawkins ([11]), whose analysis of *around* is used, but also Cuyckens ([6]), whose analyses of other prepositions are used, does not consider movement/linear extension as a distinguishing feature. In the analyses of all five prepositions, the choice was made to follow this line: movement and linear extension are shared together.

4.4 *Along*

4.4.1 Linguistic analysis: the meanings of *along*

Along is a preposition that has a relatively simple meaning. The preposition refers to a movement (or non-moving oblong thing or configuration of things) that is parallel to an oblong or line-like landmark. This parallel movement or thing can be either at some small distance of, or coinciding with the landmark. Both (configurations matching the) meanings of *along* take place within a plane, and thus extend in not more than two dimensions. My analysis of these two meanings of *along*, based on the analyses of Cuyckens ([6]), and Hawkins ([11]), is as follows.

In the enumeration, abbreviations are mentioned that refer to meanings that were distinguished in the literature. "C" refers to Cuyckens, "H" refers to Hawkins. The numbers refer to separate occurrences of the prepositions that were distinguished by the concerned author[3].

along 1 (C1, H1)

> "He walks along the river."
>
> The trajector is a line. The landmark can have various forms, but it should have significant extension in at least one direction. The trajector is at some small distance from the longest side of the landmark, and runs approximately parallel to this side.

[3]One might have noticed that the first and third occurrence from Cuyckens' analysis are present in my analysis of *along*, but not the second. This meaning is absent here, because Cuyckens' research concerns the *Dutch* preposition *langs* ("along"), and this preposition seems to have a different variety of meanings than has its english counterpart: the meaning "C2" of *langs* ("Hij loopt langs de lantaarnpaal" ("He walks past the lamppost"); a trajector line running past a point landmark) is not a meaning of *along*.

along 2 (C3, H2)

"They made their way along the Via del Corso."

This second occurrence of *along* is similar to the first. Also here, the trajector is a line and the landmark can have any shape as long as it has significant extension in at least one direction. In this case, however, the trajector coincides with the longest side of the landmark instead of running parallel to at it some distance.

4.4.2 A 9-intersection modeling of the meanings of *along*

The two meanings of *along* have a number of aspects in common. In both cases, the trajector is a line and thus can best be modeled by a line. The landmark might be something that has extension in multiple dimensions, but only one of these dimensions - the direction of the 'longest side' - is relevant. Because only one dimension of the landmark is relevant for both these meanings, the landmark can be modeled by a line. This line represents the longest side of the landmark. In the cases of both occurrences of *along*, the trajector and the (longest side of the) landmark run parallel to each other. The difference between **along 1** and **along 2** is that in the first case, the two lines are at some distance of each other, whereas in the case of the second occurrence, the two lines coincide completely.

The model of **along 1** will be the following.

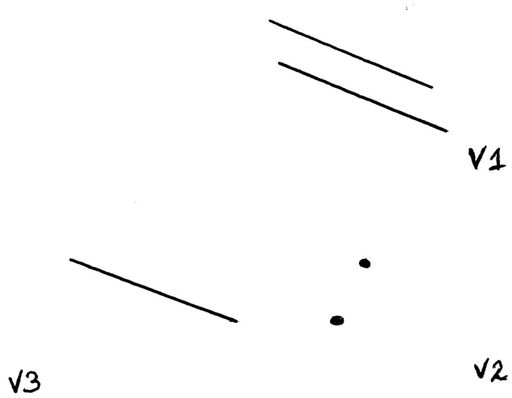
$$\begin{pmatrix} \mathrm{L1}^\circ \cap \mathrm{L2}^\circ = \emptyset & \mathrm{L1}^\circ \cap \delta\mathrm{L2} = \emptyset & \mathrm{L1}^\circ \cap \mathrm{L2}^- \neq \emptyset \\ \delta\mathrm{L1} \cap \mathrm{L2}^\circ = \emptyset & \delta\mathrm{L1} \cap \delta\mathrm{L2} = \emptyset & \delta\mathrm{L1} \cap \mathrm{L2}^- \neq \emptyset \\ \mathrm{L1}^- \cap \mathrm{L2}^\circ \neq \emptyset & \mathrm{L1}^- \cap \delta\mathrm{L2} \neq \emptyset & \mathrm{L1}^- \cap \mathrm{L2}^- \neq \emptyset \end{pmatrix}_{\mathrm{v1}}$$

$$\begin{pmatrix} \mathrm{P1} \cap \mathrm{P2} = \emptyset \end{pmatrix}_{\mathrm{v2}}$$

$$\begin{pmatrix} \mathrm{L1}^\circ \cap \mathrm{L2}^\circ \neq \emptyset & \mathrm{L1}^\circ \cap \delta\mathrm{L2} = \emptyset & \mathrm{L1}^\circ \cap \mathrm{L2}^- = \emptyset \\ \delta\mathrm{L1} \cap \mathrm{L2}^\circ = \emptyset & \delta\mathrm{L1} \cap \delta\mathrm{L2} \neq \emptyset & \delta\mathrm{L1} \cap \mathrm{L2}^- = \emptyset \\ \mathrm{L1}^- \cap \mathrm{L2}^\circ = \emptyset & \mathrm{L1}^- \cap \delta\mathrm{L2} = \emptyset & \mathrm{L1}^- \cap \mathrm{L2}^- \neq \emptyset \end{pmatrix}_{\mathrm{v3}}$$

From the combination of these three views it becomes clear that trajector and landmark both are lines, and that these lines run in parallel. The second view determines this parallelism; the fact that there exists a perspective in which two lines are viewed as two single points, means that both lines are straight lines and that the lines run in parallel. The third view furthermore determines that the lines do overlap completely, seen from some perspective, and thus that the lines are of the same size. The three views together thus form a quite complete model.

The following is a pictorial representation of this model of **along 1**.



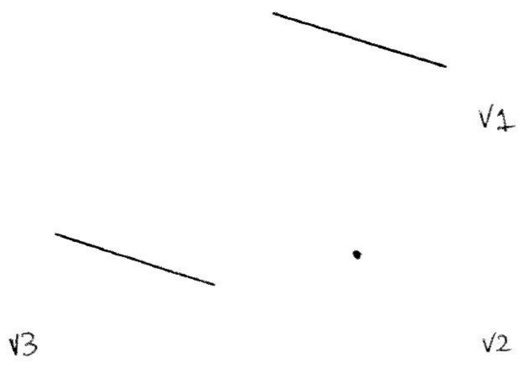
The model of **along 2** will be the following.

$$\begin{pmatrix} L1^{\circ} \cap L2^{\circ} \neq \emptyset & L1^{\circ} \cap \delta L2 = \emptyset & L1^{\circ} \cap L2^{-} = \emptyset \\ \delta L1 \cap L2^{\circ} = \emptyset & \delta L1 \cap \delta L2 \neq \emptyset & \delta L1 \cap L2^{-} = \emptyset \\ L1^{-} \cap L2^{\circ} = \emptyset & L1^{-} \cap \delta L2 = \emptyset & L1^{-} \cap L2^{-} \neq \emptyset \end{pmatrix}_{\text{v1, v3}}$$

$$\begin{pmatrix} P1 \cap P2 \neq \emptyset \end{pmatrix}_{\text{v2}}$$

Also these three views combine into a complete model. From the combination of the first and the third view, it becomes clear that both trajector and landmark are a line, and that these lines do completely overlap. The second view then determines that the lines are straight lines.

The following picture is a representation of this model.



4.4.3 Analysis of the models of *along*

Comparing the meanings

Considering the models of the two distinguished meanings of *along*, observations can be made concerning what would be the core meaning of this preposition. I understand 'core meaning' to refer to the set of those aspects of meaning that are shared by all, or (in the case of prepositions that have many distinguished meanings) most, of the occurrences. 'Prototype' is a related notion; I understand it to I refer to the meaning (one of the distinguished occurrences) of a preposition that is the most typical occurrence of that preposition. The prototype will be the occurrence that, of all the distinguished meanings, has the strongest resemblance with the core meaning. Also, the prototype often is a meaning from which other occurrences seem to be derived; the prototype is the most central occurrence in the family resemblances 'network'. Whereas the core meaning is just a set of aspects of meaning (that may not be instantiated by one of the occurrences; all occurrences might have certain additional aspects of meaning), the prototype of a preposition thus is an actual occurrence.

The common aspects of meaning of *along* are the fact that both the trajector and (the relevant part of) the landmark are a line, that these lines coincide when viewed from (at least) some perspective (view 3), and that they (at least) run in parallel. The set of these aspects thus is the core meaning of this preposition. The difference between the two meanings of *along* consists in the coincidence or otherwise of the lines.

Because only two meanings are distinguished, no useful categorization or grouping of meanings can be made, and comparing these two meanings thus provides no ground for inferring which of the meanings is the most prototypical. Other arguments can be found, however, that do point toward a prototype. For configurations to which the meaning of **along 1** applies, no other suitable prepositions are available: these occurrences are quite typical occurrences of *along*, because they are very a-typical occurrences of any other preposition. The configurations to which the **along 2** meaning is applicable, on the other hand, are similar to configurations that can be described using other prepositions. When small changes would be applied on an **along 2** configuration, this configuration might have turned into, for example, an occurrences of *over*. (Compare, for example, "along the road" to "over the bridge".) Because **along 1** clearly is a more a-typical occurrences of any other preposition than is **along 2**, **along 1** may be declared the prototype of *along*.

Judging the models

What can be said about the degree in which the models do indeed represent the meanings of *along*? The models seem to be quite complete; most relevant aspects of meaning are represented. An aspect that is not represented and that seems relevant to me (and that also is designated in [14] as a relevant aspect of meaning), is the distance between trajector and landmark, in the case of **along 1**. Two lines that run in parallel but that are far apart, will not classify to be an instance of *along*, but such an instance is not excluded by the model.

This missing aspect is a non-topological one. Other non-topological aspects that may be aspects of meaning are, in any case, no *relevant* aspects of meaning. The precise shape of the trajector and the landmark is not represented, but this is not a shortcoming: the model is a schematized representation of the situations *along* applies to. This preposition can refer to both the combination of a winding river and a similar path and, for example, the combination of a straight road and a similar cycle lane. Such situations all are conceptualized as a configuration of two parallel lines, and the model does suffices to represent these.

4.5 *Across*

4.5.1 Linguistic analysis: the meanings of *across*

One of the most original aspects of meaning of *across* is the fact that trajector and landmark are situated crosswise. Some line-shaped or at least oblong landmark is traversed by a line-shaped trajector, or a trajector is at the other side of such a landmark, such that a(n imaginary) cross is formed. Not in all of the occurrences of *across*, however, the trajector traverses the landmark to its other side. In some occurrences the trajector just is some straight path that lies within a landmark.

Below, the diverse meanings of *across* that are distinguished are enumerated. This analysis is based on the analysis of Hawkins ([11]), and the abbreviations ("H1", "H2", etc.) refer to meanings that were distinguished by Hawkins.

across 1 (H3)

"The little puppy scampered across the street."

The trajector is a line, the landmark is a (more or less) line-shaped part of the horizontal plane. (This region need not to be strictly line-shaped; it might have any form as long as it has a 'longest side'. In other words: it should have extension in at least one direction, and not be square-like.) The trajector traverses the landmark (crosses the landmark to arrive at the other side of it), approximately in the direction in the horizontal plane that is perpendicular to the longest side of the landmark. The trajector thus forms a cross with the longest axis of the landmark.

across 2 (H4)

"The little bread shop is across the street."

This occurrence is the end-point derivative of **across 1**. "End-point" indicates that only the end point of what normally is the trajector, is relevant in this case. Just as in the case of **across 1**, here the landmark is an oblong part of the horizontal plane. In this case, not the actual trajector, but some auxiliary trajector is a line that traverses the landmark, within the horizontal plane, in a direction that is approximately perpendicular to its longest side. The actual trajector is located at the end point of this auxiliary trajector.

across 3 (H2)

"Harvey made his way across the room."

The trajector is a line, the landmark is some region within the horizontal plane. The trajector is completely inside (i.e. part of) the landmark.

across 4 (H1)

"There were four deep lines across his forehead."

The trajector is a line, the landmark is some region. The trajector is completely inside (i.e. part of) the landmark. This occurrence thus is the same as **across 3**, except that now it is not necessary that the landmark is part of the horizontal plane - landmark and trajector are in some arbitrary plane instead.

across 5 (H5)

> "They were trying to sell the fight to theaters across the U.S."
>
> The landmark is a region in the horizontal plane, the trajector also is extended in two dimensions. The trajector is completely inside (i.e. part of) the landmark. The trajector 'crosses' the landmark in various directions. Instead of just *across*, one might use *all across* in the case of this occurrence. Then it is emphasized that the trajector indeed crosses the landmark in *a lot of* directions. "All" does not literally mean "all". If the trajector really was extended "all across the landmark area", then the whole landmark would be covered by the trajector. That is not the case. "All" should be interpreted as "in all parts of", given *some* partition of the landmark. (It is thus a bit vague in which cases "all" does apply.)

4.5.2 A 9-intersection modeling of the meanings of *across*

A number of interesting differences and resemblances between the five distinguished meanings of *across* can be noted. In all cases, the landmark has extension in two dimensions, and the total configuration of the trajector and the landmark resides completely within the plane that extends in those two dimensions. **Across 1** and **across 2** are meanings in which the trajector is a line that is partly outside the landmark. **Across 3**, **across 4** and **across 5** are meanings in which the trajector is completely inside the landmark. In the case of **across 3** and **across 4**, this trajector is extended in only one direction (as it is in the cases **across 1** and **across 2**), whereas in the case of **across 5**, the trajector is extended in both of the dimensions in which the landmark has extension.

The model for **across 1** can be the same as for **across 2**, considered that in the case of **across 2** the auxiliary trajector will be modeled, instead of the actual trajector. In the cases of **across 1** and **across 2**, the (auxiliary) trajector extends, as was said, in only one direction. The trajector thus can best be represented by a line. The landmark should be some oblong or line-like region, of which the longest side forms a cross with the line-trajector. An option is to represent the landmark by use of a region, but then it will be impossible to represent what its 'longest side' is. Also the 'cross' will, in this way of modeling, disappear from the configuration - for a region is not defined as being oblong. A better option will be to choose a line for the landmark; this line then will represent the longest side of the landmark.

The configuration in the model should thus consists of a line trajector that crosses a line landmark. Seen from some perspective, indeed two crossing lines are visible. Of this perspective it should be said that it is the top view (or: bottom view), because in this way the model will be compatible with the fact that the trajector and the landmark are necessarily in a horizontal configuration. Because the configuration that matches the meaning of these two occurrences resides completely within that horizontal plane, in the two other perspectives - orthogonal to the first perspective and to each other - that are part of the model, the picture will be different: what is visible in these two views is only one-dimensional.

The model of **across 1** en **across 2** will be the following.

$$\begin{pmatrix} L1^\circ \cap L2^\circ \neq \emptyset & L1^\circ \cap \delta L2 = \emptyset & L1^\circ \cap L2^- \neq \emptyset \\ \delta L1 \cap L2^\circ = \emptyset & \delta L1 \cap \delta L2 = \emptyset & \delta L1 \cap L2^- \neq \emptyset \\ L1^- \cap L2^\circ \neq \emptyset & L1^- \cap \delta L2 \neq \emptyset & L1^- \cap L2^- \neq \emptyset \end{pmatrix} \text{v1 = top view}$$

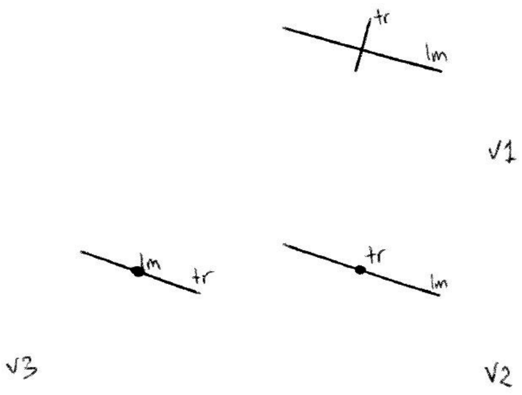
$$\begin{pmatrix} L^\circ \cap P \neq \emptyset \\ \delta L \cap P = \emptyset \\ L^- \cap P = \emptyset \end{pmatrix} \text{v2}$$

$$\begin{pmatrix} P \cap L^\circ \neq \emptyset & P \cap \delta L = \emptyset & P \cap L^- = \emptyset \end{pmatrix}_{\text{v3}}$$

These three views together form a model that is as complete as is possible; each one of the views adds information to the combination of the other two views. The second and third view add, together, to the top view the information that the configuration indeed is completely within the horizontal plane. The addition of this second and third view also determines that the trajector and (the longest side of) the landmark both are straight lines that are perpendicular to each other; configurations in which the crossing of the two lines is *not* perpendicular are excluded. The fact that for both of the lines a perspective exists in which the line is visible as a point, also makes clear that the lines are straight lines.

One might argue that the perpendicularity of trajector and landmark that is contained in this model is too strong; cases in which the trajector runs only approximately, and not precisely, perpendicular to the landmark should not be excluded by the model. They aren't. The model is a schematized (see [12]) representation of configurations that match this meaning of *across*. Also cases in which trajector and landmark are in an angle of, say, 85 degrees, are schematized as being perpendicular. Note that this schematization is of the same sort of the schematization that is present in, for example, the modelings of *along*, in which case trajector and landmark are represented by straight lines that are strictly parallel, while *along* applies to slithering landmarks and (approximately parallel) slithering trajectors as well.

The following is a pictorial representation of this model.



In the meanings of **across 3** and **across 4**, the trajector is inside the landmark. The landmark is some region, which in the case of **across 3** should be part of the horizontal plane. The models for **across 3** and **across 4** can be the same, except that only in the case of **across 3** it should be added that one specific view necessarily is the top (or bottom) view. (In the case of **across 4**, the situation of the views in space is completely arbitrary; the only demand is, of course, that the three views are orthogonal to each other.)

The model for **across 3** and **across 4** will be as follows.

$$\begin{pmatrix} L^\circ \cap R^\circ \neq \emptyset & L^\circ \cap \delta R = \emptyset & L^\circ \cap R^- = \emptyset \\ \delta L \cap R^\circ \neq \emptyset & \delta L \cap \delta R = \emptyset & \delta L \cap R^- = \emptyset \\ L^- \cap R^\circ \neq \emptyset & L^- \cap \delta R \neq \emptyset & L^- \cap R^- \neq \emptyset \end{pmatrix} \text{v1; } \textbf{across 3}\text{: top view}$$

$$\begin{pmatrix} L1^\circ \cap L2^\circ \neq \emptyset & L1^\circ \cap \delta L2 = \emptyset & L1^\circ \cap L2^- = \emptyset \\ \delta L1 \cap L2^\circ \neq \emptyset & \delta L1 \cap \delta L2 = \emptyset & \delta L1 \cap L2^- = \emptyset \\ L1^- \cap L2^\circ \neq \emptyset & L1^- \cap \delta L2 \neq \emptyset & L1^- \cap L2^- \neq \emptyset \end{pmatrix} \text{v2}$$

$$\begin{pmatrix} P \cap L^\circ \neq \emptyset & P \cap \delta L = \emptyset & P \cap L^- = \emptyset \end{pmatrix}_{\text{v3}}$$

Just as in the case of the models of **across 1** and **across 2**, the views of this model complement each other. The second and third view make clear that the configuration resides completely within a plane. The third view determines that the trajector is a straight line (for only something that fits within one dimension can in a view be seen as a point).

The last meaning of *across* ("(all) across the U.S.") is different from the above occurrences with respect to some important aspect. In the case of the first four occurrences, the trajector is extended in only one dimension. In the case of **across 5**, however, the trajector has extension in two dimensions. The landmark of **across 5** also is two-dimensional. The trajector of the other occurrences of *across* travels to the other side of the landmark, in one direction. In this occurrence the trajector extends in various directions, and travels to diverse corners or parts of the landmark.

When "all" is added right before the preposition, the directions in which the trajector extends are even more numerous, or at least: emphasis is added on the fact that the trajector travels in *a lot of* different directions. Because the boundary between the case with "all" and the case without is vague, and because both cases are topologically indistinguishable (in both cases, the trajector is a line that extends in various directions inside a region), no separate model will be made for the case in which "all" is added.

In the model of **across 5**, the landmark will be represented by a region and the trajector by a line. The model for **across 5** will be as follows.

$$\begin{pmatrix} L^\circ \cap R^\circ \neq \emptyset & L^\circ \cap \delta R = \emptyset & L^\circ \cap R^- = \emptyset \\ \delta L \cap R^\circ \neq \emptyset & \delta L \cap \delta R = \emptyset & \delta L \cap R^- = \emptyset \\ L^- \cap R^\circ \neq \emptyset & L^- \cap \delta R \neq \emptyset & L^- \cap R^- \neq \emptyset \end{pmatrix} \text{v1 = top view}$$

$$\begin{pmatrix} L1^\circ \cap L2^\circ \neq \emptyset & L1^\circ \cap \delta L2 = \emptyset & L1^\circ \cap L2^- = \emptyset \\ \delta L1 \cap L2^\circ \neq \emptyset & \delta L1 \cap \delta L2 = \emptyset & \delta L1 \cap L2^- = \emptyset \\ L1^- \cap L2^\circ \neq \emptyset & L1^- \cap \delta L2 \neq \emptyset & L1^- \cap L2^- \neq \emptyset \end{pmatrix} \text{v2, v3}$$

This model does not completely represent the meaning of **across 5**. The representation of the trajector is not sufficient, because the trajector is not 'just a line'. The trajector is explicitly a slithering or branched line, that extends in many directions within a plane, and this important aspect can not be represented. An alternative way to model the trajector would be to choose a region to represent it. In that case the extension of the trajector in all the dimensions in which the landmark is extended would be represented. A region however, would be much too massive (for the trajector indeed does not cover the whole landmark), and thus the region is a worse option for modeling the trajector than the line is.

Representing the exact shape of the trajector is thus a problem. What is represented, however, is that the trajector is not a *straight* line. If it were, in one of the views this trajector would have been represented as a point. The fact that both in view 2 and in view 3 the trajector is visible as a line, determines that the trajector extends in both of the dimensions in which the landmark is extended. What the model does represent furthermore, is that the trajector is completely inside the landmark, that the landmark is a region and that the configuration as a whole is situated within a plane.

4.5.3 Analysis of the models of *across*

Comparing the meanings

The five meanings of *across* have various mutual differences and commonalities. Few aspects can be found that are shared by all five occurrences. What is shared by all five meanings, is the fact that the configuration representing the meaning occupies (exactly) two dimensions. In four of the five cases, the configuration resides completely within a horizontal plane; only in the case of **across 4**, this is not an aspect of meaning. It seems plausible that this **across 4** meaning is a derived one, and that the horizontality is part of the core meaning of *across*. What also seems to be a core aspect of meaning of this preposition, is the fact that the trajector is line-shaped. Occurrences that possibly do not have this property, are **across 2** and **across 5**. **Across 2** is the end-point derivative of **across 1** and thus provides no counter-evidence against the claim that the core trajector of this preposition is a line. **Across 5** actually is a special case. The trajector of this occurrence does extend in two instead of one dimension. This trajector, however, still can be seen as line-shaped; instead of a simple straight line now it is a complex of straight lines, running in various directions. **Across 5** can be seen as a derivative of **across 3**: instead of running only in one direction towards the other side of a region (inside that region, and in the horizontal plane), now the trajector crosses the landmark region in various directions.

The conclusion thus seems to be that the preposition *across* typically refers to a configuration, completely within the horizontal plane, of a line-shaped trajector that crosses (either inside or to the other side of) some landmark. The core meaning of *across* thus would have these aspects, and probably these aspects would be present in the most prototypical meaning. What other aspects of meaning would determine the prototype? Can one of the five distinguished meanings be indicated as the most prototypical one?

A choice, then, has to be made between the area landmark, combined with a trajector that runs inside it, and the line landmark, which the trajector crosses to its other side. In three of the five cases, the area landmark, which the trajector completely is inside of, occurs. For lack of a better argument, one might conclude that this landmark type is more prototypical than the line-shaped landmark, that occurs only twice. The conclusion then might be that the most prototypical meaning is a configuration within the horizontal plane, consisting of a (single) line trajector that is completely within an area landmark. This combination of aspects of meaning is instantiated in the case of **across 3**, which therefore seems to be the most prototypical occurrence.

When the prototype of a polysemous prepositions is defined as the most average meaning, **across 3** indeed is the prototype. When, however, the prototype would be defined as the most original meaning, maybe **across 1** would be the winner, because this meaning seems to have the strongest affinity with the noun 'cross', that the preposition would be related to.

Talmy ([26]) hands tools to unify this cross-shapedness with the landmark being an area. He articulates the meaning of *across* as follows: "a horizontal [line trajector] that runs perpendicularly from one edge to the other of a [region landmark] bounded by two opposite parallel edges, where this [region] is 'not laterally collapsible.' " ([26], p. 221). This last phrase refers to the relative length of the region's two axes: an axis parallel to the trajector and an axis perpendicular to the first one. The meaning of the phrase is that the axis running perpendicular to the trajector cannot be so short that it can conceptually collapse into the path line itself. In other words: some non-negligible axis that can be crossed by the trajector should necessarily exist. Both a line-shaped landmark that is perpendicular to the trajector *and* an area landmark with significant extension perpendicular to the trajector meet this criterion.

Judging the models

What can be said about the degree of completeness of the modelings of the different meanings of *across*? Are all relevant aspects of meaning represented in the models? What is missing in the models, but indeed seems to be relevant, is information about the relative length of the trajector line. Especially in the cases where the landmark is an area, it would be relevant that the trajector has *some significant* length - the trajector indeed must travel some significant part of the landmark to pass as 'crossing the landmark'.

This shortcoming holds for the cases of **across 3** and **across 4**. In the case of **across 5**, the model is even more restricted: in this case not only the length of the line but also its shape or nature is not sufficiently represented. In the other cases, the lines are modeled as straight lines (in one of the perspectives the lines are visible as a point) and in that way the (schematized) shape of the lines indeed is represented. In the case of **across 5**, however, the model only contains the information that the line is *not* a straight line. The fact that the line has a certain shape (running in diverse directions within the landmark area) is not represented.

Certain non-topological aspects of meaning thus are relevant for *across*, and as a consequence the models of especially **across 3**, **across 4**, and, above all, **across 5** are incomplete. The models of **across 1** and **across 2**, in contrast, are quite complete. This can be explained by the fact that the length of the lines is much less relevant here (because for a line trajector to cross a line landmark a very small length already suffices), and by the fact that no specific (line) shape other then the straight line has to be represented in this cases.

The models of **across 1** and **across 2** do, however, have some other shortcoming. In the case of these models, the choice was made to let the landmark line represent the *longest side of the* landmark. The aspects of perpendicularity of the trajector and the (longest side of) landmark now indeed is represented, but, strictly spoken, the aspect of *crossing* the landmark ('running from one side to the other') is not. The models of **across 1** and **across 2** do not exclude situations in which the (auxiliary) trajector only crosses the longest side of the landmark, but in which this trajector stays completely inside the (two-dimensional) landmark. The fact that the trajector necessarily has to run to the other side of the landmark-as-a-whole thus is not represented.

Funny enough, the modeling choice to let the landmark of the model represent the longest side of the landmark was made to be able to include some non-topological, but quite relevant, aspect of meaning in the models (the aspect that the trajector is perpendicular to *the longest side of* the landmark), and has as a consequence that some *topological* aspect of meaning (the fact that the trajector starts and ends outside the landmark) is absent.

4.6 *Through*

4.6.1 Linguistic analysis: the meanings of *through*

Also for this preposition, diverse meanings can be distinguished. The meaning of *through* might be paraphrased as 'into and out of again' (into the landmark on one side and of out the landmark on the other side), although this does not apply to all occurrences of this preposition. In what might be seen as the prototype ([6]), this 'into and out of' does apply however: the trajector traverses the landmark from side to side via its interior.

In all occurrences of *through*, three dimensions are relevant. In most cases, the landmark itself has three relevant dimensions. In the single case in which the landmark is only significantly extended in two dimensions, the trajector extends in the other dimension, and as a consequence the configuration as a whole occupies all three dimensions.

This three-dimensionality, besides, is an aspect of meaning that distinguishes *through* from *across*. As was addressed above, the meanings of *across* all match a two-dimensional configuration. *Through* might be seen as the three-dimensional variant of *across*. This comparison will be elaborated on later.

The following occurrences of *through* can be distinguished. These analysis of the meanings is based on [11] (refered to with "H1", "H2", etc.) and [6] (refered to with "C1", "C2", etc.).

through 1 (H1, C1)

> "The train went through the tunnel."
>
> The trajector is a line. The landmark envelops or encompasses part of the trajector, in a three-dimensional way. The trajector thus is partly 'inside' the landmark, but each of the endpoints of the trajector are outside the landmark: the trajector goes into the landmark and (on the other end of it) out of it again.

through 2 (H2, C2)

> "He walked through the fog."

The trajector is a line. The landmark envelops or encompasses the whole trajector, in a three-dimensional way. The boundaries of the landmark may be vague. The trajector is somewhere inside the landmark; it travels from some unspecified point inside the landmark to another unspecified point inside the landmark.

through 3 (C3)

"He thrust a knife through his heart."

This occurrence of *through* is similar to both **through 1** and **through 2**. The trajector is a line. The landmark three-dimensionally envelops or encompasses part of the trajector. One endpoint of the trajector is, as in the case of **through 1**, outside the landmark. The other endpoint of the trajector is, as in the case of **through 2**, somewhere (at some unspecified point) inside the landmark. The trajector thus goes into the landmark, but not out of it again.

This occurrence of *through* can be seen as a derived case of **through 1**: the configuration is precisely the same as in the case of **through 1**, except that in this case of **through 3**, the trajector travels only half of the path of the trajector of **through 1**. Starting from the configuration of **through 1**, the landmark should be split into two symmetric parts and then the part of the trajector that is in one of the parts should be removed, to get the configuration of this **through 3**.

through 4 (C5, H3)

"My house is through that tunnel."

This occurrence is a derived case of **through 1**. In this case, the trajector is of arbitrary shape, and is located at the end of an auxiliary trajector ('potential path'). The auxiliary trajector is the same as the trajector in the case of **through 1**: line-shaped. The landmark envelops or encompasses part of this auxiliary trajector, as the landmark of **through 1** encompasses or envelops part of the 'actual' trajector.

through 5 (C4)

"He stuck his pen through the sheet of paper."

This occurrence of *through* is different from all other occurrences, in the sense that the landmark of this occurrence does not envelop or encompass the trajector (or some auxiliary one) at all. The trajector is a line, and does make its way to the other side of the landmark, but the landmark does not have any significant extension in the direction in which the trajector is extended. In the other two dimensions, the landmark does have relevant extension. The landmark here functions as a barrier instead of as a medium.

through 6 (H4)

"There are thousands of useful throwaways all through your house."

In this occurrence of *through*, both the trajector and the landmark have three relevant dimensions. The trajector, that might consist of various units, is completely inside the landmark. The trajector is scattered and occupies various locations in diverse parts of the landmark. When "all" is added to the preposition ("all through your house"), it is emphasized that the trajector indeed extends into various parts of the landmark: given *some* partition of the landmark, the trajector is present in all of those parts. (For example: throwaways are present in all of the rooms of your house.)

Note: this occurrence is comparable to **across 5**: in both cases, the trajector has extension in all the dimensions in which the landmark is extended, whereas in cases of the 'normal' occurrences of both *across* and *through*, the trajector has extension in only one dimension. The trajectors in these special cases are branched or zigzagging lines, that extend in various directions within some (two- (**across 5**) or three-dimensional (**through 6**)) landmark. (And, instead of lines, the trajector may consist of points on (end-point) locations on such (imaginary) lines, as is the case with the throwaways.)

4.6.2 A 9-intersection modeling of the meanings of *through*

Through 1 and **through 4** (which are identical if the auxiliary trajector of **through 4** is regarded to be the trajector) are similar to **through 5**, in the sense that these meanings all can be labeled as 'in and out again'. The trajector is line-shaped and thus can best be represented by a line, and the landmark extends in multiple dimensions, implying that the region seems to be the appropriate modeling choice.

In all of these cases, part of the (auxiliary) trajector is inside the landmark, and the boundary parts of the trajector are outside the landmark. The difference between **through 1** and **through 4** on the one hand, and **through 5** on the other hand, is that in the case of the former a substantial part of the trajector is inside the landmark. In the latter case however, most of the trajector is outside the landmark; only a small part of the interior of the trajector coincides with the landmark.

In the case of **through 5**, the extension of the landmark in the direction in which the trajector extends is negligible. The landmark only has relevant extension in the other two dimensions. In the cases of **through 1** and **through 4**, on the other hand, the extension of the landmark in the direction of the trajector *is* important. The landmark has relevant extension in all three dimensions.

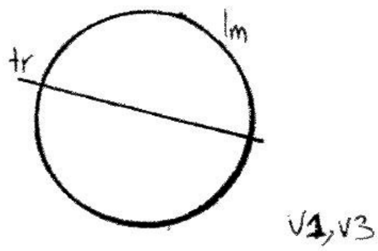
The model for **through 1** can be the same as for **through 4**, considered that in the case of **through 4** the auxiliary trajector will be modeled, instead of the actual trajector. The model for these two occurrences will be the following.

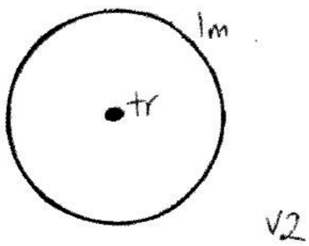
$$\begin{pmatrix} \mathrm{L}^\circ \cap \mathrm{R}^\circ \neq \emptyset & \mathrm{L}^\circ \cap \delta\mathrm{R} \neq \emptyset & \mathrm{L}^\circ \cap \mathrm{R}^- \neq \emptyset \\ \delta\mathrm{L} \cap \mathrm{R}^\circ = \emptyset & \delta\mathrm{L} \cap \delta\mathrm{R} = \emptyset & \delta\mathrm{L} \cap \mathrm{R}^- \neq \emptyset \\ \mathrm{L}^- \cap \mathrm{R}^\circ \neq \emptyset & \mathrm{L}^- \cap \delta\mathrm{R} \neq \emptyset & \mathrm{L}^- \cap \mathrm{R}^- \neq \emptyset \end{pmatrix}_{\text{v1, v3}}$$

$$\begin{pmatrix} \mathrm{P} \cap \mathrm{R}^\circ \neq \emptyset & \mathrm{P} \cap \delta\mathrm{R} = \emptyset & \mathrm{P} \cap \mathrm{R}^- = \emptyset \end{pmatrix}_{\text{v2}}$$

Viewed from *some* perspective, view 2 thus is visible. The existence of this view determines that the trajector is extended in at most one dimension, so the combination of views determines that the trajector is a straight line. The fact that the landmark is modeled as a region in all the three orthogonal views brings about that the landmark extends in three dimensions.

A pictorial representation of this model is the following.





As was said, the landmark of **through 5** is not extended in the direction in which the trajector is extended, but does have extension in the two directions perpendicular to this one. The model of **through 5** will be as follows.

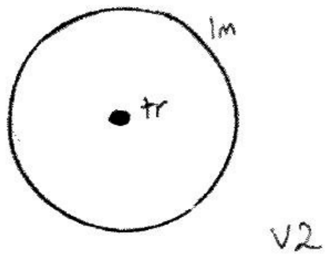
$$\begin{pmatrix} L1^\circ \cap L2^\circ \neq \emptyset & L1^\circ \cap \delta L2 = \emptyset & L1^\circ \cap L2^- \neq \emptyset \\ \delta L1 \cap L2^\circ = \emptyset & \delta L1 \cap \delta L2 = \emptyset & \delta L1 \cap L2^- \neq \emptyset \\ L1^- \cap L2^\circ \neq \emptyset & L1^- \cap \delta L2 \neq \emptyset & L1^- \cap L2^- \neq \emptyset \end{pmatrix}_{v1,\ v3}$$

$$\begin{pmatrix} P \cap R^\circ \neq \emptyset & P \cap \delta R = \emptyset & P \cap R^- = \emptyset \end{pmatrix}_{v2}$$

These views together constitute a model that represents **through 5** as completely as possible. The second view determines that the trajector is extended in at most one dimension; it is not just a line, but a straight line. The second view furthermore determines that the landmark is extended in at least two dimensions. The combination of the three views adds to this that the landmark is at most three-dimensional; the landmark thus is a ‘straight plane’.

Note that the model excludes case in which the angle between the trajector and the landmark is not exactly 90 degrees. This is not problematic, although such cases of course also suffice to be instantiations of this meaning, because of the idea of schematization: the model is an abstract representation of all, slightly different, configurations to which this **through 5** is applicable.

A pictorial representation of this model of **through 5** is the following.



Through 2, **through 3** and **through 6** are topologically different from the above meanings, and from each other. In the case of **through 2**, to begin with, the trajector is completely inside the landmark. With respect to the nature of trajector and landmark, however, **through 2** is quite similar to **through 1**: the trajector is a straight line (extended in only one direction), and the landmark is extended in three dimensions.

The model of **through 2** will be as follows.

$$\begin{pmatrix} L^\circ \cap R^\circ \neq \emptyset & L^\circ \cap \delta R = \emptyset & L^\circ \cap R^- = \emptyset \\ \delta L \cap R^\circ \neq \emptyset & \delta L \cap \delta R = \emptyset & \delta L \cap R^- = \emptyset \\ L^- \cap R^\circ \neq \emptyset & L^- \cap \delta R \neq \emptyset & L^- \cap R^- \neq \emptyset \end{pmatrix}_{\text{v1, v3}}$$

$$\begin{pmatrix} P \cap R^\circ \neq \emptyset & P \cap \delta R = \emptyset & P \cap R^- = \emptyset \end{pmatrix}_{\text{v2}}$$

These three views are together a complete model of this **through 2** meaning. The first and third view show that the trajector is a line, and the second view determines that this line is a straight line. The fact that the landmark is modeled as a region in all three views determines that the landmark is three-dimensional.

Through 3 has aspects of both **through 1** and **through 2**. The trajector is partly inside (to be precise: part of its interior and one of its boundaries are) and partly outside the landmark.

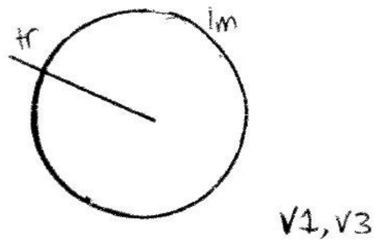
The model of **through 3** will be as follows.

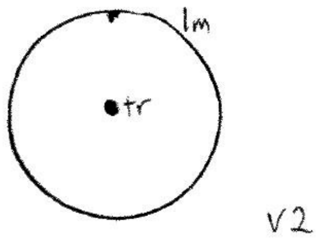
$$\begin{pmatrix} L^\circ \cap R^\circ \neq \emptyset & L^\circ \cap \delta R \neq \emptyset & L^\circ \cap R^- \neq \emptyset \\ \delta L \cap R^\circ \neq \emptyset & \delta L \cap \delta R = \emptyset & \delta L \cap R^- \neq \emptyset \\ L^- \cap R^\circ \neq \emptyset & L^- \cap \delta R \neq \emptyset & L^- \cap R^- \neq \emptyset \end{pmatrix}_{\text{v1, v3}}$$

$$\begin{pmatrix} P \cap R^\circ \neq \emptyset & P \cap \delta R = \emptyset & P \cap R^- = \emptyset \end{pmatrix}_{\text{v2}}$$

The combination of these three views constitutes a quite complete model of **through 3**. It is determined that the trajector is a straight line (extended in exactly one dimension), and the landmark extends in all three dimensions. It is also determined that the trajector is partly inside and partly outside the landmark: the boundary of the trajector intersects with both the interior and the exterior of the landmark.

The following is a pictorial representation of the above model.





As was said, also the model of **through 6** is different from the other models. In the case of this last occurrence, not only the landmark has extension in three dimensions (as is the case in almost all of the occurrences of *through*), but also the trajector is extended in all these three dimensions.

Just as in the case of the comparable occurrence **across 5** ("all across the U.S."), the trajector of this **through 6** can best be modeled by a line. The landmark will be modeled as a region in all three views. No separate model will be made for the case in which "all" is added, because the cases with and without this "all" are topologically indistinguishable.

The model for **through 6** will be as follows.

$$\begin{pmatrix} L^\circ \cap R^\circ \neq \emptyset & L^\circ \cap \delta R = \emptyset & L^\circ \cap R^- = \emptyset \\ \delta L \cap R^\circ \neq \emptyset & \delta L \cap \delta R = \emptyset & \delta L \cap R^- = \emptyset \\ L^- \cap R^\circ \neq \emptyset & L^- \cap \delta R \neq \emptyset & L^- \cap R^- \neq \emptyset \end{pmatrix} \text{v1, v2, v3}$$

Unfortunately, this model is no complete representation of the meaning. What is determined is that the landmark is extended in three dimensions, and that the landmark is no straight line - but a slithering, zigzagging or random-shaped line instead.

4.6.3 Analysis of the models of *through*

Comparing the meanings

As in the case of *across*, also in the case of *through*, the diverse meanings of this preposition have various mutual differences and commonalities. Few aspects of meaning are shared by all six occurrences. One such aspect is the fact that the configurations that correspond to the meanings all occupy three dimensions. In five of the six occurrences, furthermore, it is the case that the landmark itself is extended in all three dimensions. The landmark, in these cases, has as a function to envelop or encompass (large part of) the trajector. Another aspect that seems to be a core aspect of meaning of this preposition, is the fact that the trajector is a (straight) line. Only **through 6** is an exception: in that case the trajector has extension in three dimensions instead of just one. **Through 6**, nevertheless, can be seen as derived from the other meanings, especially from **through 2**. In the case of **through 2**, the trajector is extended in one dimension and runs completely within the three-dimensional landmark. In the case of **through 6**, the trajector also runs completely within the three-dimensional landmark, but now has extension in all three dimensions. The trajector can still be line-shaped (and thus be a complex-shaped or branched line) or this line can be disintegrated, into separate units.

Considering the above, the typical or core meaning of *through* can be ascribed the following properties: the trajector is a (straight) line and the landmark is three-dimensional and envelops the trajector. To determine which of the distinguished six meanings is the most prototypical, it should be decided, subsequently, which of the following is more typical for *through*: a trajector that is completely inside the landmark, or a trajector that is only largely enveloped by the landmark but of which the endpoints are outside the landmark. The former variant is instantiated in the cases of **through 2** and **through 6**, and the latter in the cases of **through 1**, **through 4** (considering the auxiliary trajector as trajector) and **through 5** (in which case, moreover, no significant part of the trajector at all is enveloped). **Through 3** is an intermediate case: only one of the endpoints of the trajector of this occurrence is outside the landmark.

To decide which of the six occurrences is the prototype, one may consider the (derivative) relations between the different meanings. As is discussed above, **through 4** is the end-point variant of **through 1**. The models of these two meanings are the same, except that in the case of **through 4** the auxiliary trajector instead of the actual trajector is modeled. Also **through 5** seems to be derived from **through 1**. The models of these two occurrences display strong similarities. The second view is exactly the same. The most striking difference between the first and third views is that the landmark of **through 1** is represented by a region, whereas the landmark of **through 5** is represented by a line. Considering all three views, the conclusion can be that the landmark of **through 5** is the same as the landmark of **through 1**, except that it is flattened in the direction in which the trajector is extended: it doesn't have extension in that dimension. The only other difference between the two meanings is the fact that the interior of the trajector does intersect with the boundary of the landmark in the case of **through 1**, but does not in the case of **through 5**. This discrepancy can be explained by the nature of the line and the region: a line cannot cross a region without crossing its boundaries, whereas a line-line cross does not affect the boundaries of the lines. Not only **through 1**, but also **through 2** seems to have derivatives. As was said before, **through 6** is a variant of **through 2**. The model of **through 6** consists of three identical views that are the same as the first and the third view of **through 2**.

Both **through 1** and **through 2** thus have other occurrences of *through* as derivatives, so these two meanings can be considered to be in the running to be declared the prototype. **Through 3** has not yet be classified: is this meaning, that is related both to **through 1** and to **through 2**, a derivative of the one or of the other? Analyzing the case of **through 3** can be used to determine which of these two candidates wins. For the following reasons, it seems more plausible that **through 3** is a derivative of **through 1** than that is derived from **through 2**. Just as in the case of **through 1**, the trajector of **through 3** starts outside the landmark and this trajector, it seems, would have ended outside the landmark, on the other side of it, as well, *were it not the case that it was brought to a halt by the (non-porous) landmark*. Starting from the meaning of **through 2**, however, no such explanation of the properties of **through 3** can easily be given.

Also the modelings provide evidence for the claim that **through 3** is more strongly related to **through 1** than to **through 2**. **Through 1** and **through 3** differ only with respect to one intersection ($\delta L \cap R^\circ$), whereas **through 3** has three intersections different compared to **through 2** ($L^\circ \cap \delta R$, $L^\circ \cap R^-$ and $\delta L \cap R^-$) **Through 3**, in which the properties of **through 1** and **through 2** are combined, thus seems to be more strongly related to and more plausibly a derivative of **through 1** than it is of **through 2**.

To conclude, **through 1** seems to have **through 4**, **through 5** and **through 3** as its derivatives, whereas only **through 6** is derived from **through 2**. Considering this central place in the 'network' **through 1** thus occupies, and the compatibility of this occurrence with the core aspects of meaning that were named above, **through 1**, in which case the (straight line) trajector is largely enveloped by the (three-dimensional) landmark, but of which the endpoints are outside the landmark, can be declared the most prototypical meaning of this preposition.

Through vs. across

As was mentioned before, *through* might be seen as the three-dimensional variant of the preposition *across*. The models provide a method to systematically determine what exactly this comparison comprises. On the basis of the models, individual occurrences of *through* can be compared to occurrences of *across*.

Both **through 1** and **through 5** are similar to **across 1**. This similarity appears from the following: the models of these three occurrences all have, and none of the other occurrences of either *across* or *through* has, at least one view (view 1 in the case of **across 1** and view 1 and view 3 in the cases of **through 1** and **through 5**) in which the boundaries of the trajector line only intersect with the exterior of the landmark. The trajectors of these three meanings, accordingly, do begin and end outside the landmark. This aspect of meaning unifies these three occurrences and distinguishes them from all other occurrences of *across* and *through*.

Across 2 and **through 4** are the same as, respectively, **across 1** and **through 1**, except that an auxiliary trajector occupies the place of the trajector. Because the choice was made to model auxiliary trajectors as a trajector, these occurrences share the similarities of the above mentioned group of occurrences.

Across 3 and **across 4**, which are the same except for the directionality of the configuration, are similar to **through 2**. In at least one view of each of the models of these three occurrences, the trajector is a line that is inside the landmark region. In most other occurrences of *through* and *across* - **through 6** and **across 5** are exceptions - no such view can be found. The fact that the trajector is modeled as a point in at least one of the views, additionally, distinguishes these three occurrences from **across 5** and **through 6**.

The last occurrences that can be grouped together are **across 5** and **through 6**. These meanings have in common that, in all views, the trajector is completely inside the landmark (interior and boundary of trajector do intersect only with the interior of the landmark), that in at least one of the views the landmark is represented as a region, and that no views exist in which the trajector is represented as a point. This latter aspect distinguished these two meanings from all other occurrences of both *across* and *through*. The trajectors of these two occurrences thus have extension in more than one direction.

All occurrences of *across* and *through* now are mentioned and classified, except **through 3**. This occurrence does not belong in any of the above created groupings. As was mentioned earlier, **through 3** actually is a mixture of **through 1** and **through 2**. The endpoint of the trajector that is outside the landmark, would make this occurrence a member of the group of **through 1**, **through 5**, and **across 1**, and the endpoint of the trajector that is inside the landmark would group this occurrence with **through 2**, **across 3**, and **across 4**. The similarity of this **through 3** with **through 1** is stronger than its similarity with **through 2**, as was shown above. This occurrence, to conclude, can be seen as a partial member of both of these categories, and it is more a member of the former than of the latter.

What the comparison of these two prepositions remarks, apart from the fact that indeed these prepositions are strongly related, is that **through 3** is the only occurrence of this preposition that has no *across* counterpart (- and no *across* occurrences that have no *through* counterpart do exist either). An *across* counterpart of **through 3** nevertheless seems to exist. Remember that **through 3** is the variant of **through 1** in which the trajector was brought to a halt before it could reach the other side of the landmark. A similar variant of *across* is thinkable: "The dog was running across the street when a car hit him.". A subtle difference exists, however, between **through 3** and this thinkable occurrence of *across*. Whereas in this *across* occurrence, the continuous tense of the verb is used ("was running"), in the case of **through 3**, the simple tense occurs ("He thrust a knife through his heart."). This indicates, I think, that this thinkable occurrence of *across* is not really comparable to **through 3**. In the case of **through 3**, the trajector indeed starts outside and ends inside the landmark. In the case of this *across*, on the other hand, the trajector actually crosses the landmark from side to side: the *trajector* isn't interrupted by the car that hits the dog; only the running action of the dog (which is: following the 'path' across the street) was brought to an halt. If this subtle difference indeed exists and this explanation is correct, then this thinkable occurrence of *across* would be just the same as **across 1**.

To conclude the comparison of these two prepositions, for *across* and *through* taken together three main categories can be distinguished. The first category contains meanings that consist of a straight line trajector that runs from one side of the landmark to the other side ('in and out again'). The second category contains cases in which the trajector is a straight line that runs in one direction inside the landmark. The final main category contains the occurrences in which the trajector runs inside the landmark and is extended in all dimensions in which the landmark has extension.

Judging the models

What are the shortcomings of the models of *through*, what relevant aspects of meaning are not represented and what aspects are? One of the shortcomings of some of the models of *across* possibly also holds for some of the models of *through*: the fact that the relative length of the trajector line is not specified. In the case of **through 2**, the same problem occurs as does in the cases of **across 3** and **across 4**. If the trajector of **through 2** didn't have some significant length, the preposition *through* would not apply (but probably *in* would instead), it seems.

A similar problem can be found in the cases of **through 1** and **through 4**. In this cases, it seems relevant that a significantly long part of the (auxiliary) trajector is inside the landmark (for only then it can be said that the (auxiliary) trajector is enveloped by the landmark) - and the model does not determine this length.

Also **through 6** is subject to the same shortcomings as is the similar occurrence of *across* (**across 5**): the fact that the trajector extends in various directions within the landmark is relevant, but this property of the trajector is not sufficiently represented.

Some other kind of shortcomings, additionally, can be mentioned. For the cases in which the trajector starts and ends outside the landmark, the models do indeed represent this fact, but it is, for most of these cases, not represented that the trajector travels in the landmark and out again *exactly one time*. Considered strictly, the models do not exclude cases in which the trajector runs in the landmark and out again and in again and out again (et cetera). (The model of **through 5** is an exception: in this case the model *does* determine that the trajector runs through the landmark only once - the straightness of the trajector *and* landmark lines leaves no other possibility.)

4.7 *Around*

4.7.1 Linguistic analysis: the meanings of *around*

Around seems to be a more complex preposition than are the three prepositions that are discussed above. A lot of different meanings of *around* can be distinguished. In the literature, some consensus exists about the most central (aspect of) meaning of this preposition: *around* refers to a circular shape or movement. All different occurrences of the preposition do contain this circular aspect to some extent.

The theories on *around* of both Hawkins ([11]) and Dewell ([7]) have contributed to my own analysis of the meanings of *around*: the set of different meanings of *around* that are enumerated below. In the enumeration, abbreviations (letter-number combinations) are used, that refer to the accessory meanings of *around* distinguished in the literature. "H" refers to Hawkins, "D" to Dewell.

around 1 (H1, D1 (only the non-contact variant), D2 (only the non-contact variant))

"The children stood around the show of the clowns."

The trajector has approximately the shape of a circle, the trajector completely surrounds, and is completely outside the landmark. There is no contact between trajector and landmark.

around 2 (H2, D1 (only the contact variant), D2 (only the contact variant))

"He tied a ribbon around the vase."

The trajector has approximately the shape of a circle, the trajector completely surrounds the landmark and, opposing this meaning of *around* to **around 1**, there is contact between the trajector and the landmark. Because of this contact, the landmark should be approximately circular-shaped, for else the trajector could not be circular.

around 3 (H5)

"On their way to school, they walked around the bad-smelling garbage dump."

The landmark has a circle-like shape, and the trajector runs approximately parallel to part of the boundary of this landmark. The trajector thus is part of an approximately circular shape, and travels half of this shape. The trajector partially surrounds, and is completely outside the landmark. There is no contact between trajector and landmark.

around 4 (H10 - D3)

"The school is around the corner."

Of **around 3**, an end-point derivative is thinkable ("He lives around the garbage dump."). This **around 4** is a special case of this thinkable[4] end-point focus derivative of **around 3**. What makes this **around 4** different, is that special restrictions hold for the shape of the landmark. Instead of just some approximately circular shape, in this case the landmark should necessarily be a corner. Furthermore, the trajector now doesn't travel half of a circle, but (approximately) a quarter circle instead.

In this case of **around 4**, the landmark thus has the shape of a corner. The auxiliary trajector ('potential path') is a line that follows the shape of the boundary of the landmark, without contacting the landmark, and that travels approximately a quarter circle. The actual trajector is located at the end-point of this auxiliary trajector.

around 5 (D4)

"I can't see around the truck in front of me."

This occurrence of *around* is very similar to **around 3**. In both cases, the trajector is part of a circle, and travels from one side of the landmark to another side of it, while the landmark forms an obstacle around which the trajector curves, running approximately parallel to the boundary of the landmark. In the case of this **around 5**, however, the trajector does not

[4]Although this end-point focus variant of **around 3** is thinkable, possibly it doesn't exist. The configuration that would be expressed by using this end-point focus occurrence can, after all, be expressed in an alternative way. Instead of saying "He lives around the dump." one can say: "He lives behind the dump.". The end-point variant would thus not be necessary; its meaning can be expressed using a locational preposition.

actually exist (because it is not possible to see around an object). The trajector in this case can be called a ‘search path’ ([7]).

around 6 (H9 - D5)

“There were little acorns all around the tree.”

Here, the trajector is not (just) a (semi)circle, but is extended to a plane. Contrasting the case of **around 1**, where the trajector is only the perimeter of the circle, in this case of *around* also the surface of the (more or less) circular shape that surrounds the landmark is part of the trajector. The trajector of **around 6** can be either a ‘massive’ circle-shaped plane (the circular shape is completely covered; “There was paint all around the table.”) or ‘multiplex’ (units are ‘scattered’ all over the circular shape, in between the units is ‘empty’ space; “acorns all around the tree”).

Note: often “all” will occur directly in front of the preposition. This addition makes it clearer that indeed a plane is covered, instead that the trajector only forms a circle on a certain distance around the landmark.

around 7 (H8)

“The bees swarmed around the flower.”

This case is similar to **around 6**; instead of a two-dimensional trajector, now the trajector even extends in three dimensions. The trajector is of approximately globular shape, the trajector surrounds the landmark in three dimensions, and can be, as is the case with **around 6**, either massive or multiplex (“The atmosphere is around the globe.” vs. “bees swarming around a flower”). Also here, “all” will frequently precede the preposition.

around 8 (H4 - D8)

“The ice-skaters glide around the track.”

In this variety of *around*, the trajector coincides with the landmark. The landmark should be (the perimeter of) a more or less circular shape.

Note: in Dutch, this *around* can be translated as “rond”, but this “rond” then should be used as a postposition (“Hij schaatste de baan *rond*.” and not “Hij schaatste *rond* de baan.”) Because of this syntactic property, in Dutch this occurrence of *around/rond* can be distinguished especially easily from the other occurrences; *rond* used as a postposition always has this meaning, and can only occur in combination with a circular landmark (“het veld rond” (“around the field”) is ungrammatical, for a “veld” (“field”) is (usually) not circular).

around 9 (H3 - D7)

“Take a lap around the field.”

The landmark is some area. The trajector is completely *inside* the area, and is (more or less) circular.

Note: in Dutch, this occurrence of *around* is not translated as “rond(om)”; instead, other prepositions are used, combined with the noun “rondje” (“lap”). Both “loop een rondje *over* (“over”) het veld” (“take a lap around the field”) and “loop een rondje *door* (“through”) de kamer” (“walk around the room”) are Dutch equivalents of this **around 9**: they refer to some circular path inside some area-landmark.

around 10 (H6 - D7)

"The little boy wandered around the shopping center."

Also in this case the landmark is some area and the trajector is inside this area. In this case, however, the shape of the trajector is quite random: the trajector is a path that traverses the area in a criss-cross manner. "All" might be added to the preposition, resulting in a stronger emphasis on the fact that the trajector travels to various locations within the landmark.

Note: This occurrence is in some sense similar to **across 5**. In both cases, the trajector is completely within some area landmark and the trajector extends in all the dimensions in which that landmark is extended. The difference concerns the precise shape of the trajector. The trajector of **across 5** extends in various directions, stretching out into various corners of the landmark. This trajector can be seen as a set of straight lines. The trajector of this **around 10**, on the other hand, does not have any specific, sharp form. The trajector is slithering and random and would contain curved parts rather than parts of straight lines.

Also note: in Dutch, this *around* can be translated as "door" ("through"): "Hij liep *door* het winkelcentrum" ("He walked around the shopping center") refers to following some (criss-cross) path inside the shopping center. ("Hij liep het winkelcentrum *door*", on the other hand, should be translated with the preposition *through*: "He walked through the shopping center" refers to some straight route that goes through the shopping center.)

around 11 (H7)

"There are thousands of useful throwaways around your house."

This occurrence of *around* is similar to **around 10**, but now three in stead of two dimensions are important, both for the trajector and for the landmark. The trajector travels to various locations inside the three-dimensional landmark, in a random, slithering or scattered manner. Also in the case of this occurrence, "all" might be added, emphasizing that the trajector indeed is present in many different parts of the landmark .

Note: this occurrence thus can be seen as the three-dimensional variant of **around 10**, and is also comparable to **through 6**, which can be seen as the three-dimensional variant of **across 5**. The difference between **through 6** and this **around 11** concerns, again, the shape of the trajector. The trajector of **through 6** has specific extension in various directions, whereas the trajector of **around 11** is random and slithering.

4.7.2 A 9-intersection modeling of the meanings of *around*

Now the diverse meanings of *around* are distinguished, these meanings can be the input for the translation to the 9-intersection model. To make this 'translation' possible, the topological features of the meanings of *around* should be made clear. In the above set of meanings, three categories of meanings can be distinguished, in all of which the topological relations between the trajector and the landmark are different. These three major categories of meanings of *around* are as follows:

1. **around 1 - around 7**: meanings of around in which the trajector is outside the landmark. These occurrences of *around* can be translated in Dutch as "rond", "rondom" or "om", used regularly, as a preposition.

2. **around 8**: meaning of around in which the trajector coincides with the (boundary of the) landmark. This occurrence of *around* can be translated in Dutch as "rond", but then used as a postposition.

3. **around 9 - around 11**: meanings of around in which the trajector is inside the landmark. These occurrences of *around* are not translatable as "rond", "rondom" or "om"; in Dutch, other prepositions are used.

The occurrences of *around* within each group show similarities, and also the modelings of the diverse meanings will appear similar: more similarities will appear within the groups than between the groups. Now the models will be built, starting with the first category and the first occurrence in that group.

In the case of **around 1**, the trajector is a line that has approximately the shape of a circle, and the landmark is some round-like area. The trajector completely - in a two-dimensional way - surrounds the landmark.

Around 1 is in some sense very similar to **around 2**: in both cases the trajector is an approximately circular line that completely surrounds an approximately circular-shaped area landmark. The difference is that in the case of **around 2**, the trajector and the landmark are in contact, whereas in the case of **around 1** these are not.

A difficult aspect of the modeling of the meanings of *around*, is that the trajector in many occurrence of this preposition is a line, but that this line is curved, forming a (part of a) circle. In the case of most of the meanings of the prepositions that were discussed above (*along*, *across*, *through*), a straight line was suitable to represent the trajector, because the trajectors of these meanings were schematizable as a straight line. The 'straightness' of a line can be modeled, for from some perspective a straight line is viewed as a point. Modeling a curved line is less easy; a part of a circle can not easily be modeled distinguishable from some other curved line or from a zigzagging line.

The modeling of a full circle, moreover, is problematic in another way. A full circle, strictly seen, is not a line. The line was defined as "a sequence of [...] connected 1-cells [...] such that they neither cross themselves nor form cycles" ([18], p. 198) and is considered to have an interior, exterior, and boundary. The boundary was defined, in section 2.3.4 above, as the (two, in the case of an unbranched line) nodes at which exactly one 1-cell ends. A circle does not have such end points, and therefore the circle does not fit the definition of a line.

To represent a circle, a new entity thus might be invoked. The topological entity that is most suitable to represent a circle is the so-called *closed path* (or: *closed line*). This entity has no boundary, because the sequence of 1-cells starts and ends at the same point - no nodes thus exist at which only one 1-cell ends. The interior and exterior of a closed path nevertheless are the same as those of a (normal) line.

The 3D-9-intersection model that is applied in this thesis, however, does not have the closed path as one of its building blocks. The choice was made to let the model only contain the building blocks of the 'standard' 9-intersection model: the point, the line, and the region. Also the models of *around* will thus be built without the notion of the closed path.

In the case of **around 1**, the trajector is a line that completely surrounds the landmark. A line would not be suitable to model this trajector, for then its 'circularity' could not be represented. An alternative way of modeling would be better. The choice was made to represent the trajector as the boundary of a region. The landmark will be modeled by a normal region, that is inside the trajector region. The model of **around 1**, in which the boundary of R1 represents the trajector, will then be the following.

$$\begin{pmatrix} \mathrm{R1}^\circ \cap \mathrm{R2}^\circ \neq \emptyset & \mathrm{R1}^\circ \cap \delta\mathrm{R2} \neq \emptyset & \mathrm{R1}^\circ \cap \mathrm{R2}^- \neq \emptyset \\ \delta\mathrm{R1} \cap \mathrm{R2}^\circ = \emptyset & \delta\mathrm{R1} \cap \delta\mathrm{R2} = \emptyset & \delta\mathrm{R1} \cap \mathrm{R2}^- \neq \emptyset \\ \mathrm{R1}^- \cap \mathrm{R2}^\circ = \emptyset & \mathrm{R1}^- \cap \delta\mathrm{R2} = \emptyset & \mathrm{R1}^- \cap \mathrm{R2}^- \neq \emptyset \end{pmatrix} \text{v1}$$

$$\begin{pmatrix} \mathrm{L1}^\circ \cap \mathrm{L2}^\circ \neq \emptyset & \mathrm{L1}^\circ \cap \delta\mathrm{L2} \neq \emptyset & \mathrm{L1}^\circ \cap \mathrm{L2}^- \neq \emptyset \\ \delta\mathrm{L1} \cap \mathrm{L2}^\circ = \emptyset & \delta\mathrm{L1} \cap \delta\mathrm{L2} = \emptyset & \delta\mathrm{L1} \cap \mathrm{L2}^- \neq \emptyset \\ \mathrm{L1}^- \cap \mathrm{L2}^\circ = \emptyset & \mathrm{L1}^- \cap \delta\mathrm{L2} = \emptyset & \mathrm{L1}^- \cap \mathrm{L2}^- \neq \emptyset \end{pmatrix} \text{v2, v3}$$

This model is a quite complete representation of **around 1**. It is represented that the trajector completely surround the landmark, and that the both trajector and landmark are approximately circular. Also it is represented that the configuration is contained within a plane

The modeling of **around 2** should be similar to the modeling of **around 1**, for these two meanings are quite similar. Whereas the (line) trajector of **around 1** is distinct from the landmark, however, the (line) trajector of **around 2** is completely contacting the boundary of the landmark region. The choice is made to model 'contact' as 'intersection with the boundary'. This implies that the model of **around 2** will be as follows.

$$\begin{pmatrix} \mathrm{L}^\circ \cap \mathrm{R}^\circ = \emptyset & \mathrm{L}^\circ \cap \delta\mathrm{R} \neq \emptyset & \mathrm{L}^\circ \cap \mathrm{R}^- = \emptyset \\ \delta\mathrm{L} \cap \mathrm{R}^\circ = \emptyset & \delta\mathrm{L} \cap \delta\mathrm{R} \neq \emptyset & \delta\mathrm{L} \cap \mathrm{R}^- = \emptyset \\ \mathrm{L}^- \cap \mathrm{R}^\circ \neq \emptyset & \mathrm{L}^- \cap \delta\mathrm{R} = \emptyset & \mathrm{L}^- \cap \mathrm{R}^- \neq \emptyset \end{pmatrix} \text{v1}$$

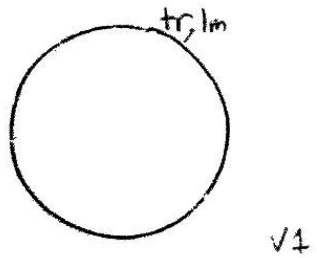
$$\begin{pmatrix} \mathrm{L1}^\circ \cap \mathrm{L2}^\circ \neq \emptyset & \mathrm{L1}^\circ \cap \delta\mathrm{L2} = \emptyset & \mathrm{L1}^\circ \cap \mathrm{L2}^- = \emptyset \\ \delta\mathrm{L1} \cap \mathrm{L2}^\circ = \emptyset & \delta\mathrm{L1} \cap \delta\mathrm{L2} \neq \emptyset & \delta\mathrm{L1} \cap \mathrm{L2}^- = \emptyset \\ \mathrm{L1}^- \cap \mathrm{L2}^\circ = \emptyset & \mathrm{L1}^- \cap \delta\mathrm{L2} = \emptyset & \mathrm{L1}^- \cap \mathrm{L2}^- \neq \emptyset \end{pmatrix} \text{v2, v3}$$

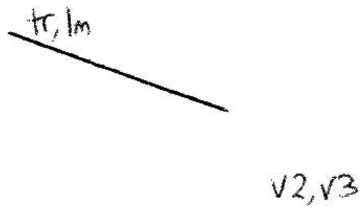
Note that in this model the line is used to form a circle. The boundary of the landmark region does only intersect with the interior and boundary of the trajector line, and not with the exterior of the line: the whole region boundary thus is 'covered' by the trajector. If it is assumed that the line does not overlap itself (traveling more than a full circle), the conclusion can be that the boundary points of the line coincide; these two points both coincide[5] and do intersect (overlap) with the landmark boundary. (Because of this coinciding of its two boundary points, the line is changed into a closed path; closed paths, however, are not part of the model - the intersection matrix only considers a normal line and a region.)

[5]The fact that the boundary points of the line coincide ensures that the line forms a closed path. The consequence is that these coinciding boundary points, strictly seen, aren't boundary points any more. "δL" thus becomes meaningless. Because the choice was made, however, to let the models consist only of points, lines, and regions, and not of closed paths, "δL" is not removed from the intersection matrix.

The fact that the trajector completely surrounds the landmark is represented in view 1 (for the boundary of the landmark does not intersect with the exterior of the trajector). And because interior and boundary of the trajector do only intersect with the boundary of the landmark, it is represented that the trajector is completely in contact with the (boundary of the) landmark.

The following is a pictorial representation of the above model.





Around 3 is different from these first two models. Just as in the case of **around 1**, the trajector of **around 3** is not in contact with the landmark, but now the trajector does only partially surround the landmark. The trajector thus does not form a complete circle - it only has the shape of half of a circle. The trajector will be modeled as a line and the landmark as a region.

The model of **around 3** will be as follows.

$$\begin{pmatrix} \mathrm{L}^\circ \cap \mathrm{R}^\circ = \emptyset & \mathrm{L}^\circ \cap \delta\mathrm{R} = \emptyset & \mathrm{L}^\circ \cap \mathrm{R}^- \neq \emptyset \\ \delta\mathrm{L} \cap \mathrm{R}^\circ = \emptyset & \delta\mathrm{L} \cap \delta\mathrm{R} = \emptyset & \delta\mathrm{L} \cap \mathrm{R}^- \neq \emptyset \\ \mathrm{L}^- \cap \mathrm{R}^\circ \neq \emptyset & \mathrm{L}^- \cap \delta\mathrm{R} \neq \emptyset & \mathrm{L}^- \cap \mathrm{R}^- \neq \emptyset \end{pmatrix} \mathrm{v1}$$

$$\begin{pmatrix} \mathrm{L1}^\circ \cap \mathrm{L2}^\circ \neq \emptyset & \mathrm{L1}^\circ \cap \delta\mathrm{L2} \neq \emptyset & \mathrm{L1}^\circ \cap \mathrm{L2}^- \neq \emptyset \\ \delta\mathrm{L1} \cap \mathrm{L2}^\circ = \emptyset & \delta\mathrm{L1} \cap \delta\mathrm{L2} = \emptyset & \delta\mathrm{L1} \cap \mathrm{L2}^- \neq \emptyset \\ \mathrm{L1}^- \cap \mathrm{L2}^\circ = \emptyset & \mathrm{L1}^- \cap \delta\mathrm{L2} = \emptyset & \mathrm{L1}^- \cap \mathrm{L2}^- \neq \emptyset \end{pmatrix} \mathrm{v2}$$

$$\begin{pmatrix} \mathrm{L1}^\circ \cap \mathrm{L2}^\circ \neq \emptyset & \mathrm{L1}^\circ \cap \delta\mathrm{L2} \neq \emptyset & \mathrm{L1}^\circ \cap \mathrm{L2}^- \neq \emptyset \\ \delta\mathrm{L1} \cap \mathrm{L2}^\circ \neq \emptyset & \delta\mathrm{L1} \cap \delta\mathrm{L2} = \emptyset & \delta\mathrm{L1} \cap \mathrm{L2}^- \neq \emptyset \\ \mathrm{L1}^- \cap \mathrm{L2}^\circ \neq \emptyset & \mathrm{L1}^- \cap \delta\mathrm{L2} \neq \emptyset & \mathrm{L1}^- \cap \mathrm{L2}^- \neq \emptyset \end{pmatrix} \mathrm{v3}$$

This model does not completely represent the meaning of **around 3**. What is contained in the model is that the trajector is on more than one side of the landmark, and that it doesn't travel much more than a semi-circle.

Around 5 is very similar to **around 3**. The only difference is that the trajector of **around 5** is not an actual trajector - it is a ‘search path’ instead.

The model of **around 5** thus is the model of **around 3**, given this different nature of the trajector.

Around 4 differs from **around 3**. Not only is this **around 4** an end-point focus case, but also now the trajector travels approximately a quarter circle instead of a semi-circle. Furthermore, the landmark should be specifically a corner. For such a specific form, however, no modeling tools are available; the best option to choose for the landmark is the region. The auxiliary trajector will be modeled by a line.

The model of **around 4** will be as follows.

$$\begin{pmatrix} \mathrm{L}^\circ \cap \mathrm{R}^\circ = \emptyset & \mathrm{L}^\circ \cap \delta\mathrm{R} = \emptyset & \mathrm{L}^\circ \cap \mathrm{R}^- \neq \emptyset \\ \delta\mathrm{L} \cap \mathrm{R}^\circ = \emptyset & \delta\mathrm{L} \cap \delta\mathrm{R} = \emptyset & \delta\mathrm{L} \cap \mathrm{R}^- \neq \emptyset \\ \mathrm{L}^- \cap \mathrm{R}^\circ \neq \emptyset & \mathrm{L}^- \cap \delta\mathrm{R} \neq \emptyset & \mathrm{L}^- \cap \mathrm{R}^- \neq \emptyset \end{pmatrix} \mathrm{v1}$$

$$\begin{pmatrix} \mathrm{L1}^\circ \cap \mathrm{L2}^\circ \neq \emptyset & \mathrm{L1}^\circ \cap \delta\mathrm{L2} \neq \emptyset & \mathrm{L1}^\circ \cap \mathrm{L2}^- \neq \emptyset \\ \delta\mathrm{L1} \cap \mathrm{L2}^\circ \neq \emptyset & \delta\mathrm{L1} \cap \delta\mathrm{L2} = \emptyset & \delta\mathrm{L1} \cap \mathrm{L2}^- \neq \emptyset \\ \mathrm{L1}^- \cap \mathrm{L2}^\circ \neq \emptyset & \mathrm{L1}^- \cap \delta\mathrm{L2} \neq \emptyset & \mathrm{L1}^- \cap \mathrm{L2}^- \neq \emptyset \end{pmatrix} \mathrm{v2,\ v3}$$

View 2 and view 3 are the same. The fact that from two orthogonal perspectives this configuration is visible (partial overlap between landmark and trajector), determines that the trajector travels not much more than a quarter-circle and in any case not more than a semi-circle. The path of the trajector can not travel much less than a quarter-circle too, for then in a view orthogonal to view 2 (or 3), landmark and trajector would be visible as completely apart form each other.

Around 6 differs from the above five occurrences concerning an essential aspect of meaning: instead of a circle or part of a circle, now the trajector is a plane (which is: a circle that is filled in). The trajector thus can best be modeled by a region. The landmark, however, also is region-like, and this region is surrounded by the trajector-region. Actually, thus, the trajector is some region of which some part is missing, and no modeling option is available for something like this. This problem can be solved by choosing to model the landmark of this **around 6** as a point instead of as a region. The landmark, in this way, is schematized as a point. Because a point does not have any extension, now the trajector is a region of which only some extension-less part is missing, which is the same as a normal region.

(Modeling the trajector as a region will, however, only be used in one of the views. As most of the meanings of *around*, this meaning resides completely within one plane, and thus in only one of the orthogonal views the model will be two-dimensional.)

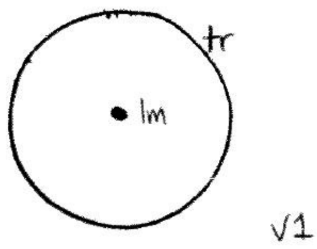
The model of **around 6** will be as follows.

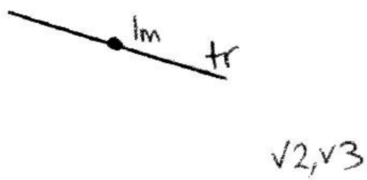
$$\begin{pmatrix} \mathrm{R}^\circ \cap \mathrm{P} \neq \emptyset \\ \delta\mathrm{R} \cap \mathrm{P} = \emptyset \\ \mathrm{R}^- \cap \mathrm{P} = \emptyset \end{pmatrix} \mathrm{v1}$$

$$\begin{pmatrix} \mathrm{L}^\circ \cap \mathrm{P} \neq \emptyset \\ \delta\mathrm{L} \cap \mathrm{P} = \emptyset \\ \mathrm{L}^- \cap \mathrm{P} = \emptyset \end{pmatrix} \mathrm{v2,\ v3}$$

This model does represent all relevant aspects of meaning of **around 6**. What is clear from the model is that the landmark is inside the trajector and that the trajector is on all sides of the landmark.

This following picture is a representation of this model.





As was said, **around 7** can be seen as the three-dimensional variant of **around 6**. In the case of **around 6**, the configuration is (only) extended within a plane, whereas in the case of **around 7**, the configuration extends in all three dimensions. The trajector thus surrounds the landmark in all directions. The model will consist of three identical orthogonal views.

The model of **around 7** will be as follows.

$$\begin{pmatrix} \mathrm{R}^{\circ} \cap \mathrm{P} \neq \emptyset \\ \delta\mathrm{R} \cap \mathrm{P} = \emptyset \\ \mathrm{R}^{-} \cap \mathrm{P} = \emptyset \end{pmatrix}_{\text{v1, v2, v3}}$$

From the totality of views, it is clear that the trajector has extension in all dimensions, and that the landmark is inside the trajector. It follows, furthermore, that the landmark is surrounded by the trajector in all dimensions.

Now the second category of meanings of *around*, consisting only of **around 8**, will be subject of the modeling. **Around 8** has some aspects that can be modeled quite easily - the fact that the trajector and the landmark do coincide completely, for example. Less easy however, it is to represent that the trajector and the landmark are approximately circle-shaped, and form a 'closed path'.

The trajector and the landmark both are lines, but when these would be modeled as such, the result will be a far from complete model. In all views, what is visible is two lines that coincide completely; not modeled would be the fact that in one view, these lines have the shape of a closed path. Because this closedness is an essential aspect of meaning of this occurrence, a model in which this aspect is not represented does not suffice.

An alternative way of modeling would be better. As was done in the case of **around 1**, the boundary of a region will be used to represent one of the two entities. Instead of modeling both trajector and landmark as lines, in this modeling of **around 8** the landmark is modeled as the boundary of a region. The trajector is represented by a line and this line completely coincides with the landmark.

The model of **around 8**, in which the landmark is represented by R's boundary, then will be as follows.

$$\begin{pmatrix} \mathrm{L}^\circ \cap \mathrm{R}^\circ = \emptyset & \mathrm{L}^\circ \cap \delta\mathrm{R} \neq \emptyset & \mathrm{L}^\circ \cap \mathrm{R}^- = \emptyset \\ \delta\mathrm{L} \cap \mathrm{R}^\circ = \emptyset & \delta\mathrm{L} \cap \delta\mathrm{R} \neq \emptyset & \delta\mathrm{L} \cap \mathrm{R}^- = \emptyset \\ \mathrm{L}^- \cap \mathrm{R}^\circ \neq \emptyset & \mathrm{L}^- \cap \delta\mathrm{R} = \emptyset & \mathrm{L}^- \cap \mathrm{R}^- \neq \emptyset \end{pmatrix} \mathrm{v1}$$

$$\begin{pmatrix} \mathrm{L1}^\circ \cap \mathrm{L2}^\circ \neq \emptyset & \mathrm{L1}^\circ \cap \delta\mathrm{L2} = \emptyset & \mathrm{L1}^\circ \cap \mathrm{L2}^- = \emptyset \\ \delta\mathrm{L1} \cap \mathrm{L2}^\circ = \emptyset & \delta\mathrm{L1} \cap \delta\mathrm{L2} \neq \emptyset & \delta\mathrm{L1} \cap \mathrm{L2}^- = \emptyset \\ \mathrm{L1}^- \cap \mathrm{L2}^\circ = \emptyset & \mathrm{L1}^- \cap \delta\mathrm{L2} = \emptyset & \mathrm{L1}^- \cap \mathrm{L2}^- \neq \emptyset \end{pmatrix} \mathrm{v2,\ v3}$$

As in the case of **around 2**, also here it should be noted that the line trajector is used to form a 'closed path'; its boundary points coincide. This modeling of **around 8** is quite complete. The model does not determine that the landmark (and, consequently, the trajector) has the shape of an exact circle, but that aspect is not necessarily part of the meaning. It *is* determined that the landmark (and the trajector) travels the full 'circle', i.e. forms a closed path. The model also contains the fact that landmark and trajector do completely overlap.

Finally, the occurrences in the last category will be considered. These are the meanings of which the trajector is inside (or: part of) the landmark.

In the case of **around 9** a similar way of modeling as is applied in the cases of **around 1** and **around 8** will be applied. Instead of a line, the boundary of a region will be chosen to represent the trajector. The landmark will be modeled as a normal region.

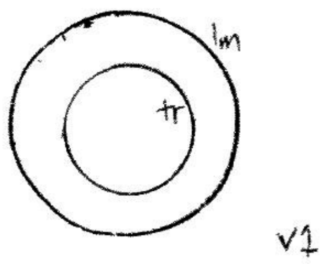
The model of **around 9**, in which the boundary of R1 represents the trajector, will be as follows.

$$\begin{pmatrix} \mathrm{R1}^\circ \cap \mathrm{R2}^\circ \neq \emptyset & \mathrm{R1}^\circ \cap \delta\mathrm{R2} = \emptyset & \mathrm{R1}^\circ \cap \mathrm{R2}^- = \emptyset \\ \delta\mathrm{R1} \cap \mathrm{R2}^\circ \neq \emptyset & \delta\mathrm{R1} \cap \delta\mathrm{R2} = \emptyset & \delta\mathrm{R1} \cap \mathrm{R2}^- = \emptyset \\ \mathrm{R1}^- \cap \mathrm{R2}^\circ \neq \emptyset & \mathrm{R1}^- \cap \delta\mathrm{R2} \neq \emptyset & \mathrm{R1}^- \cap \mathrm{R2}^- \neq \emptyset \end{pmatrix} \mathrm{v1}$$

$$\begin{pmatrix} \mathrm{L1}^\circ \cap \mathrm{L2}^\circ \neq \emptyset & \mathrm{L1}^\circ \cap \delta\mathrm{L2} = \emptyset & \mathrm{L1}^\circ \cap \mathrm{L2}^- = \emptyset \\ \delta\mathrm{L1} \cap \mathrm{L2}^\circ \neq \emptyset & \delta\mathrm{L1} \cap \delta\mathrm{L2} = \emptyset & \delta\mathrm{L1} \cap \mathrm{L2}^- = \emptyset \\ \mathrm{L1}^- \cap \mathrm{L2}^\circ \neq \emptyset & \mathrm{L1}^- \cap \delta\mathrm{L2} \neq \emptyset & \mathrm{L1}^- \cap \mathrm{L2}^- \neq \emptyset \end{pmatrix} \mathrm{v2,\ v3}$$

This is a quite complete modeling of **around 9**. It is represented that the trajector travels a full circle (although the shape of the trajector is not necessarily circular), and that this trajector is completely within an area landmark.

The following is a pictorial representation of this model.



Around 10 is quite similar to **around 9**: in both cases the configuration resides within one plane, the trajector is completely inside the landmark, and the trajector is no straight line. The model of **around 10** will be as follows.

$$\begin{pmatrix} L^\circ \cap R^\circ \neq \emptyset & L^\circ \cap \delta R = \emptyset & L^\circ \cap R^- = \emptyset \\ \delta L \cap R^\circ \neq \emptyset & \delta L \cap \delta R = \emptyset & \delta L \cap R^- = \emptyset \\ L^- \cap R^\circ \neq \emptyset & L^- \cap \delta R \neq \emptyset & L^- \cap R^- \neq \emptyset \end{pmatrix} \text{v1}$$

$$\begin{pmatrix} L1^\circ \cap L2^\circ \neq \emptyset & L1^\circ \cap \delta L2 = \emptyset & L1^\circ \cap L2^- = \emptyset \\ \delta L1 \cap L2^\circ \neq \emptyset & \delta L1 \cap \delta L2 = \emptyset & \delta L1 \cap L2^- = \emptyset \\ L1^- \cap L2^\circ \neq \emptyset & L1^- \cap \delta L2 \neq \emptyset & L1^- \cap L2^- \neq \emptyset \end{pmatrix} \text{v2, v3}$$

This combination of views excludes configurations in which the trajector is a straight line. The trajector might have the shape of a perfect circle as well as a lot of random-like, zigzagging shapes.

Around 11, finally, will be modeled. This occurrence of *around* is similar to **around 10**. Whereas the configuration matching the meaning of **around 10** resides within a plane, the configuration of **around 11** extends in three dimensions. The model of **around 11** will be as follows.

$$\begin{pmatrix} L^\circ \cap R^\circ \neq \emptyset & L^\circ \cap \delta R = \emptyset & L^\circ \cap R^- = \emptyset \\ \delta L \cap R^\circ \neq \emptyset & \delta L \cap \delta R = \emptyset & \delta L \cap R^- = \emptyset \\ L^- \cap R^\circ \neq \emptyset & L^- \cap \delta R \neq \emptyset & L^- \cap R^- \neq \emptyset \end{pmatrix} \text{v1, v2, v3}$$

This model does not completely represent the meaning of **around 11**. It is determined that the landmark extends in all three dimensions. It is also determined that the trajector extends in at least two dimensions (for no view exists in which the trajector is viewed as a point). It should furthermore be determined, however, that the trajector extends in all three dimensions.

4.7.3 Analysis of the models of *around*

Comparing the meanings

The diversity of meanings of *around* is a lot larger than that of the previous discussed prepositions. This makes it more difficult to search for core aspects of meaning and to decide which of the distinguished meanings would be the most prototypical. Nevertheless, an effort is made in this direction.

Comparing the models for the diverse occurrences, aspects of meaning can be found that are shared by most of the meanings. First, in most cases the trajector has the shape of a line, but is no straight line. This property holds in all cases except for **around 6** and **around 7**; in these two cases the trajector is two- or three-dimensional. Secondly, in most cases the landmark is no line. The landmark is either a point (which can be seen as a very small region) or a region, or even a volume (which is the three-dimensional variant of the region). The only exception is **around 8**, in which case the landmark *is* line-shaped. Furthermore it can be mentioned as a shared aspect of meaning that in most of the cases the configuration of trajector and landmark resides within a plane. (Additionally, this plane usually is the horizontal plane, it seems, although this is not explicitly part of the meanings.) Only the configurations matching the meanings **around 7** and **around 11** extend in three dimensions. In both these cases, besides, all orthogonal views of the model are the same.

The above is not sufficient to decide which of the occurrences is the most prototypical. The only conclusion can be that **around 6**, **around 7**, **around 8**, and **around 11** probably are not the most prototypical meaning, because of their deviations of the above mentioned 'core' aspects of meaning. Subsequently, the number of occurrences of some aspects of meaning can be counted. The tentative conclusion might be that the prototype of *around* has the following properties: the trajector is a line, the landmark is a region (region landmarks are more frequent than point or three-dimensional landmarks), and the configuration as a whole resides within a plane.

Another method to determine which meaning would be the most prototypical, is to decide what (derivational) relations can be found between the diverse occurrences. **Around 1**, **around 2**, **around 3**, **around 4**, and **around 5** are similar meanings and seem to be derivatives of each other. According to Dewell ([7]), these meanings indeed are strongly related. **Around 1** and **around 2** are undistinguishable in Dewell's analysis, and also the meanings in which the trajector does not travel a whole circle are shared in the same semantic category ("[D]epending on the context a completed around path can be anything from a semi-circle to a single full circle to a continuing orbit." ([7], p. 384)).

The models of these five occurrences also show that these meanings are related. In all cases, the trajector is represented by a line (or a region boundary, which is a (closed) line), and the landmark is represented, in one of the views, by a region. These properties, combined with the fact that the trajector is outside the landmark, are unique for these five occurrences. These occurrences thus are grouped together rightly.

Which of these five meanings would be the most prototypical? The trajector of **around 2** intersects with the landmark boundary, whereas in all other cases trajector and landmark are disconnected. Based on this aspect of meaning, **around 2** can be seen as the outsider within this group.

Around 5 is the same as **around 3**, except that its trajector is a search path instead of an actual path, and will be left to one side for the moment. **Around 1**, **around 3** and **around 4** differ only with respect to the degree in which the trajector surrounds the landmark. In the case of **around 1**, it is represented that the trajector completely surrounds the landmark. The trajectors of **around 3** and **around 4** do not travel this full circle. The first view is the same for these two models, and just represents a line trajector that is outside a region landmark. The second and third view together determine to what extent the landmark is surrounded by the trajector. The trajector of **around 3** is represented as traveling approximately a semi-circle, and the trajector of **around 4** travels an even smaller part.

Comparing these three models, and also considering the models of the other occurrences of *around*, leads to the observation that **around 1** is probably the most prototypical of these three meanings. In the case of most of the meanings of *around*, after all, the trajector is completely, and not just partly, surrounding the landmark (or, when the trajector is within the landmark: travels a full circle-like shape).

Considering the whole group of these first five occurrences of *around*, the conclusion can be that **around 1** is the most prototypical of these five meanings. **Around 3** and **around 4** differ from **around 1** regarding the fact that the trajector of these two cases travels a partial instead of a full 'circle'. **Around 5** is a variant of **around 3**, in which the trajector is a search path. **Around 2**, finally, differs from the other occurrences of this group with respect to the intersection relation of the trajector and the landmark: the trajector of **around 2** coincides with the landmark boundary whereas in the other cases the trajectors and landmarks are disconnected.

The next two meanings of *around*, **around 6** and **around 7**, seem to be derived cases of **around 1**. As in the case of **around 1**, the trajector of **around 6** travels a full circle. Instead of (only) the perimeter of the circle, the trajector now (also) covers the surface of the circle. In the case of **around 7**, the trajector is even extended to a sphere (which in fact is a filled-up circle extended from two-dimensional to three-dimensional).

Considering the next category of meanings, containing of only **around 8**, it strikes that the model of **around 8** is the same as the model of **around 2**, except that the landmark of **around 8** is represented by the boundary of a region whereas the landmark of **around 2** is the region as a whole. In contrast to the case of **around 2**, the trajector of **around 8** does not surround the landmark, but coincides with it.

Both **around 8** and **around 9** can be seen as derivatives of **around 1**. In all three cases, the trajector travels a full circle. In the cases of **around 8** and **around 9**, however, the centre of the circle is implicit. Instead of traveling around the landmark, the trajector travels around some point in (the centre of) the landmark. If this explanation is correct, **around 8** can be considered a direct relative of **around 1**, and it is not necessary to invoke **around 2** as 'missing link'.

Also for the last two occurrences, **around 10** and **around 11**, the models provide clues to decide how these meanings are related to other occurrences of *around*. The model of **around 10** is the same as the model of **around 9**, except for the fact that the trajector of **around 10** is modeled, in view 1, as a line, whereas the trajector of **around 9** is represented by a region boundary.

These two occurrences thus only differ with respect to the nature or shape of the trajector (circular vs. random/zigzagging) and **around 10** can be seen as a relative of **around 9**. **Around 11**, finally, is the three-dimensional variant of **around 10**: what is only one of the views in the case of **around 10** is what is visible from all perspective in the case of **around 11**.

When all these (derivational) relations between the diverse occurrences are considered, the conclusion can be that **around 1** is the most prototypical meaning. This meaning consists of a line trajector and a region landmark and resides within a plane, and this is compatible with what was concluded above about core aspect of meaning of this preposition.

Judging the models

Now the question will be considered to what extent the models of *around* are good models. What aspects of meaning are represented, and what aspects are absent in the models?

An important problem that occurs in some of the modelings is that it cannot be represented that the trajector travels some part of a closed path or full 'circle'. In the cases in which the trajector travels a full circle, however, this closedness of the trajector nevertheless is represented. The model provided tools to do this: the trajector was represented by the boundary of a region (**around 1**, **around 9**), or as a line that intersects with a region boundary (**around 2**, **around 8**)[6]. Using the region boundary to represent the trajector (or landmark, as is done in the case of **around 8**) is, however, a less elegant way of modeling, because the region boundary isn't a separate entity that was acknowledged as a building block of the model.

The cases in which the trajector travels a partial circle are more problematic. In these cases - **around 3**, **around 4**, and **around 5** - no region boundary could be used to model the trajector (or the landmark with which the trajector coincides). The modelings of these meanings do represent the fact that the trajector is to some, inexactly specified extent surrounding the landmark, but not exactly what part of a 'circle' is traveled (a semi-circle or a quarter circle).

Another problem, appearing in the cases of **around 10** and **around 11**, is the same kind of problem that the models of **across 5** and **through 6** suffer from. These meanings all have a trajector that is a zigzagging or random-shaped line, but what is represented in the models is only that the trajector is a line and no straight line.

Also shortcomings occur that are not related to the nature of the trajector line. To mention one: in the cases of **around 1**, **around 3**, **around 4**, and **around 5**, not only the fact that the trajector travels some specific part of a full 'circle' is not represented, but also information is missing in the models about the distance between trajector and landmark - which has to be relatively small for the preposition to apply.

What the modelings of *around* show in general, is that the differences and commonalities between the diverse occurrences of this preposition can be modeled quite well, but that some of the core properties of this preposition, aspects of meaning that are shared by most of the occurrences, can not completely be

[6]As is discussed above, this brings about its own problems: the trajector line, in these cases, was 'forced' to become a closed line.

represented. The modeling of such a preposition, however, still can be very informative: topological properties of and topological differences between diverse meanings of this preposition are highlighted.

The models indicate, for example, that three different topological relations between trajector and landmark do exist in the wide range of different meanings of this preposition: the trajector can be outside the landmark (no intersection of interior and boundary of the trajector with the interior of the landmark), coincide with the landmark, or be inside the landmark (interior and boundary of the trajector only intersect with the interior of the landmark).

Furthermore, it is clear that within each of these three categories, the shape and precise nature of the trajector can vary. The trajector can travel a full or a partial 'circle', and can be either approximately circular or zigzagging or even random-shaped. *Topological* differences within each of the three categories, however, are much less common. The few that can be found concern a difference in dimensionality: **around 7** is the three-dimensional variant of **around 6**, and **around 11** is the three-dimensional variant of **around 10**. (Note that these differences could not have been noticed when the default (two-dimensional) 9-intersection model would have been used!)

4.8 *Over*

4.8.1 Linguistic analysis: the meanings of *over*

Over is the most complex of all the discussed prepositions. *Over* has a lot of different meanings, and a lot of aspects of meaning play a role. Furthermore, this preposition has aspects of meaning that can not easily be (9-intersection) modeled. The most general description of the meaning of *over*, which might be seen as the core meaning ([15]), is 'above and across' .

The diverse occurrences of *over* can be classified into three categories, that all have their own central aspects of meaning. In the first category, the meaning of *over* is roughly: 'above (which means in this case: higher than and not in contact with), and across (meaning in this case: having extension in some direction, and stretching out not only above but also above and next to (crossing from side to side))'. The trajector thus has extension in (at least) one dimension. In two of the cases of this category, however, the trajector does not have any relevant extension, and might be seen as a point. These cases are exceptions; the one-dimensional trajector, that fits the 'across' aspect of meaning, is the 'default' in this category.

The two exceptions are very similar to some occurrence of *above*. Why would these two cases exist then? If we mean 'above', why not use the preposition *above*? Apparently, these occurrences of *over* do indeed have a (slightly) different meaning. As Dewell puts it: "(...) *over* and *above* are never entirely synonymous, and *over* always suggests scanned extent relative to the [landmark] while *above* always profiles the ordinary location of a [trajector] whose shaped extent is not at issue." ([8], p. 283). By using the preposition *over* instead of *above*, we hint at a whiff of 'acrossness' that is present.

A relevant aspect of the landmarks in this category is the extension in the horizontal direction parallel to the direction in which the trajector is extended. Because the stereotype trajector is line-shaped, this extension of the landmark can determine whether the trajector crosses the landmark to the other side or not. In the case of a point landmark and a line trajector, the trajector will necessarily traverse the landmark from side to side. In the case of a landmark that does have extension in the parallel horizontal direction, the trajector should be long enough to reach to the other side of the landmark.

Extension of the landmark in the other horizontal dimension is only relevant in the exceptional cases where the trajector is not line-shaped. There, the trajector is located somewhere above the landmark, and it makes a difference whether the landmark is only a point, in which case the trajector has to be precisely above that point, or whether the landmark is extended in the horizontal plane, in which case the trajector can be located anywhere above it. It is not important whether the landmark is extended in the vertical dimension. This is because the trajector is above and not in contact with the landmark; the trajector's shape will therefore not be influenced by the shape of the landmark.

The second category of meanings of *over* are cases in which the trajector *is* in contact with the landmark. Therefore, and of course because the trajector is above (thus: in contact with the upper side of) the landmark, it is important whether the landmark has vertical extension (in the upper direction of the landmark). In fact, most of the meanings in this category do have vertical extension, and when they do not, at least there is some hint of 'aboveness': the landmark is higher than something else. The vertical extendedness indeed is a crucial aspect of the meanings in this category. Similar cases without this vertical extendedness would surely not be described using the preposition *over*, but using other prepositions (*through*, *along*, *across*). Because of the vertical extension, the trajector - that follows the surface of the landmark - has to 'climb', go upwards, leading to an 'above' aspect of meaning. Also extension in the horizontal direction parallel to the direction of the trajector is relevant for this category. This is because the trajector needs to go 'across, to the other side of' the landmark; the amount of extension of the landmark in this direction determines what the length of the trajector should be to form a configuration that fits into this category. In short, the occurrences that fit into this category of *over* have 'above' and 'across', and contact between trajector and landmark, as central aspects of meaning. *Over* is the appropriate prepositions for the cases in this category, precisely because of the combination of 'aboveness' and 'acrossness'.

The third category of meanings is the only one in which 'above' is not an aspect of meaning. To be precise: 'aboveness' might be a feature of *some* of the occurrences of *over* that reside within this category, but it is not an aspect that holds for all the occurrences of this category. Also the aspect of meaning 'acrossness' is, strictly seen, not present in this category, for then essentially the trajector should be line-shaped (extended in only one, horizontal, dimension) and that is not the case here. A derived variant of 'acrossness', however, indeed is present: instead of having extension in only one direction (and traveling across the landmark in this way), now the trajector has extension in all the directions of a plane (and thus travels across the landmark in some extended way).

The central aspect of meaning in this category is 'covering': the landmark is covered (restrained from sight, viewed from some, routine, perspective) by the trajector. The landmarks in this category are areas and so are the trajectors, which should be able to cover the landmark. The trajector should be as least as large as the landmark. The landmark may have extension in the third dimension as well, but this dimension is not relevant, for the covering concerns an area. It is also irrelevant whether the trajector is in contact with the landmark or not - both are possible -, for a landmark can be restrained from sight in both ways. (Sometimes it may be even unclear, viewed from the routine perspective, whether the trajector is in contact with the landmark or not.)

The covering of the landmark *can* be done by a trajector that is *above* the landmark; this will especially be the case when the landmark is relatively low, below human's eye; for then, viewed by a normal human being, the landmark will be restrained from sight. When, however, the landmark is some horizontal plane that is above human's eye, the covering will be done by a trajector that is *below* the landmark. It is possible to cover some vertical plane, too; then the trajector will also be vertical and (from the viewer's perspective) *in front of* the landmark.

Each of the above described categories contains a number of different occurrences of *over*. Below, each distinguished occurrence of *over* will be addressed separately. The analysis and the description of the meanings of each of the occurrences are based on the analyses of Hawkins ([11]) and Lakoff ([15]). After the denomination of each occurrence, a series of abbreviations (letter-number combinations) follows, for example "(H1, L10)". These abbreviations refer to the occurrences of *over* that are distinguished by Hawkins and Lakoff. (Besides, when one of the occurrences of the preposition that is distinguished here, is 'labelled' with more than one letter-number combination, it does not necessarily hold that the meanings these abbreviations refer to are equal to *each other*.)

over 1 (H1, L10)

"A red sign is over the door."

The trajector is some point and the landmark is some point. The landmark may have vertical extension. The trajector is above the landmark. There is no contact between trajector and landmark.

over 2 (H2, L10)

"The plane is now over the Pacific Ocean."

This occurrence is similar to **over 1**, but now the landmark has extension in (all directions of) the horizontal plane (and possibly also vertical extension). The trajector thus is some point that is somewhere above the area landmark, without contact.

over 3 (H3; L1 (only the non-contact variant), L11)

"The advance plane flew over the bomb target."

The trajector has the shape of a line, the landmark is some point, possibly having vertical extension. The landmark may also have extension in a horizontal direction, but that then should be the perpendicular direction compared to the direction of the trajector. (If the landmark had extension in the horizontal direction parallel to the direction of the trajector, then this would be a significantly different meaning, see **over 5**.) The trajector is horizontal and above the landmark, and crosses to the other side of the landmark, without contact.

over 4 (L4b)

"The kangaroo jumped over the statue."

Over 4 is a variant of **over 3**: the trajector is a line, the landmark is some point and the trajector is not in contact with the landmark. The landmark may have vertical extension and may have horizontal extension in the perpendicular direction. In this occurrence of *over*, however, the trajector is not only (at some point) above the landmark, but also some parts of the trajector, namely: its boundary points, are on the ground (i.e. on the level of the lowest point of the landmark).

over 5 (H4; L1 (only the non-contact variant), L2, L11)

"The plane flew over the Ocean."

The trajector has the shape of a line, the landmark has extension in the horizontal plane, at least in the direction parallel to the direction of the trajector. The landmark might also have vertical extension. The trajector is horizontal and above and across the landmark, without contact.

over 6 (H5, L6)

"The proud troops marched over the recently taken hill."

The trajector is a line, the landmark is extended both in the two horizontal dimensions (of which only the direction parallel to the direction of the trajector is relevant) and in the vertical dimension. The trajector is above and completely in contact with the landmark, the boundary parts of the trajector are at ground level.

over 7 (H6, L5)

"The fanfare walked over the bridge."

The trajector is a line, the landmark is extended in one horizontal direction. The trajector follows the landmark in this direction, in continuous contact with the upper side of the landmark. The landmark might have extension in the vertical direction; when no significant vertical extension is present, the landmark should be above something else. The boundary parts of the trajector are at ground level.

over 8 (H7, L7)

"The child climbed over the wall."

The trajector is a line, the landmark is extended in the vertical dimension, and also a little in the horizontal dimension parallel to the direction of the trajector. The landmark might have extension in the perpendicular horizontal dimension, compared to the direction of the trajector, but extension in this dimension will be irrelevant. The trajector is in contact with the upper side of the landmark, and the boundary parts of the trajector are at ground level.

over 9 (H9, L9)

"The enemy camp is just over the hill."

This occurrence of *over* is a derivative of **over 6**. In this case, the trajector is of arbitrary shape, and is located at the end of an auxiliary trajector ('potential path'). The auxiliary trajector is the same as the trajector of **over 6**: a line that is above and completely in contact with the landmark, and of which the boundary parts are at ground level. The landmark is, just as in the case of **over 6**, extended in the horizontal dimension in which also the trajector is extended (and possible, but irrelevant, in the other horizontal dimension), and in the vertical dimension.

over 10 (L8)

"The city is over the bridge"

Also in this case, the trajector is of arbitrary shape and some auxiliary trajector exists of which the shape *is* important. The shape of the auxiliary trajector of this **over 10** is the same as the 'actual' trajector of **over 7**: a line that is in continuous contact with the upper side of the landmark, that follows the direction of that landmark, and of which the boundary parts are at ground level. The landmark is extended in one horizontal dimension, and possibly in the vertical dimension. The trajector is located at the end of the auxiliary trajector.

over 11 (H8)

"He fell over the cliff."

This variant of *over* is a bit like **over 8**: in both cases the landmark is extended in the vertical dimension and a little in the parallel horizontal dimension. Extension in the perpendicular horizontal direction is irrelevant. The trajector is a line that is in contact with the upper side of the landmark, and of which a part is on the ground. The difference between **over 8** and **over 11** is that the trajector of **over 11** is only on one side of the landmark, whereas the trajector of **over 8** extends on both sides.

over 12 (H10 (although this H10 is somewhat 'stricter'; H10 necessarily involves contact between trajector and landmark, whereas my **over 12** possibly involves contact), L12, L14, L15)

"A cloth is spread over the table."

Both the trajector and the landmark are extended in the two horizontal dimensions. The landmark may also have vertical extension and in that case, the trajector probably also will, because in most cases, the trajector follows the shape of the landmark. The trajector is above the landmark and is at least as big as the upper surface of the landmark. The trajector thus covers the landmark. The trajector can be both 'massive' (the landmark really is completely covered; "a cloth over the table") and 'multiplex' (units are 'scattered' over the landmark, in between the units is 'empty' space; "raisins all over the floor"). The trajector can also be a path; the path in "Anne walked all over the hill looking for her dog." covers the surface of the hill. In cases of this **over 12** in which the trajector is not massive, the preposition is necessarily preceded by "all" ("all over").

In the case of this **over 12**, there is usually contact between landmark and trajector (gravity will usually let the trajector make contact with the landmark), but also non-contact cases are possible. "Superman flew all over the city." is a non-contact example of this **over 12**.

over 13 (H11, L16, L18, L19)

"I pulled the shade down over the window."

Over 13 is a rotated version of **over 12**. The landmark is a plane that is extended in the vertical dimension and in one of the horizontal dimensions. The trajector is extended in the same directions as is the landmark. Extension in the third dimension is optional. The trajector is as least as large as the landmark (so, seen from some perspective, the trajector completely covers the landmark). Also in this case, the trajector can be massive ("shade over window") or multiplex ("There were spots all over her face."). Contact and non-contact are both options too.

over 14 (L16, L18, L19)

"Spiders were all over the ceiling."

This occurrence of *over* is also a rotated variant of **over 12**. Just as in the case of **over 12**, both the trajector and the landmark are extended in the two horizontal dimensions, and the trajector is as least as big as the landmark. In this case, however, the trajector is *below* the landmark (so, when viewed from below, the trajector covers the landmark). Massive and multiplex trajectors, and contact and non-contact cases, are all possibilities.

4.8.2 A 9-intersection modeling of the meanings of *over*

The diverse meanings of *over* are distinguished above. In this section, the translation of these meanings to 9-intersection models is performed. It is clear from the start that such modelings cannot easily be built for this preposition. Most of the meanings contain an 'above' aspect of meaning, which is a projective instead of a topological aspect. This aspect can not be represented in the models. For each occurrence, however, it will be tried to build a model as complete as is possible.

First the meanings of the first category will be taken into account. **Over 1**, to start with, has a point as trajector and a point as landmark. These two points are completely separate from each other. Furthermore, the trajector point should be (straight) above the landmark point. The following seems to be the best way to model this meaning.

$$\left(\text{ P1} \cap \text{P2} \neq \emptyset \ \right)_{\text{v1 = top view}}$$

$$\left(\text{ P1} \cap \text{P2} = \emptyset \ \right)_{\text{v2, v3}}$$

It is thus determined that the two points are above each other, and completely separate from each other. It is not represented, however, that the trajector is above the landmark and not the other way round.

Over 2 is similar to **over 1** and also the accompanying models can be. The trajector is a point and this point is separate from and above a region landmark. Because the region extends only in the horizontal plane, in the top (or bottom) view a region is visible, but in all the views orthogonal to this one, the landmark is viewed as a line.

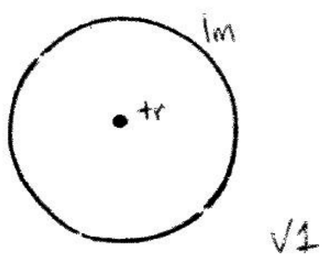
The model of **over 2** is the following.

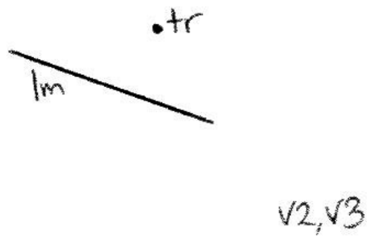
$$\left(\text{ P} \cap \text{R}^{\circ} \neq \emptyset \quad \text{P} \cap \delta\text{R} = \emptyset \quad \text{P} \cap \text{R}^{-} = \emptyset \ \right)_{\text{v1 = top view}}$$

$$\begin{pmatrix} P \cap L^{\circ} = \emptyset & P \cap \delta L = \emptyset & P \cap L^{-} \neq \emptyset \end{pmatrix}_{v2,\ v3}$$

The combination of views makes clear that trajector and landmark are above each other (but which one is higher is not determined). The fact that in all views orthogonal to the top view, the landmark is visible as a line, means that this region indeed is in the horizontal plane. (The lines that are visible in view 2 and view 3 thus are horizontal lines.)

The following is a pictorial representation of this model.





Over 3 differs from **over 1** only with respect to the fact that in the case of **over 3** the trajector is a line instead of a point. The model of **over 3** is the following.

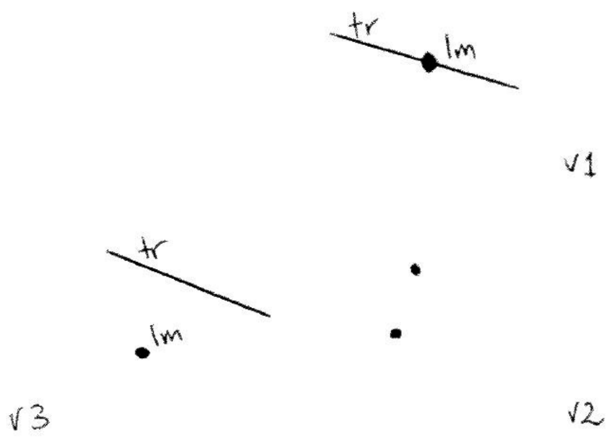
$$\begin{pmatrix} L^{\circ} \cap P \neq \emptyset \\ \delta L \cap P = \emptyset \\ L^{-} \cap P = \emptyset \end{pmatrix}_{v1\ =\ \text{top view}}$$

$$\begin{pmatrix} P1 \cap P2 = \emptyset \end{pmatrix}_{v2}$$

$$\begin{pmatrix} L^{\circ} \cap P = \emptyset \\ \delta L \cap P = \emptyset \\ L^{-} \cap P \neq \emptyset \end{pmatrix}_{v3}$$

The model determines that line and point are above each other (although it is not determined which is above which), and that trajector and landmark are separate from each other. It is also clear that the trajector is a straight horizontal line, because it is visible as a point in a view orthogonal to the top view.

The picture below is a representation of this model.



Over 4 is similar to, but different from **over 3**. In this case, the trajector is not a straight line, but a curved line. The boundary parts of this trajector are on the ground, where also the landmark is. The model of **over 4** is the following.

$$\begin{pmatrix} L^\circ \cap P \neq \emptyset \\ \delta L \cap P = \emptyset \\ L^- \cap P = \emptyset \end{pmatrix} \text{v1 = top view}$$

$$\begin{pmatrix} L^\circ \cap P = \emptyset \\ \delta L \cap P \neq \emptyset \\ L^- \cap P = \emptyset \end{pmatrix} \text{v2}$$

$$\begin{pmatrix} L^\circ \cap P = \emptyset \\ \delta L \cap P = \emptyset \\ L^- \cap P \neq \emptyset \end{pmatrix} \text{v3}$$

The combination of view 1 and view 3 determines that trajector and landmark are above each other (but which one is higher is not determined). This model does also represent the fact that the trajector is not a horizontal straight line. Furthermore, it is determined that (at least part of) the boundary of the trajector is on the same height as is the landmark.

Over 5 has the same landmark as **over 2** and the same trajector as **over 3**. The model of **over 5** is the following.

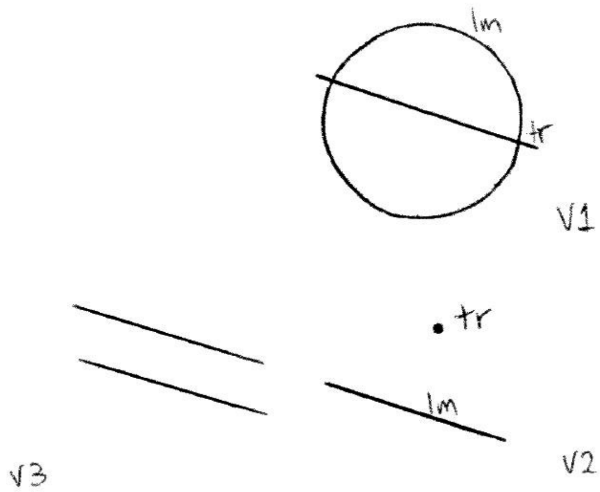
$$\begin{pmatrix} L^\circ \cap R^\circ \neq \emptyset & L^\circ \cap \delta R \neq \emptyset & L^\circ \cap R^- \neq \emptyset \\ \delta L \cap R^\circ = \emptyset & \delta L \cap \delta R = \emptyset & \delta L \cap R^- \neq \emptyset \\ L^- \cap R^\circ \neq \emptyset & L^- \cap \delta R \neq \emptyset & L^- \cap R^- \neq \emptyset \end{pmatrix} \text{v1 = top view}$$

$$\begin{pmatrix} P \cap L^\circ = \emptyset & P \cap \delta L = \emptyset & P \cap L^- \neq \emptyset \end{pmatrix}_{\text{v2}}$$

$$\begin{pmatrix} L1^\circ \cap L2^\circ = \emptyset & L1^\circ \cap \delta L2 = \emptyset & L1^\circ \cap L2^- \neq \emptyset \\ \delta L1 \cap L2^\circ = \emptyset & \delta L1 \cap \delta L2 = \emptyset & \delta L1 \cap L2^- \neq \emptyset \\ L1^- \cap L2^\circ \neq \emptyset & L1^- \cap \delta L2 \neq \emptyset & L1^- \cap L2^- \neq \emptyset \end{pmatrix} \text{v3}$$

The fact that the line goes through the region in the top view, and that landmark and trajector are separate in some other view, determines that the landmark and the trajector are above each other. It is also determined that the trajector is a straight line. The fact that the landmark is a region in the top view and a line in all views orthogonal to the top view, makes clear that the landmark indeed is horizontal. That the trajector is horizontal, is determined by the fact that it is visible as a point in a view ortogonal to the top view.

The picture below is a representation of this model.



Now the meanings of the second category will be modeled. A common aspects of meaning of the occurrences in this category, that is also the most important aspect that distinguishes this category from the first, is the fact that trajector and landmark are in contact with each other.

As in the cases of *around* for which this is relevant, also here contact between trajector and landmark will be modeled as 'intersection with the boundary of'. Besides, in the case of some of the occurrences in this category, the landmark might have extension in the horizontal direction perpendicular to the direction in which the trajector is extended. This possible extension of the landmark, however, is, as was said above, in none of the cases relevant. Therefore, the choice was made to not model this perpendicular extension. This choice has as a consequence that all the models of this category are at most two-dimensional. The only dimensions that are present in the modelings are the dimension in which the trajector extends and the vertical dimension.

In the case of **over 6**, the landmark has extension in the vertical dimension and in one of the horizontal dimensions. This landmark can, in some side (or front or back) view, best be modeled by a region. In the views orthogonal to this one, the landmark will be visible as a line.

Over 9 is a derivative of **over 6**. What is the actual trajector in the case of **over 6** is the auxiliary trajector of **over 9**. Apart from this difference, the two occurrences are precisely the same. One and the same model can be built for these two occurrences, given the fact that in the case of **over 9**, not the actual trajector but the auxiliary trajector is modeled.

The model of **over 6** and **over 9** is the following.

$$\begin{pmatrix} L1^\circ \cap L2^\circ \neq \emptyset & L1^\circ \cap \delta L2 \neq \emptyset & L1^\circ \cap L2^- \neq \emptyset \\ \delta L1 \cap L2^\circ = \emptyset & \delta L1 \cap \delta L2 = \emptyset & \delta L1 \cap L2^- \neq \emptyset \\ L1^- \cap L2^\circ = \emptyset & L1^- \cap \delta L2 = \emptyset & L1^- \cap L2^- \neq \emptyset \end{pmatrix} \text{v1 = top view}$$

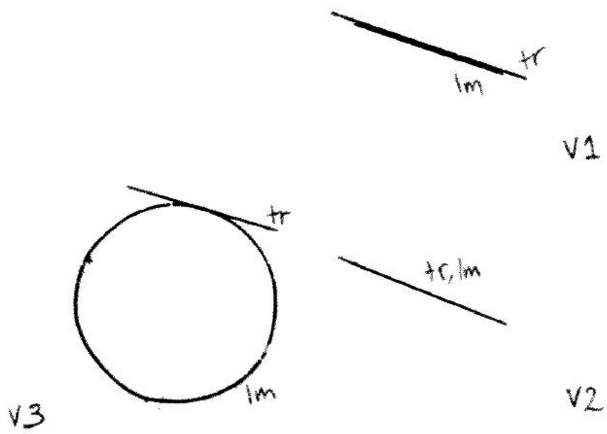
$$\begin{pmatrix} L1^\circ \cap L2^\circ \neq \emptyset & L1^\circ \cap \delta L2 = \emptyset & L1^\circ \cap L2^- = \emptyset \\ \delta L1 \cap L2^\circ = \emptyset & \delta L1 \cap \delta L2 \neq \emptyset & \delta L1 \cap L2^- = \emptyset \\ L1^- \cap L2^\circ = \emptyset & L1^- \cap \delta L2 = \emptyset & L1^- \cap L2^- \neq \emptyset \end{pmatrix} \text{v2}$$

$$\begin{pmatrix} L^\circ \cap R^\circ = \emptyset & L^\circ \cap \delta R \neq \emptyset & L^\circ \cap R^- \neq \emptyset \\ \delta L \cap R^\circ = \emptyset & \delta L \cap \delta R = \emptyset & \delta L \cap R^- \neq \emptyset \\ L^- \cap R^\circ \neq \emptyset & L^- \cap \delta R \neq \emptyset & L^- \cap R^- \neq \emptyset \end{pmatrix} \text{v3}$$

Unfortunately, this model does not completely represent the meaning of **over 6**. It does, however, represent this meaning for a large part. Viewed from some perspective, a region is visible, and from all the perspectives orthogonal to this one, this landmark is visible as a line. This means that the landmark indeed is a region, having extension only within a plane. Because view 1 is the top view, it is determined that the region extends in a vertical plane. This also means that the line that is visible in view 2 is a vertical line. Furthermore it is known that the trajector sticks out on both sides of the landmark in the top view, and does not in view 2. (In view 2, trajector and landmark coincide completely.) This means that the trajector sticks out on both sides of the landmark *horizontally*, but does not have more extension than the landmark in the vertical direction.

What the model does represent, thus, is that part of the trajector is in contact with part of the landmark, and that the trajector goes 'across' the landmark. It is not represented that the trajector is above the landmark (- a configuration in which the trajector is on the lowest side of the landmark also is possible). Information about the precise shape of the landmark is absent in the modeling too.

The following is a pictorial representation of this model.



Over 7 is different from **over 6** with respect to the shape and dimensionality of the landmark. In the case of **over 7**, the landmark only has extension in

a horizontal dimension. In the analysis, it was said that vertical extension is possible, but this extension is negligible and will not be modeled.

Over 10 is the end-point derivative of **over 7**. For these two meanings, the same model will suffice, given the fact that in the case of **over 10** the auxiliary trajector instead of the actual trajector will be modeled.

The model of **over 7** and **over 10** is the following.

$$\begin{pmatrix} \mathrm{L1}^\circ \cap \mathrm{L2}^\circ \neq \emptyset & \mathrm{L1}^\circ \cap \delta\mathrm{L2} \neq \emptyset & \mathrm{L1}^\circ \cap \mathrm{L2}^- \neq \emptyset \\ \delta\mathrm{L1} \cap \mathrm{L2}^\circ = \emptyset & \delta\mathrm{L1} \cap \delta\mathrm{L2} = \emptyset & \delta\mathrm{L1} \cap \mathrm{L2}^- \neq \emptyset \\ \mathrm{L1}^- \cap \mathrm{L2}^\circ = \emptyset & \mathrm{L1}^- \cap \delta\mathrm{L2} = \emptyset & \mathrm{L1}^- \cap \mathrm{L2}^- \neq \emptyset \end{pmatrix} \text{v1 = top view, v3}$$

$$\begin{pmatrix} \mathrm{P1} \cap \mathrm{P2} \neq \emptyset \end{pmatrix}_{\text{v2}}$$

Also in the case of **over 7**, the model does not completely determine the meaning. The top view determines that the trajector does stick out on both sides of the landmark in a horizontal direction. The 'across' aspect of meaning thus is contained in the model. Also the fact that the trajector is in contact with the landmark is determined. View 2, in which only two overlapping points are visible, determines that the lines are straight lines; the configuration extends in only one dimension. What the model does not contain, is that the lines are horizontal lines.

Over 8 is similar to **over 6**. In both cases, the landmark is extended in the horizontal dimension in which also the trajector is extended, and in the vertical dimension. The difference between these two occurrences is that the landmark is more 'vertical' (having more extension in the vertical than in the horizontal direction) in the case of **over 8** and more 'horizontal' in the case of **over 6**. This distinction, however, concerns the exact shape of the landmark and can not be modeled.

The result of the modeling of **over 8** will thus be exactly the same as the model of **over 6**. That model represents the meaning of **over 8** as incomplete as it represents the meaning of **over 6**. Because information about the shape of the landmark is missing, the difference between **over 6** and **over 8** is not contained in the models.

Over 11 is comparable to **over 8**. The difference is that the trajector of **over 11** is the same as only one half of the trajector of **over 8**. The trajector of **over 11** does not start at one side of the landmark and cross to its other side; instead this trajector starts half way the landmark, and does stick out of the landmark only on one of its sides.

The model of **over 11** is the following.

$$\begin{pmatrix} \mathrm{L1}^\circ \cap \mathrm{L2}^\circ \neq \emptyset & \mathrm{L1}^\circ \cap \delta\mathrm{L2} \neq \emptyset & \mathrm{L1}^\circ \cap \mathrm{L2}^- \neq \emptyset \\ \delta\mathrm{L1} \cap \mathrm{L2}^\circ \neq \emptyset & \delta\mathrm{L1} \cap \delta\mathrm{L2} = \emptyset & \delta\mathrm{L1} \cap \mathrm{L2}^- \neq \emptyset \\ \mathrm{L1}^- \cap \mathrm{L2}^\circ \neq \emptyset & \mathrm{L1}^- \cap \delta\mathrm{L2} \neq \emptyset & \mathrm{L1}^- \cap \mathrm{L2}^- \neq \emptyset \end{pmatrix} \text{v1 = top view}$$

$$\begin{pmatrix} \mathrm{L1}^\circ \cap \mathrm{L2}^\circ \neq \emptyset & \mathrm{L1}^\circ \cap \delta\mathrm{L2} = \emptyset & \mathrm{L1}^\circ \cap \mathrm{L2}^- = \emptyset \\ \delta\mathrm{L1} \cap \mathrm{L2}^\circ = \emptyset & \delta\mathrm{L1} \cap \delta\mathrm{L2} \neq \emptyset & \delta\mathrm{L1} \cap \mathrm{L2}^- = \emptyset \\ \mathrm{L1}^- \cap \mathrm{L2}^\circ = \emptyset & \mathrm{L1}^- \cap \delta\mathrm{L2} = \emptyset & \mathrm{L1}^- \cap \mathrm{L2}^- \neq \emptyset \end{pmatrix} \text{v2}$$

$$\begin{pmatrix} \mathrm{L}^\circ \cap \mathrm{R}^\circ = \emptyset & \mathrm{L}^\circ \cap \delta\mathrm{R} \neq \emptyset & \mathrm{L}^\circ \cap \mathrm{R}^- \neq \emptyset \\ \delta\mathrm{L} \cap \mathrm{R}^\circ = \emptyset & \delta\mathrm{L} \cap \delta\mathrm{R} \neq \emptyset & \delta\mathrm{L} \cap \mathrm{R}^- \neq \emptyset \\ \mathrm{L}^- \cap \mathrm{R}\circ \neq \emptyset & \mathrm{L}^- \cap \delta\mathrm{R} \neq \emptyset & \mathrm{L}^- \cap \mathrm{R}^- \neq \emptyset \end{pmatrix} \text{v3}$$

Also in the case of this occurrence, the model does not completely, but for a large part, determine the meaning. As is the case with the model of **over 6** (and **over 8** and **over 9**), from the totality of the three views of **over 11**, it is clear that the landmark extends in precisely two dimensions and is in a vertical plane. It is also known that the lines of view 2 are vertical lines, so the models determine that the trajector does not stick out, related to the landmark, in the vertical direction. Both view 1 and view 3 imply that the trajector is partly in contact with part of the landmark, and that the trajector sticks out on one side of the landmark, in the horizontal direction.

The last category of occurrences of *over* contains three different meanings, but these three meanings are very similar to each other. The same model can be built for each of these three occurrences. Unfortunately, a single model is not sufficient to model any of the occurrences of this category. This is because some aspects of meaning of the three meanings in this category are variable. For each of the occurrences, two aspects may vary: trajector and landmark may be either in contact or not in contact with each other, and the trajector may be either larger than (case '>') or as large as (case '=') the landmark. Four models thus have to be built.

Furthermore, effort has to be taken to distinguish between **over 12**, **over 13** and **over 14**. This can be done be specifying the perspective of the models. **Over 12** and **over 14** are cases in which landmark and trajector are in a horizontal plane: viewed from a top (or bottom) perspective, the trajector and landmark are visible as regions. The models described below will be models for **over 12** and **over 14** by specifying that view 1 is the top or bottom view.

Over 13 is somewhat different from the other two meanings: in this case, trajector and landmark are in a vertical plane. The models below will thus be models for **over 13** when it is specified that view 2 or view 3 is the top (or bottom) view - and view 1 is a side view.

The distinction between **over 12** and **over 14** can not be made. This is because of the 'transparent' way of modeling that was chosen - in which a view is not a view of a configuration of trajector and landmark, but a combination of two separate views of trajector and landmark. Whether the trajector is in front of the landmark or the other way round can not be determined.

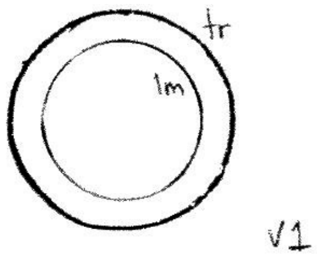
Besides: in the analysis it was said that landmark and trajector might also have extension in the third dimension. This optional extension is not modeled, because it is irrelevant for the meanings of the occurrences in this category.

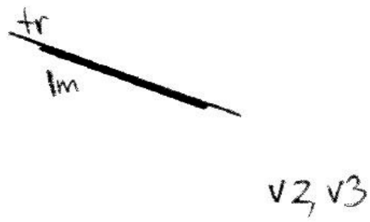
If the trajector is larger than and contacting the landmark (case '> and contact'), the model of **over 12**, **over 13** and **over 14** is as follows.

$$\begin{pmatrix} \mathrm{R1}^\circ \cap \mathrm{R2}^\circ \neq \emptyset & \mathrm{R1}^\circ \cap \delta\mathrm{R2} \neq \emptyset & \mathrm{R1}^\circ \cap \mathrm{R2}^- \neq \emptyset \\ \delta\mathrm{R1} \cap \mathrm{R2}^\circ = \emptyset & \delta\mathrm{R1} \cap \delta\mathrm{R2} = \emptyset & \delta\mathrm{R1} \cap \mathrm{R2}^- \neq \emptyset \\ \mathrm{R1}^- \cap \mathrm{R2}^\circ = \emptyset & \mathrm{R1}^- \cap \delta\mathrm{R2} = \emptyset & \mathrm{R1}^- \cap \mathrm{R2}^- \neq \emptyset \end{pmatrix} \mathrm{v1}$$

$$\begin{pmatrix} \mathrm{L1}^\circ \cap \mathrm{L2}^\circ \neq \emptyset & \mathrm{L1}^\circ \cap \delta\mathrm{L2} \neq \emptyset & \mathrm{L1}^\circ \cap \mathrm{L2}^- \neq \emptyset \\ \delta\mathrm{L1} \cap \mathrm{L2}^\circ = \emptyset & \delta\mathrm{L1} \cap \delta\mathrm{L2} = \emptyset & \delta\mathrm{L1} \cap \mathrm{L2}^- \neq \emptyset \\ \mathrm{L1}^- \cap \mathrm{L2}^\circ = \emptyset & \mathrm{L1}^- \cap \delta\mathrm{L2} = \emptyset & \mathrm{L1}^- \cap \mathrm{L2}^- \neq \emptyset \end{pmatrix} \mathrm{v2, v3}$$

The following is a pictorial representation of this model.





If the trajector is as large as and contacting the landmark (case '= and contact'), the model of **over 12**, **over 13** and **over 14** is as follows.

$$\begin{pmatrix} R1^\circ \cap R2^\circ \neq \emptyset & R1^\circ \cap \delta R2 = \emptyset & R1^\circ \cap R2^- = \emptyset \\ \delta R1 \cap R2^\circ = \emptyset & \delta R1 \cap \delta R2 \neq \emptyset & \delta R1 \cap R2^- = \emptyset \\ R1^- \cap R2^\circ = \emptyset & R1^- \cap \delta R2 = \emptyset & R1^- \cap R2^- \neq \emptyset \end{pmatrix} \text{v1}$$

$$\begin{pmatrix} L1^\circ \cap L2^\circ \neq \emptyset & L1^\circ \cap \delta L2 = \emptyset & L1^\circ \cap L2^- = \emptyset \\ \delta L1 \cap L2^\circ = \emptyset & \delta L1 \cap \delta L2 \neq \emptyset & \delta L1 \cap L2^- = \emptyset \\ L1^- \cap L2^\circ = \emptyset & L1^- \cap \delta L2 = \emptyset & L1^- \cap L2^- \neq \emptyset \end{pmatrix} \text{v2, v3}$$

If the trajector is larger than and not contacting the landmark (case '> and non-contact'), the model of **over 12**, **over 13** and **over 14** is as follows.

$$\begin{pmatrix} R1^\circ \cap R2^\circ \neq \emptyset & R1^\circ \cap \delta R2 \neq \emptyset & R1^\circ \cap R2^- \neq \emptyset \\ \delta R1 \cap R2^\circ = \emptyset & \delta R1 \cap \delta R2 = \emptyset & \delta R1 \cap R2^- \neq \emptyset \\ R1^- \cap R2^\circ = \emptyset & R1^- \cap \delta R2 = \emptyset & R1^- \cap R2^- \neq \emptyset \end{pmatrix} \text{v1}$$

$$\begin{pmatrix} L1^\circ \cap L2^\circ = \emptyset & L1^\circ \cap \delta L2 = \emptyset & L1^\circ \cap L2^- \neq \emptyset \\ \delta L1 \cap L2^\circ = \emptyset & \delta L1 \cap \delta L2 = \emptyset & \delta L1 \cap L2^- \neq \emptyset \\ L1^- \cap L2^\circ \neq \emptyset & L1^- \cap \delta L2 \neq \emptyset & L1^- \cap L2^- \neq \emptyset \end{pmatrix} \text{v2, v3}$$

If the trajector is as large as and not contacting the landmark (case '= and non-contact'), the model of **over 12**, **over 13** and **over 14** is as follows.

$$\begin{pmatrix} R1^\circ \cap R2^\circ \neq \emptyset & R1^\circ \cap \delta R2 = \emptyset & R1^\circ \cap R2^- = \emptyset \\ \delta R1 \cap R2^\circ = \emptyset & \delta R1 \cap \delta R2 \neq \emptyset & \delta R1 \cap R2^- = \emptyset \\ R1^- \cap R2^\circ = \emptyset & R1^- \cap \delta R2 = \emptyset & R1^- \cap R2^- \neq \emptyset \end{pmatrix} \text{v1}$$

$$\begin{pmatrix} L1^\circ \cap L2^\circ = \emptyset & L1^\circ \cap \delta L2 = \emptyset & L1^\circ \cap L2^- \neq \emptyset \\ \delta L1 \cap L2^\circ = \emptyset & \delta L1 \cap \delta L2 = \emptyset & \delta L1 \cap L2^- \neq \emptyset \\ L1^- \cap L2^\circ \neq \emptyset & L1^- \cap \delta L2 \neq \emptyset & L1^- \cap L2^- \neq \emptyset \end{pmatrix} \text{v2, v3}$$

None of these four models does completely represent the meaning. The contact cases, however, are less incomplete than the non-contact cases. In both of the contact cases, it is clear that trajector and landmark indeed are two-dimensional entities, and that they are extended in one and the same plane. This is clear from the fact that both in view 2 and in view 3 only overlapping lines are visible. Also it is determined, in the contact cases, that the trajector sticks out on both sides of the landmark (case '>') or that trajector and landmark are of the same length (case '=').

What is not determined however - and this is a missing element in all the four cases - is that the landmark is behind (or above, or below) the trajector. The reason that this aspect can not be represented, is that the choice was made to model the views 'transparent'. In this case, the consequence of this method is that the models are not specific enough: they do represent the actual meaning, but some other meanings are not excluded. The transparent way of modeling, of course, has also a lot of advantages. This method has created, for example, the possibility to represent information about both the shape of the trajector and the shape of the landmark, even when the landmark is restrained from sight by the trajector.

What additionally is missing in the non-contact cases is information about the relative orientation of trajector and landmark. From the fact that two separate lines are visible in view 2 and 3, it can be derived that landmark and trajector are separate things, but that these two are in parallel is not at all clear.

4.8.3 Analysis of the models of *over*

Comparing the meanings

Because *over* has a rich variety of meanings, deciding which of the meanings is the most prototypical is not easy. First it will be investigated what aspects of meaning seem to be core aspects of meaning of this preposition. In by far most of the occurrences, in the top view the trajector and the landmark do intersect (**over 13** is the only exception). This means that trajector and landmark are (at least partially) above each other (or, when also in the other views intersection between trajector and landmark exists, that they overlap).

A clear difference, besides, between the first five occurrences on the one hand and occurrences **over 6** to **over 11** on the other, concerns the existence of overlap in the orthogonal views that are not top views. In the cases of **over 1**, **over 2**, **over 3**, and **over 5**, in view 2 and in view 3 the trajector and the landmark do not intersect at all. In these occurrences the trajector and landmark are strictly above each other; one of them is higher than the other, and no overlap or contact between them exists. (The case of **over 4** is slightly different, for in this occurrence in only one of the views no overlap exists.) The occurrences **over 6** to **over 11**, on the contrary, do have intersecting trajectors and landmarks in all three views. This means that trajector and landmark are not distinct from each other.

Further aspects of meaning that occur in many of the occurrences of this preposition concern properties of the trajector and properties of the landmark, instead of properties of the relation between these two.

The trajector of *over* typically is a line. In only two of the occurrences of this preposition, the trajector has extension in less then one dimension (**over 1** and **over 2**). As was stated above, these occurrences are exceptional cases; these two meanings - in which the trajector is a point - are not the most prototypical meanings of *over*. In the meanings of the third category (**over 12**, **over 13**, and **over 14**), the trajector is two-dimensional. Also this type of trajector is not part of the core meaning of this preposition. As was argued, the 'extended acrossness' that is part of the meaning in these three occurrences is a derived aspect of meaning. In the eleven other occurrences, the trajector indeed is line-shaped. The conclusion thus might be that the most prototypical trajector of *over* is a line trajector.

It is less easy to decide what kind of landmark is the most typical for *over*. A large variety of landmarks occurs. In a few cases (**over 1**, **over 3**, and **over 4**), the landmark is a point. In even less cases (**over 7** and **over 10**), the landmark is a (horizontal) line. In all other cases, the landmark is represented by a region. In the cases of **over 2**, **over 5**, **over 12**, and **over 14**, this region is extended within the horizontal plane. The landmark of **over 6**, **over 8**, **over 9**, **over 11**, and **over 13** is vertically extended. Which of these types of landmark would be the most prototypical one? Maybe the conclusion should be that the typical landmark of *over* does not have many specific properties. This seems plausible at least for the non-contact cases: it is possible for a trajector to travel over some landmark independent of the shape of that landmark.

Based on the above observations, what can be said about the core meaning of *over* is that trajector and landmark are (at least partially) in one and the same vertical plane (i.e. they are above each other or do overlap). Furthermore, the typical trajector is line-shaped. To find more core aspects of meaning of *over* and to determine which of the occurrences would be the most prototypical meaning, the (derivational) relations between the diverse occurrences can be analyzed.

Within the first main group of meanings, two derivational relations should be clear now: because a line trajector is more typical than a point trajector, it can be stated that **over 1** is a derivative of **over 3**, and that **over 2** is a derivative of **over 5**. The models indeed indicate that **over 1** and **over 3**, and **over 2** and **over 5**, are strongly similar. The only difference between **over 1** and **over 3** is that the trajector of the latter is a line, whereas the trajector of the former is a point. Both top views indicate coincidence, and all non-top views indicate separation (no intersection). Also the models of **over 2** and **over 5** differ only with respect to the nature of the trajector, and also here the top views indicate coincidence and the other views indicate separation.

Over 4 seems to be a derived case too. This occurrence is the only meaning in which the trajector is vertically extended while this is not enforced by the shape of the landmark, so this aspect of meaning is not a core aspect. The model of **over 4** is most similar to the model of **over 3**. In both cases, the trajector is a line that intersects with the point landmark in the top view and that is distinct from the point landmark in (at least) one of the side views. The only difference is that in view 2 the trajector of **over 3** is visible as a point that is not contacting the landmark, whereas the trajector of **over 4** is a line of which the boundary intersects with the landmark. The trajector of **over 3** is thus strict higher (or lower) than the landmark, whereas part of the trajector of **over 4** is at the same level as is the landmark. Within this first category of meanings, **over 1**, **over 2**, and **over 4** thus are derived cases, and **over 3** and

over 5 are in the running to be acclaimed the prototype.

Also within the second category of meanings some derivational relations can be found. **Over 9** and **over 10** are end-point derivatives of, respectively, **over 6** and **over 7**, and **over 11** is the 'half' variant of **over 8**. **Over 6** and **over 8**, of which the modelings are identical, and **over 7**, thus qualify as possibly most prototypical meanings. The models of **over 6** and **over 8** on the one hand, and **over 7** on the other, display quite a few similarities. First of all, the top views of these two modelings are exactly the same. Furthermore, the fact that the trajector has the same vertical extension as the landmark is a commonality; in both cases this vertical extension is visible in view 2. The difference between the occurrences consists in the fact that the landmark (and, consequently, the trajector) of **over 6** has extension in the vertical direction as well, instead of only in one horizontal direction.

The similarity of **over 8** and its 'half' variant **over 11** is also clear from the models. In the top view three intersections differ: $\delta L1 \cap L2^\circ$, $L1^- \cap L2^\circ$, and $L1^- \cap \delta L2$. This indicates that the trajector of **over 11** does stick out of the landmark (in horizontal direction) only on one side; the other boundary point of the trajector is within the horizontal scope of the landmark. The second views of these two meanings coincide: in both cases the vertical extension of the trajector is the same as the vertical extension of the landmark. In view 3 one intersection differs ($\delta L1 \cap \delta L2$), indicating that one of the boundary points of the trajector of **over 11** does intersect with the boundary of the landmark, whereas the boundary points of **over 8** do not.

In the last category, the models provide few motivation to distinguish derivational relations. The only relation that can be ascribed to the meanings in this category is that the meaning of **over 13** is a derivative of the meanings of **over 12** and **over 14**. These latter two meanings have aspects that are shared by most other occurrences of this preposition, namely that in the top view the trajector and the landmark do intersect. **Over 13** is the only one of all occurrences for which this aspect of meaning does not hold, and therefore this occurrence should be seen as less prototypical.

As was said above, the third category contains meanings that are derived from the more primary 'above and across' meanings of *over*. The prototype of this preposition, accordingly, should be sought in the first two categories. No strong evidence can be found, however, to decide whether the meanings in category 1 or those in category 2 are more prototypical. Nevertheless, the following can be noted.

The meanings in the first category seem to be more 'exclusively' occurrences of *over*. When slight changes are applied to occurrences of the second category, after all, other prepositions than *over* (for example: *across*) become applicable to these configurations. The occurrences of the first category, on the contrary, are much less similar to occurrences of other prepositions; other prepositions are less applicable on the occurrences in the first category than on meanings of the second category. This might imply that the meanings in the first category are more typical occurrences of *over* than those in the second.

Judging the models

The models of the meanings of *over* have one important shortcoming: the 'above' aspect of meaning, that is present in almost all occurrences of this preposition, can not completely be represented. This is not surprising, for this aspect of meaning is a projective and a non-topological aspect. (Thanks to the properties of the 3D-9-intersection model, that the 'default' 9-intersection model lack, partially the 'above' aspect of meaning nevertheless *can* be represented: the fact that trajector and landmark are above each other is determined.) Apart from the fact that this important aspect is represented only partially, the models of *over* are quite complete.

The models provide insights into the meanings of *over*, and in the relations between the diverse meanings of this preposition and to meanings of other prepositions. One insight that the models yield is the following. Almost all of the occurrences of *over* share the aspect of meaning that trajector and landmark are above each other. The models represent this aspect and in this way the diverse, strongly different occurrences of this preposition are united. Furthermore, the meanings of *over* are distinguished from the meanings of the other prepositions, because only the models of *over* contain this aspect of meaning. The models thus show that the various meanings of *over* - no matter how diverse these are - indeed are strongly related, as senses of one and the same preposition.

Another insight that is provided by the modelings is the importance of the distinction between contact and non-contact cases. Thanks to focussing on topological aspects of meaning, this aspect was highlighted. This is because it is necessary to decide about the nature of the relation between trajector and landmark - contacting or not - when topological models are to be built. These topological differences indeed appeared to be relevant: two main categories of meanings of *over*, within which the occurrences are strongly related to each other, have the contact/non-contact distinction as discriminating property.

In general, the modelings of *over* have shown that this preposition is a complex one. It is the only of the five discussed prepositions in which a projective aspect of meaning is crucial. Furthermore, a lot of different kinds of trajectors and landmarks occur: these can be one-, two-, or three-dimensional, and have various different shapes. Also the topological relations between the trajector and the landmark vary widely: intersections exist between interiors of both objects, but also, to mention a few, between the interior of the trajector and the boundary of the landmark, and, for example, between the landmark and the boundary of the trajector.

4.9 General comparison and analysis of the modelings

In the previous sections, modelings of the diverse occurrences of the five prepositions were built and analyzed, and for each of the prepositions the diverse modelings of its meanings were compared. Furthermore, a cross-preposition comparison of the modelings of **across** and **through** is present in the above sections. A general, cross-preposition comparison of all the modelings, however, was not yet made. In this section some similarities and resemblances between models of different prepositions will be discussed.

When all the models are considered, a few models, of different prepositions, appear to be equal. The model of **across 5** is exactly the same as the model of **around 10**, and the model of **through 6** is the same as the model of **around 11**. (These four meanings will be discussed later on, together with other meanings that can be grouped with these.) Apart from these cases, no models (of different prepositions) can be found that are the same. Some groupings of meanings nevertheless can be made, based on certain aspects of meaning that appear from the models.

A first grouping that can be made results from distinguishing one- and two-dimensional modelings from three-dimensional ones. The following meanings have modelings that extend in less than three dimensions: both occurrences of *along* (of which the modeling of **along 2** even is one-dimensional), all occurrences of *across*, **around 1** to **around 6** and **around 8** to **around 10**, **over 1** (of which the modeling even is one-dimensional), **over 3** and **over 4**, and **over 6** to **over 14**[7]. The modelings of all occurrences of *through*, of **around 7** and **around 11**, of **over 2** and **over 5**, and of **over 12** to **over 14**[8] are three-dimensional.

What can be gathered from these partitioning? What does it mean that a meaning of a preposition matches a two- or a three-dimensional configuration? Why are some meanings two-, and other three-dimensional? First, a remark should be made concerning the occurrences of the second category of *over* (**over 6** tot **over 11**). The choice was made to represent these meanings as two-dimensional (having extension only in the vertical and one of the horizontal dimensions), although the configurations of some of these meanings in fact can be three-dimensional.

Considering all models, a first things that stands out is that many meanings match two-dimensional configurations. This might surprise one, for the world we interact with is three-dimensional. Apparently, two-dimensional configurations are nevertheless sufficient to match meanings of linguistic expressions we apply to real-world configurations. The third dimension might be irrelevant to understand and recognize a certain spatial structure. This is in line with the idea of schematization: simple, possibly two-dimensional structures help to make sense of the complex, three-dimensional world. Probably, if three-dimensionality is not an inherent aspect of the meaning of a certain occurrence, then that meaning is understood as a two-dimensional spatial structure. If three-dimensionality is an inherent aspect of a certain meaning, then of course the meaning matches a three-dimensional configuration. This holds for all the meanings that have three-dimensional models.

Considering the two-dimensional models, furthermore, it appears that many of these occurrences are horizontal configurations. Most of the *across* occurrences explicitly are horizontal, but also in the case of *around* and *across* it appears that the meanings usually apply to horizontal configurations. Considering the way the world is, and the way we interact with it, it is not surprising that among the meaningful spatial structures that exist, horizontal ones are most common.

Over, as was said, is an exception to this. As is not surprising, most of the models of *over* (all but (the contact cases of) the 'covering senses' **over 12** and **over 14**) are vertically extended. This vertical extension, obviously, is necessary to express the 'above' aspect of meaning. Most cases of *over* have extension in one or both of the horizontal dimensions too, which makes the configurations two- or three-dimensional.

The models of all five prepositions can also be categorized in another way.

[7]Regarding the last three occurrences of *over* it should be noted that only the contact cases of these meanings are represented in two-dimensional models.

[8]The modelings of only the non-contact cases of these three occurrences of *over* are three-dimensional.

The trajector can be either inside or outside the landmark (or something in between). Considering the occurrences in which the trajector is outside the landmark, it appears that in most of these cases the shape and nature of the landmark are quite irrelevant. This holds in the case of most of the meanings of *around* and of some meanings of *over*. It is not surprising that the landmark shape is of minor importance in the cases in which the trajector is outside the landmark. When the trajector is outside the landmark, after all, the shape of the trajector is less dependent on the shape of the landmark than when the trajector is inside or coinciding with the landmark.

For the occurrences in which the shape and nature of the landmark are quite irrelevant, sometimes the choice was made to model the landmark as a point and sometimes as a region. Because this choice didn't influence the extent to which the model is an adequate representation of the corresponding meaning very much, the choice could be based on modeling convenience considerations. Whether the point or the region was chosen depended on which choice would result in the most complete model. In the case of **around 6**, for example, the landmark is modeled as a point, because then it was easier to model the nature of the trajector correctly than when a region would be chosen for the landmark. The trajector of **around 1**, in contrast, was modeled as a region.

Now, another group of occurrences, of different prepositions, will be discussed. This group consists of the following meanings: **across 5**, **through 6**, **around 6**, **around 7**, **around10**, **around 11**, **over 12**, **over 13**, and **over 14**. The fact that these meanings have certain relevant properties in common can not be deduced from the models. This is because these meanings were not quite easily modelable; in fact the modelings of these occurrences are quite incomplete. The fact that these meanings are similar manifests itself in the fact that the prepositions can be combined with "all" ("all across", "all around", etc.)[9].

In the case of all the occurrences within this group, the trajector extends *within a certain area (or, in the three-dimensional cases: space)* - but does not necessarily completely cover that area (or space). The preposition expresses that the trajector is present at various locations within that area or space (for example: "bees swarm around a flower": bees are at various locations within an approximately circular space in the centre of which the flower is). When "all" is added, it is additionally expressed that the area is covered at least to a certain degree. This can be understood as a quantificational aspect of meaning: the trajector should be present in all parts of the area - given a certain partitioning. This 'partitioning' can be anything: in the case of "throwaways all through the house" it might be the case, for example, that throwaways should be present in all rooms of the house.

The trajector of all these occurrences can also have variable natures. It can be massive, in which case the whole area or shape will be covered. Examples of this variant are: "Paint was all over the floor." and "The atmosphere is all around the globe.". Another possibility is that the trajector consist of various lines, or of various points (which can be seen as (end) points on imaginary lines). Examples of this variant are "Bees are swarming around the flower.",

[9]One might object that also in some other occurrences, "all" can be added in front of the preposition. This is the case, for example, with *along*: "We walked all along the river.". Such occurrences, nevertheless, aren't quantificational, because it isn't the case that the trajector extends within some area or plane. The trajector is line-shaped instead.

“He traveled all across the country.” and “Throwaways are all through the house.”.

Because of the quantificational aspect of the meanings of all these occurrences, the (3D-)9-intersection model cannot adequately represent these meanings. The trajector should be present within some area or space, covering that area or space *to some extent*. It is not sufficient to only represent that the trajector is within the area or space; also information about the nature or extent of the overlap should be represented. It is not possible to do this in the 9-intersection model.

This group of ‘quantificational’ occurrences can be split into subcategories. In some cases, the trajector does not extend outside the landmark. In these cases the area or space in which the trajector has extension is equal to the landmark. The occurrences that fall within this subcategory are **across 5**, **through 6**, **around 10**, and **around 11**. In other cases, the trajector extends in some area or space around the landmark. **Around 6** (two-dimensional) and **around 7** (three-dimensional) together constitute this subcategory. The ‘covering senses’ of *over* constitute the final subcategory. In these cases, the trajector extends within an area that is parallel to, and close to (possibly contacting) the (surface of the) landmark and that is at least as large as this landmark surface.

As was observed above, the model of **across 5** is the same as the model of **around 10**, and the model of **through 6** is the same as the model of **around 11**. Is this due to limitations of the model or are these occurrences indeed equal to each other? It seems to me that the difference in meaning is very subtle. The meaning of **across 5**, which can be seen as a derived case of **across 3**, is somewhat ‘across-like’: the trajector consists of (approximately) straight lines, that extend in various directions, crossing the landmark. (As a derived variant, the landmark might also be scattered, consisting of points instead of of lines.) The trajector of **around 10**, on the other hand, doesn’t have that ‘straight line’ nature of *across*. **Around 10** can be seen as a derivative of **around 9**: the trajector still is curved, but, as opposed to the trajector of **around 9**, now it isn’t a complete circle, but some random curved lines instead. (Also in the case of this occurrence, the trajector can be scattered, point-like instead of line-like.) **Through 6** and **around 11**, which are three-dimensional variants of **across 5** and **around 10**, differ in the same way.

5 Discussion

5.1 The meaning of the results

The research presented in this thesis has as a result more insight into the spatial semantics of a number of prepositions. The insight that is gained is provided with the aid of a formal and spatial modeling tool, with which models of the meanings of the prepositions are built. This modeling tool has topological aspects of meaning as its focus.

The work presented in this thesis contributes to linguistics and cognitive science in a number of ways. First of all, insight is gained into the nature of the meanings of the five prepositions that are analyzed. Moreover, insight is provided into the relations and resemblances between the diverse meanings of these polysemous prepositions. Especially regarding these relations and resemblances between meanings, the formal nature of the modeling tool was of great value. Because aspects of meaning were distinguished formally, systematic analysis and comparison of the meanings was made possible.

Secondly, the fact that my approach yields some interesting results, implies that a formal approach of semantics can be valuable. My research also shows that the ideas from Cognitive Linguistics can be successfully combined with a formal approach of language and meaning. This might be a motivation for proponents of this movement to deviate from informal research methods to a more formal approach.

Also on a more detailed level, my approach and methodology bring new ideas to the field of research. The 9-intersection model was applied before on spatial natural-language terms, but the three-dimensional 9-intersection model is completely new and yields the possibility to represent meanings much better than a two-dimensional model can. Furthermore, the application of such a model with the goal of gaining insight into the *resemblances* between various meanings of a preposition is new, and appeared to be valuable. Specifically for the analysis of relations and resemblances between meanings, the 3D-9-intersection model can be a useful tool.

Thirdly, my research shows that meaning indeed can be found in spatial structures. A meaning of a preposition can be represented *as* some spatial structure. This fits into the idea of Embodied and Embedded Cognition that meaning stems from our bodily interaction with the (spatial) environment. (The results of my research thus might be considered supportive for the framework of EEC.)

Furthermore, representing senses of words as spatial structures is elegant, because in this way no language is used to define the meaning of linguistic expressions. A circularity is prevented: the meanings of linguistic expressions are defined without making use of linguistic expressions. Spatial meanings of prepositions thus can be defined non-linguistically, and in this way are grounded outside language. Moreover, because spatial terms are used metaphorically and constitute a skeleton for other domains of language, a general semantic representation of language could be built based on spatial structures.

5.2 Limitations and further research

Of course, my research is not perfect and has certain shortcomings. Regarding certain aspects, the research might have limited scope and besides, some aspects of the methodology and approach that were chosen might have their disadvantages.

One indication that my approach is not perfect can be found in the fact that some of the modelings are incomplete. In the case of some of the occurrences, non-topological aspects of meaning that could not be represented are important aspects of meaning. In these cases, the 3D-9-intersection model appears not to suffice to represent the meaning of the concerned occurrence. This shortcoming of the model emerges, for example, in the case of most of the occurrences of *over*, in which the projective aspect of meaning 'above' is crucial, and in some of the cases of *around*, in which the round shape of the trajector is important. Such aspects of meaning could be represented in the modelings at most partially.

A disadvantage of focussing exclusively on topological aspects of meaning, accordingly, is that, although topological aspects of meaning often are core aspects of meaning, sometimes non-topological aspects of meaning also are important, and this kind of aspects can not completely be modeled when the chosen modeling tool is used.

As was stated earlier in this thesis, a model generally has the strongest explanatory power when it is relatively simple, focussing on a restricted number of aspects of the phenomenon under consideration. However, as was also suggested earlier, it might work well to start with a simple model, but then adding more and more aspects. Following this line of thinking, it might be a possibility to extend the 3D-9-intersection model by adding non-topological aspects of meaning.

This idea is not completely new. In [10] and [25], for example, metric details were suggested that can be added to the 9-intersection model. The metric details that were added can define non-topological properties of a spatial relation between two objects. For example, the relative length or size of the part of a line, region or region boundary that is on one side of the intersection can be specified, or the relative distance between the region boundary and certain parts of the line.

My three-dimensional 9-intersection model might be extended in a similar way. Using this extended model, some meanings of the five prepositions that were analyzed in this thesis could be represented much better than the 'normal' 3D-9-intersection model made possible. The meaning of **along 1**, to mention one, could be represented by specifying, in addition to what what the 'normal' 3D-9-intersection model represents, that all parts of the trajector line are on some relatively small distance from the landmark boundary.

For many non-topological aspects of meaning, such an extension would be quite valuable. For projective aspects of meaning, however, such as the 'above' aspect that is present in most occurrences of *over*, adding metric details will not be sufficient. To be able to completely represent meanings in which projective aspects are important, other enhancements of the modeling tool are needed. Specifying that one of the views of a 3D-9-intersection model is, for example, a top view - as is done already in the present work - might be a first step.

Another type of extension of the 3D-9-intersection model would be to extent the set of building blocks of the model. In addition to the point, line, and region, the closed path might be accepted as one of the types of geometry the models are built of. As the occurrences of *around* have illustrated, this can be a valuable extension of the model. Furthermore, an advantage of adding the closed path to the set of building blocks is that this doesn't change the model drastically. The model will have more expressive power and still be a topological one.

Not only by extending and enhancing the modeling tool that was used, but also in other ways my research could be improved and continued. My research, for example, concerned only five preposition. It was argued earlier in this thesis, that this grasp of route prepositions is a quite representative one, containing five words that differ in many respects and that together cover the variety of route prepositions sufficiently. Other (route) prepositions, however, might also be a very interesting object of study. My modeling and analyzing approach could thus be applied to other prepositions as well. What would the model show about the semantics of, for example, *under*, *towards*, and *between*?

An especially interesting continuation of my research would be to deviate from the spatial domain and to try to describe the semantics of a broader part of language, starting from this spatial basis. If Lakoff and Johnson ([16]) are right, spatial structure is transferred through metaphor to other domains of language, and functions as a skeleton for more abstract linguistic expressions. It might be very interesting to map out these metaphors: how are complex, abstract meanings constructed, using the spatial structures that constitute the meanings of, for example, the prepositions that were discussed in this thesis? Can the metaphorical senses of, for example *through* and *over*, be explained using 3D-9-intersection modelings?

Finally, some remarks can be made regarding the purely methodological aspects of my research. The methodology that was applied in this thesis is modeling: a model of meaning is built that provides insight into the semantics of the prepositions. This methodology would be even stronger when it would be combined with other methods. In particular, it would be a valuable extension of the research presented in this thesis to include an empirical part. The models that are built can function as a hypothesis that subsequently could be tested in an experiment. Such an experiment could indicate whether the distinguished meanings and their representations in the model indeed match the concepts we human beings employ, and the meanings we ascribe to the concerned prepositions.

As would be clear now, the research presented in this thesis fits within a broad and interdisciplinary field of research, in which a lot more is to be explored. My research has been a small contribution to a theory of the (spatial) semantics of human language, and can be expanded in several ways to work towards a more complete theory. Furthermore, I hope to have shown that combining insights and methods from different disciplines can be valuable. Hopefully, my research can motivate researchers to look across the boundaries of traditional fields of research; I am convinced that that is the way to come to a better understanding of human language and cognition.

References

[1] L. Boroditsky and M. Ramscar. The Roles of Body and Mind in Abstract Thought. *Psychological Science, 13(2), 185-188*, 2002.

[2] D. Casasanto and L. Boroditsky. Time in the Mind: Using space to think about time. *Cognition (106), 579593*, 2008.

[3] D. Casasanto, O. Fotakopoulou, and L. Boroditsky. Space and Time in the Child's Mind: Evidence for a Cross-Dimensional Asymmetry. *Cognitive Science 34(3), 387-405*, 2010.

[4] A. Clark. *Being There: Putting Brain, Body and World Together Again.* Cambridge MA: The MIT Press, 1997.

[5] H. Clark. *In T. Moore (Ed.), Cognitive development and the acquisition of language (27-63)*, chapter Space, Time, Semantics and the Child. New York: Academic Press, 1973.

[6] H. Cuyckens. Family resemblance in the Dutch spatial prepositions *door* and *langs*. *Cognitive Linguistics, 6:2/3, p. 183-207*, 1995.

[7] R. Dewell. Moving around, The role of the conceptualizer in semantic interpretation. *Cognitive Linguistics 18,3*, 2007.

[8] R. Dewell. Moving Over, The role of systematic semantic processes in defining individual lexemes. *Annual Review of Cognitive Linguistics, Volume 5,Number 1, pp. 271-288(18)*, 2007.

[9] M. Egenhofer and J. Herring. Categorizing Binary Topological Relations Between Regions, Lines, and Points in Geographic Databases. Technical report, Department of Surveying Engineering, University of Maine, Orono, ME, 1991.

[10] M. Egenhofer and A.R. Shariff. Metric Details for Natural-Language Spatial Relations. *Transactions on Information Systems, Volume 16, Number 4, 295-321*, 1998.

[11] B.W. Hawkins. *The semantics of English spatial prepositions.* PhD thesis, University of California, San Diego, 1984.

[12] A. Herskovits. *Representation and processing of spatial expressions*, chapter Schematization. Mahwah, NJ: Lawrence Erlbaum Associates Publishers, 1998.

[13] P. Kay and C. McDaniel. The linguistic significance of the meanings of color terms. *Language 54, 610-646*, 1978.

[14] C. Kray, J. Baus, H. Zimmer, and H. Speiser. Two path prepositions: Along and past. In *Spatial Information Theory (Proceedings of COSIT)*, 2001.

[15] G. Lakoff. *Women, fire, and dangerous things: What categories reveal about the mind.* Chicago: University of Chicago, 1987.

[16] G. Lakoff and M. Johnson. *Metaphors we live by.* Chicago: University of Chicago, 1980.

[17] R. Langacker. *Foundations of Cognitive Grammar. 2 vols.* Stanford: Stanford University Press, 1987, 1991.

[18] D. Mark and M. Egenhofer. Modeling Spatial Relations Between Lines and Regions: Combining Formal Mathematical Models and Human Subject Testing. *Cartography and Geographical Information Systems 21 (3): 195-212*, 1994.

[19] T. Matlock, M. Ramscar, and L. Boroditsky. The experiential link between spatial and temporal language. *Cognitive Science, 29, 655-664*, 2005.

[20] M. Merleau-Ponty. *Phenomenology of Perception.* London: Routledge, 2005. (Originally published in 1945 as Phénoménology de la perception).

[21] J. Piaget and B. Inhelder. *The Child's Conception of Space.* New York: W.W. Norton, 1967.

[22] D. Pullar and M. Egenhofer. Towards Formal Definitions of Topological Relations Among Spatial Objects. In *Third International Symposium on Spatial Data Handling*, 1988.

[23] H. Putnam. *Reason, Truth, and History.* Cambridge: Cambridge University Press, 1981.

[24] T. Regier. *The human semantic potential: Spatial language and constrained connectionism.* Cambridge, MA: MIT Press, 1996.

[25] A. R. Shariff, M. Egenhofer, and D. Mark. Natural-Language Spatial Relations Between Linear and Areal Objects: The Topology and Metric of English-Language Terms. *International Journal of Geographical Information Science 12, 215-246*, 1998.

[26] L. Talmy. *Toward a cognitive semantics*, chapter How language structures space. Cambridge, MA: Massachusetts Institute of Technology, 2000.

[27] A. Tyler and V. Evans. Reconsidering Prepositional Polysemy Networks: The Case of Over. *Language, 77, 4, 724-765.*, 2001.

[28] M. Worboys. A Geometric Model for Planar Geographical Objects. *International Journal of Geographical Information Systems 6, 353-372*, 1992.