STRUCTURING WAYFINDING TASKS WITH IMAGE SCHEMATA

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A THESIS
Submitted in Partial Fulfillment of the
Requirements for the Degree of
Master of Science
(in Spatial Information Science and Engineering)

The Graduate School
University of Maine
December, 1997

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Wayfinding is a basic activity that people do throughout their entire lives as they navigate from one place to another. Many theories of spatial cognition have been developed to account for this behavior. But most of the computational models focus on knowledge representation (e.g., cognitive maps) and do not consider the process of structuring wayfinding tasks and space. This thesis presents a methodology based on image schemata to structure people's wayfinding tasks. Image schemata are recurring mental patterns (e.g., the CONTAINER or PATH schema) that people use to understand a spatial situation. They are highly structured and grounded in people's experience.

The area of our attention is airport space which is used as a case study. Many airports are badly designed and passengers are often unfamiliar with the particulars of the situations. We compare two selected airports in regard to the ease of performing a common wayfinding task. In order to do so, the methodology of structuring space with image schemata is combined with a proposed wayfinding model. We show that sequences of image schemata are sufficient to describe wayfinding tasks in spatial environments at an abstract level. Therefore, they can be used to compare the complexity of wayfinding tasks for different airports.

The integration of image schemata into the design process of spatial environments such as airports (i.e., the implementation of our method in a computer system) will help to identify architectural problems with regard to wayfinding prior to construction. Our structuring methodology can be generalized and will, thereby, contribute to the design of future geographic information systems that are supposed to integrate elements of human spatial understanding.

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ACKNOWLEDGMENTS

I am very grateful for having had the opportunity to work with Dr. Max Egenhofer, my thesis advisor. His guidance, advice, ideas, and encouragement made it a pleasure for me to do this work. I would also like to thank the other members of my advisory committee, Dr. Werner Kuhn, Dr. Andrew Frank, and Dr. Kate Beard-Tisdale for their comments and suggestions for improvement.

I want to thank Dr. Scott Freundschuh, Dr. Stephen Hirtle, Dr. David Mark, and Dr. Dan Montello for commenting on my work and providing me with numerous references. Thanks also to Julia Finkernagel and Heinz Horatschek for showing me around Frankfurt and Vienna International Airports.

My friends and colleagues at the Department of Spatial Information Science and Engineering have made my stay a wonderful experience, both scientifically and personally. Special thanks go out to Thomas Bittner, “il capo” Andreas Blaser, Dr. Doug Flewelling, Kathleen Hornsby, and Andrea Rodríguez.

Thomas Windholz has been a great friend and roommate to me. He always helped me when I needed something, cheered me up with country music, and made a terrific chess coach. Thanks also to Eric Pol and Julio Fernández for taking the time to be my chauffeurs. It would have been long walks without them.

Thanks to Waterloo & Robinson, Wolfgang Ambros, R.E.M., and all the other great musicians who helped to keep me going during the days and nights of working on this thesis.

Last but not least I want to thank my family, especially my parents for their love and support during all of my life. It has always been comforting to know that they are

there for me. Thanks also to Gwen for becoming a part of my life and for correcting my English.

This work has been partially supported by the NCGIA under NSF grants SBR-8810917 and SBR-9700465. Additional funding was provided by the Austrian government. I am grateful for this support.

To the memory of my grandfathers, Dr. Gustav Hubert and Edmund Raubal, who I am sure would be very proud of me.

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1. INTRODUCTION

> The Earth is not a brute fact to be taken as given, but always inserted between Man and the Earth is an ‘interpretation’, a structure and a perspective on the world, an ‘enlightenment’ which reveals the real within the real, a point of departure from which understanding develops.
> Eric Dardel (1952): L’Homme et la Terre

People do wayfinding throughout their entire lives. They navigate from place to place, using common-sense knowledge. Such knowledge is mediated by structures and categories of understanding people’s daily experiences in the space they live (Johnson 1987). Wayfinding is a natural skill that people learn as small children (Piaget and Inhelder 1967) and develop as they grow up. It takes place in many different situations, such as driving across a country, walking in a city, or moving through a building (Gluck 1991). In all of these situations people have one thing in common: they use common-sense knowledge of geographic space.

Within the last years research on human wayfinding has mainly dealt with the exploration of cognitive representations and has neither focused on the processes of wayfinding (e.g., the information needs) themselves (Gluck 1991) nor on the design of spatial environments. In other words, most of the work has focused on what Norman (1988) calls “knowledge in the head” (i.e., internal knowledge) instead of “knowledge in the world” (i.e., external knowledge). But as Norman argues, people do not need to have all knowledge in the head in order to behave precisely. Knowledge can be distributed—partly in the head, partly in the world, and partly in the constraints of the world (Norman 1988 p.54). Norman further states that much of the information people need to perform a task is in the world and that the human mind is perfectly tailored to make sense of this world. Piaget and Inhelder (1967) have long since argued that spatial behavior and spatial representations are very different. They distinguished between *practical space* (i.e., acting in space) and *conceptual space* (i.e., representing space). In order to build real-world spaces that are easy to navigate it is necessary to find out about how people immediately understand spatial situations, i.e., how they make sense of practical space while performing a wayfinding task. Our work focuses on properties of environments (i.e., “knowledge in the world”) as perceived and cognized by people and, therefore, deals primarily with the exploration of practical space as defined by Piaget and Inhelder. It is important to investigate people’s perceptual and cognitive structures in order to be able to model them in future spatial information and design systems. These systems can then be used to simulate real-world applications, such as wayfinding tasks, in a cognitively plausible way, because they integrate human spatial concepts. The importance of human spatial cognition in the area of geographic information systems (GIS) is also indicated by various research agendas (Mark *et al.* 1997, UCGIS 1996).

1.1 WAYFINDING IN AIRPORTS

This thesis deals with wayfinding in airports—a special case of moving through a building. Passengers at an airport have to find their way from check-in to their gate, from their gate to the baggage claim, and between gates. They are often in a hurry and must avoid getting lost. This can be a difficult task, because many airports are poorly designed, have poor signage, and are densely crowded. Also, many passengers are unfamiliar with the particular space and fast motion, which puts them in stressful situations. In an emergency case things become even worse. One could see the consequences just recently when a fire accident happened at the Düsseldorf Airport in Germany.

> On the 11th of April 1996 welding caused a big fire accident at the Düsseldorf Airport in Germany. 16 people died in the accident due to smoke-gas and 63 were severely injured.

> The airport management confirmed that during the fire a tape with wrong directions for passengers was played. Because of this passengers hurried directly into the burning arrival hall. It was highly difficult for the fire department to guide people into the secure departure hall.
>
> A huge body of men from the fire department tried to rescue passengers out of the closed danger zone until late night.
>
> (Standard 1996)

Bad architectural design (e.g., low passageways) was also blamed for the deadly outcome of this catastrophe. Had the airport been constructed with the intention of offering navigational knowledge (e.g., finding the nearest emergency exit in this case) through its design alone, then it would have been easier for passengers to find their way out of the building.

1.2 BACKGROUND OF THE THESIS

In order to make wayfinding easier for passengers at an airport it is necessary to design airport space in such a way that it facilitates people's structuring processes of tasks and space. Buildings can only be designed in a user-friendly way if one takes into account how people understand and structure space. Although most of the literature has been focusing on knowledge representation, some research has also been done on the process of structuring space itself, e.g., the architect Christopher Alexander developed a pattern language consisting of 253 patterns. These patterns are based on the experiential nature of things and help people to structure their environment (Alexander *et al.* 1977). Johnson (1987) proposed that people use so-called *image schemata* to understand the world in which they live. Image schemata are recurring mental patterns that help people to structure space in order to know what to do with it. These patterns are highly structured themselves and grounded in people's experience.

Image schemata fit into the category of so-called *alternative conceptualizations* or *cognitive models of space*—models that are built upon people's experiences with their environment. It has been argued that such conceptualizations have to be integrated into future GIS in order to match people's thinking more closely and, therefore, facilitate people's interaction with these systems (Mark 1989). The literature offers many different cognitive categorizations of space (Freundschuh and Egenhofer 1997). Couclelis and Gale (1986) proposed a formal framework based on algebraic structures of groups to distinguish six kinds of spaces: (1) pure Euclidean space, (2) physical space, (3) sensorimotor space, (4) perceptual space, (5) cognitive space, and (6) symbolic space. The gap between *perceptual space,* i.e., objects are apprehended through the senses at one place and one time, and *cognitive space,* i.e., sensory images of objects are linked to elements of cognition, such as beliefs and knowledge, might just be a definitional one because there seems to be a strong connection between the two. As Lee (1973) pointed out, percepts are not free of concepts, and concepts are not free of percepts. In order to link perceptual and cognitive space some bridges need to be built. A theoretical framework that forms one possible bridge was established by Talmy (1996). He adopted the notion of *ception* which includes the processing of sensory stimulation, mental imagery, and continuously experienced thought and affect. Image schemata could be part of such a framework because they are cognitive concepts that also occur in the perceptual domain. People sense these patterns visually, as well as they think about them in an abstract way.

1.3 GOAL AND HYPOTHESIS

The goal of this thesis is the development of a methodology to structure wayfinding tasks and space with elements of human perception and cognition. This methodology is then used in combination with a proposed wayfinding model to measure the complexity of a particular space in regard to a certain wayfinding task. The hypothesis is twofold:

- First, *representing wayfinding tasks at airports through image schemata is an appropriate method to determine the critical elements (i.e., the choices and clues) of a wayfinding model*.
- Second, *these elements account for the complexity of the wayfinding tasks as rated by travelers*.

1.4 RESEARCH DESIGN

The field of our research is human wayfinding in general and human spatial concepts (i.e., perceptual and cognitive structures of space) in particular. We do not investigate representational aspects, such as cognitive maps, but focus on properties of spatial environments as immediately perceived and cognized by people. Another important subfield that is of concern in this thesis is human spatial reasoning[1].

Based on previous work in the areas of psychology, cognitive science, artificial intelligence, urban planning, architecture, and geography, we investigate the field of human wayfinding. We look at the performance literature (i.e., empirical studies on how people find their ways) as well as the competence literature (i.e., cognitive wayfinding models). The latter includes simulations of spatial cognitive processes using computational models. In addition we deal with research on common-sense knowledge and reasoning, and *Naive Geography* (Egenhofer and Mark 1995). These areas are closely related to the methodology we develop later on.

The research in this thesis is divided into two major parts:

1.4.1 General Methodology Development

The first part of our research focuses on the development of a general methodology to structure wayfinding tasks and space with elements of human perception and cognition. We introduce the term *image schema* as the fundamental element of our methodology and explain why it is of importance for human common-sense reasoning and wayfinding. Based on image schemata we establish the general methodology that consists of four sequential stages: (1) a task sequence is formulated; (2) during interviews people describe their spatial experiences while performing a wayfinding task in the application space; (3) these interviews are analyzed and image schemata extracted; and (4) the extracted image schemata are used to structure the wayfinding task.

1.4.2 Application of Methodology

In the second research part we apply the general methodology to wayfinding in airports in order to demonstrate its usefulness and applicability. We use the four steps of the methodology in combination with a proposed wayfinding model to compare the

[1] Frank (1992) defines spatial reasoning as any reasoning process that relates to objects in space and makes use of their location, position, shape, etc.

complexity of two different airports with regard to people performing a common wayfinding task. The two airports (i.e., Vienna International Airport in Austria and Frankfurt International Airport in Germany) were selected based on the results of an informal questionnaire where we asked frequent flyers at what airports it was easiest or most difficult for them to find the place they wanted to go. The results prove our hypothesis because they show that sequences of image schemata are sufficient to describe wayfinding tasks in airports at an abstract level and can be used to compare the complexity of wayfinding tasks for different airports.

1.5 Relevance of the Work

Our methodology will help to design airport space in such a way that it facilitates wayfinding, because passengers can mainly rely on common-sense rather than expert geographic knowledge. The expected benefits are increased

- *passenger satisfaction*—passengers will save time when doing certain tasks, such as finding the right gate, emergency exit, or duty free store;
- *airport safety*—in an emergency case people will find the emergency exits much faster; and
- *airline profitability*—airlines will save money which they currently loose due to passengers and, therefore, airplanes being late.

An eventual implementation of the methodology will lead to spatial information and design systems that can be used to test airport space or other public buildings in the design phase for complexity of particular wayfinding tasks people have to perform. The structuring methodology will also highlight relevant concepts that are to be part of a comprehensive theory of *Naive Geography* (Egenhofer and Mark 1995). It will, therefore, contribute to the design of future GIS that are supposed to support common-sense reasoning.

1.6 Organization of Thesis

Chapter 2 of this thesis reviews the literature on the two areas of common-sense knowledge and human wayfinding. In particular, it addresses empirical studies of how people find their ways in various large-scale spaces—such as urban environments, subway systems, and large buildings—, and computational wayfinding models. Chapter 3 introduces image schemata as the main component of our methodology. We explain their meaning, show examples, and describe their importance for people's structuring of wayfinding tasks. Finally, we show how image schemata relate to common-sense geographic knowledge and human wayfinding. In Chapter 4 we present a methodology to structure wayfinding tasks and space according to these elements of people's perception and cognition. We describe the four stages of the methodology—(1) task description, (2) interviewing, (3) extracting image schemata from the interviews, and (4) structuring wayfinding tasks and space with the extracted image schemata. In Chapter 5 the methodology is combined with a proposed wayfinding model to compare the complexity of a common wayfinding task in two different airports. A summary, conclusions, and directions for future work are presented in Chapter 6 of the thesis.

2. COMMON-SENSE KNOWLEDGE OF GEOGRAPHIC SPACE AND HUMAN WAYFINDING

Common sense is not so common.
Voltaire

Finding one's way in an airport relies on a variety of elements. People have to make intuitive and quick decisions while at the same time they must avoid getting lost. In this chapter we first review the state-of-the-art of two areas that deal with such topics, i.e., research on common-sense knowledge and human wayfinding. We then look at empirical studies of how people find their ways in different large-scale spaces and review computational wayfinding models.

2.1 COMMON-SENSE GEOGRAPHIC KNOWLEDGE AND NAIVE GEOGRAPHY

2.1.1 COMMON-SENSE KNOWLEDGE AND GIS

Starting with people's first experiences with the environment they are establishing knowledge about the world in which they live. People need such basic knowledge for their everyday activities, such as walking, eating, shopping, and learning, and call it *common-sense knowledge*. It comprises many different domains that have complex interactions. Understanding a situation often involves concepts of quantity, time, space, physics, plans, goals, needs, and communication (Davis 1990). In this thesis we focus on the domain of space, independent of any cultural and individual differences.

Kuipers (1978) defines common-sense (geographic) knowledge as follows:

> *Common-sense knowledge of space is knowledge about the physical environment that is acquired and used, generally without concentrated effort,*

> *to find and follow routes from one place to another, and to store and use the relative position of places.*

The current generation of GIS supports common-sense knowledge of geographic space only insufficiently. Calculations in these systems are based on Cartesian coordinate space (i.e., plane Euclidean geometry) and “the standard concepts of space are not always appropriate and force the user to transform tasks into often-inappropriate form” (Frank 1992). People have to deal with incomplete information and are able to fill in the missing gaps due to common-sense knowledge. It will be important for future GIS to include common-sense knowledge and reasoning concepts that people actually use, such as rules based on common sense, hierarchical schemata, and intuition. As pointed out by Egenhofer and Mark (1995), today’s GIS lack models that integrate different kinds of spatial concepts in a cognitively sound and plausible way.

Lifschitz (1995) finds a place for the theory of common-sense reasoning in the history of logic: “It provides an axiomatic basis for reasoning about the world inhabited by ‘agents’ like us—by agents who have beliefs and goals, who perform actions in order to reach these goals and, by doing so, change the state of the world.” He also highlights the use of defaults, one of the main features of common-sense reasoning. Defaults are values or propositions that are supposed to be true unless there is information that says otherwise.

2.1.2 Qualitative Reasoning

Instead of doing exact calculations, people most often apply qualitative methods of spatial reasoning (Frank 1996, Cohn 1995, Frank 1992, Freksa 1992) that rely on magnitudes and relative, instead of absolute, values. When people perceive space through different channels they arrive at various kinds of information that are usually qualitative in nature. People rarely move through the environment using rulers or tape measures. When visually viewing a scene the result is a retinal image that is of quantitative nature, but the knowledge people retrieve from this image is qualitative (Freksa 1991). Freksa argues that such knowledge is exactly what people need for the process of spatial reasoning and mentions three advantages: (1) expressive power of qualitative constraints based on their interaction (e.g., concept of transitivity), (2) independence from specific values and scale, and (3) invariance under transformations. As an example he introduces the aquarium metaphor where observers can locate fish by qualitative means, although they have to deal with incomplete, imprecise, and subjective knowledge. An important feature that is used during this process is called *conceptual neighborhood of relations*: if relative positions of objects change gradually, the change between neighboring spatial relations is just stepwise (Freksa 1992, Egenhofer and Al-Taha 1992).

People usually use topological instead of metrical information. Topological properties of objects stay invariant under such transformations as translations, rotations, or scalings. By using abstract geometrical analysis Piaget and Inhelder (1967) demonstrated that fundamental spatial concepts are topological, but not Euclidean at all. They showed that children start to conceptualize space by building up and using elementary topological relationships, such as proximity, separation, order, and enclosure.

2.1.3 NAIVE GEOGRAPHY

Naive Geography is a current field of study that deals with common-sense geographic worlds. It establishes the link between knowledge that people have about their surrounding geographic space and the development of formal models that integrate such knowledge. Egenhofer and Mark (1995) define Naive Geography as the study of "the body of knowledge that people have about the surrounding geographic world." This definition is based on Hayes's (1985) definition of *Naive Physics*, a field that investigates people's knowledge of the everyday physical world, such as people's intuitive ideas about falling rocks or evaporating liquids.

People use concepts of Naive Geography for spatial reasoning in their everyday lives; therefore, research in this area will help us to understand how people think and how they find their way in the geographic world. This information is essential in the design process of particular spaces such as airport space. It has to be the foremost goal of the designer to create microworlds in which people can easily move around. Passengers in an airport, for example, should be able to find their ways without a big effort, relying exclusively on common-sense knowledge. In the case of an emergency situation people must make intuitive judgments, because they do not have the time to interpret complicated emergency signs.

Egenhofer and Mark suggest two different research methodologies as part of the framework for developing Naive Geography. These are directly related to the two categories of human wayfinding research (Table 2.1).

Naive Geography	**Human Wayfinding**
The development of formalisms of naive geographic models for particular tasks.	Simulations of spatial cognitive processes using computational models (Section 2.3.2).
The testing and analyzing of formal models.	Empirical results of how people find their ways (Section 2.3.1).

Table 2.1: Relation between research methodologies in Naive Geography and categories of human wayfinding research.

2.2 HUMAN WAYFINDING

Human wayfinding research investigates the processes that take place when people orient themselves and navigate through space. Theories try to explain how people find their ways in the physical world, what they need to find them, how they communicate directions, and how people's verbal and visual abilities influence wayfinding. Lynch (1960 p.3) defines wayfinding as based on "a consistent use and organization of definite sensory cues from the external environment." Wayfinding takes place in many different situations in which people find themselves, such as driving across a country, walking in a city, or moving through a building (Gluck 1991). The ultimate goal of human wayfinding is to find the way from one place to another. The space in which human wayfinding usually[2] takes place is called large-scale space (Kuipers 1978). Because

[2] Human wayfinding can also take place in virtual spaces, such as virtual geographies for the World Wide Web (Dieberger and Bolter 1995) or maps. This thesis focuses on wayfinding in large-scale space.

objects are larger than people and can, therefore, not be moved, people have to navigate through large-scale space in order to learn about it. Examples for large-scale spaces are landscapes, cities, and houses. Complementary to large-scale space is small-scale space whose objects are smaller than people (e.g., things on a desktop). Small-scale space objects are the domain of Euclidean geometry and they are usually manipulable (Ittelson 1973, Downs and Stea 1977).

2.2.1 Spatial Knowledge and Cognition

People need to have spatial knowledge and various cognitive abilities in order to succeed in wayfinding (e.g., reading a map or following a path). Human spatial knowledge of geographic space is assumed to consist of three levels: (1) *landmark knowledge* comprises salient points of reference in the environment, (2) *route knowledge* puts landmarks into a sequence (e.g., navigation paths), and (3) *survey* or *configurational knowledge* allows people to locate landmarks and routes within a general frame of reference (i.e., incorporating Euclidean measurements) (Siegel and White 1975). The cognitive abilities depend on the task at hand. Finding one's way in a street network (Timpf *et al.* 1992, Car 1996) uses a different set of cognitive abilities than navigating from one room to another in a house. People are usually good in applying their individual skills to the task at hand: if their spatial skills are weak, they use verbal skills to navigate, and vice versa (Vanetti and Allen 1988).

2.2.2 Cognitive Maps

To successfully perform wayfinding, people need clues within their environment (i.e., knowledge in the world) or representations of spatial knowledge about their environment. One useful metaphor suggests that people have a *cognitive map* in their heads (Kuipers 1982)—a mental representation that corresponds to people's perceptions of the real world—although other metaphors, such as cognitive collage and spatial mental model (Tversky 1993), or cognitive atlas (Hirtle 1997) have also been proposed. Despite the fact that these representations are called *spatial*, it is important to notice that our memory has to integrate spatial information with non-spatial information (Gärling *et al.* 1984). Considering the process of acquiring spatial knowledge of an environment, the cognitive map develops from a mental landmark map to a mental route map and should eventually result in a mental survey map. The last stage is closest to a cartographic map, though it still contains inaccuracies and distortions[3]. Davis (1990) points out two main differences between cognitive and cartographic maps: a cognitive map may consist of different knowledge structures and it has to integrate incomplete, imprecise, and subjective knowledge. This is usually not the case for cartographic representations that represent information only pictorially and are reasonably accurate and complete. People construct and develop their cognitive maps based on the recording of information through perception, natural language, and inferences. Complex environmental structures can lead to slower development of cognitive maps and also to representational inaccuracies. Considering the structure of cognitive maps, there exist two classes of theories: hierarchical and non-hierarchical. Recent studies suggest that a hierarchical model is more appropriate for cognitive maps than a non-hierarchical (Hirtle and Heidorn 1993). It includes distinct patterns of encoding spatial information at local (e.g., Euclidean knowledge) and global levels (e.g., topological knowledge). Hierarchies can either be based on explicit evidence, such as physical boundaries, or implicit evidence, such as semantic and functional clusters (McNamara *et al.* 1989). Hierarchical structures are even imposed in spaces without any inherent structure. One consequence of hierarchies in cognitive maps is that they may have an influence on wayfinding performance (i.e., bias in spatial judgments such as distance estimates) (Hirtle and Jonides 1985). This effect was also confirmed in a study by Golledge *et al.* (1985) where a hierarchical representation of route elements was found to account for different errors depending on the choice point and the complexity of the segments.

Researchers from various disciplines have thoroughly investigated the role cognitive maps play in spatial behavior, spatial problem solving, acquisition, and learning (Kitchin 1994). Much less, however, has been found out about how people immediately understand different spatial situations while performing a wayfinding task. Gluck (1991) points out this lack of information by arguing that previous work on wayfinding concentrated on the description of the cognitive map and neglected affective and logistical concerns in most of the cases. As an alternative approach Gluck suggests

[3] According to Lynch (1960), these errors in cognitive maps are most often metrical and rarely topological.

to explore the information needs. He further envisions a typology of wayfinding scenarios and proposes the use of the *sense-making* investigation method.

> *Thus "sense-making" is a creative human process of understanding the world at a particular point in time and space limited by our physiological capacities, our present, past and future (Gluck 1991 p.129).*

Such understanding can be seen as a snapshot of common-sense knowledge of space and time and is, therefore, important for the process of common-sense spatial reasoning. The idea behind the sense-making method is to look at the wayfinding process itself instead of looking at the representation (i.e., the cognitive map).

2.3 HUMAN WAYFINDING PERFORMANCE

Human wayfinding research can be divided into two categories (Gluck 1991): performance and competence (Section 2.4). The literature on *performance* discusses empirical results of how people find their ways. Investigations are based on collecting individual's perceptions of distances, angles, or locations. An example for a typical experiment is the pairwise judgment of distance between points. Such experiments help in describing features of the cognitive map.

Kevin Lynch's (1960) "The Image of the City" is the first documentation of human wayfinding research in the literature. In a study he asked people of three US cities (i.e., Boston, Los Angeles, and Jersey City) how they viewed their city—what they liked and disliked. His goal was to develop a method for the evaluation of city form based on the concept of *imageability*[4], and to offer principles for city design. As part of the interviews people had to perform mental trips across their cities, describing the sequence of things and landmarks they would see along the way. Eventually they were asked whether it was easy to find their ways in the city or not. Based on his investigations Lynch divided the contents (i.e., the physical forms) of the city images into five classes: (1) paths, (2) edges (i.e., boundaries), (3) districts (i.e., regions), (4) nodes, and (5)

[4] "*Imageability*: that quality in a physical object which gives it a high probability of evoking a strong image in any given observer." (Lynch 1960 p.9)

landmarks. These elements were described as "the building blocks in the process of making firm, differentiated structures at the urban scale" and have been the basis for later wayfinding research.

It has been established that people learn about their environment incrementally (levels of human spatial knowledge, Section 2.2.1). First, they derive knowledge about landmarks. The fact that judgments concerning landmarks are faster, indicates that people tend to give them a special status. During the next step landmarks are connected through routes. Routes have a directional basis and are subsequently integrated into a whole network. Organization of routes in such a network is primarily topological. At the final stage of the learning process people arrive at knowledge of efficient links between locations (i.e., survey knowledge). Such knowledge comprises information about distances and orientation. Gärling *et al.* (1983) assume that wayfinding is not possible unless orientation is maintained (e.g., the orientation of you-are-here-maps significantly influences the ability of people to successfully complete wayfinding tasks). They also state that distance estimates have a directional basis and generally tend to be less accurate than direction estimates. The accumulation of survey knowledge as the final stage of a spatial learning process is not undisputed. In a study about the development of cognitive mapping abilities of student nurses in a hospital, Moeser (1988) found that mental representations of survey maps do not develop automatically in all geographic spaces. The author blamed this fact on the complexity and bad design (e.g., each floor designed differently, no main corridors, no rectangular rooms) of the building and further suggested that architects—in addition to functionality of a building—should also consider people's limitations in developing mental representations of their surroundings.

Weisman (1981) identified four classes of environmental variables that influence wayfinding performance within built environments: (1) visual access, (2) the degree of architectural differentiation, (3) the use of signs and room numbers to provide identification or directional information, and (4) plan configuration. His results were confirmed by other researchers. In Gärling *et al.*'s (1983) study of orientation in a large university department visual access was regarded as an important factor, because wayfinding performance of subjects with restricted sight improved less over time. The impact of orientation tools like floor plans was also investigated. The performance of subjects with restricted sight using floor plans improved as fast as that of subjects with no restricted sight, floor plans, therefore, counteracting the negative effect. In another study Gärling *et al.* (1986) proposed to classify the environment by examining the degree of differentiation, the degree of visual access, and the complexity of spatial layout. The influence of floor plan complexity on both cognitive mapping and wayfinding performance, and the existence of an interaction between floor plan complexity and the quality of signage was demonstrated in two studies by O'Neill (1991a, 1991b). His results showed that an increase in floor plan complexity leads to a decrease in wayfinding performance. The presence of signage was an important factor but could not compensate for floor plan complexity. A difference between the use of textual signage and graphical signage was also found: textual signage produced greater accuracy (i.e., less errors) whereas graphical signage enhanced the rate of travel. Seidel's (1982) study at the Dallas/Fort Worth Airport confirmed that the spatial structure of the physical environment has a strong influence on people's wayfinding behavior. For passengers arriving at the gate with direct visual access to the baggage claim wayfinding was easier. In addition to Weisman's four classes of environmental variables, people's familiarity with the environment also has a big impact on wayfinding performance: frequency of prior use had a big facilitating effect in university buildings (Gärling *et al.* 1983) as well as in airports (Seidel 1982).

Research on people's wayfinding performance has been particularly helpful for establishing practical guidelines on how to design public buildings in order to facilitate wayfinding. Architects seem to have come to the conclusion that facilitating people's wayfinding needs more than putting up signs, because most of the time signage cannot overcome architectural failures (Arthur and Passini 1992). Therefore, wayfinding principles have to be considered during the design process—both for the overall spatial structure and for the formgiving features. Some guidelines (Arthur and Passini 1992, 1990)—despite focusing on the design and placement of signage—highly stress the importance of architectural features. In "1-2-3 Evaluation and Design Guide to Wayfinding", Arthur and Passini (1990 p.A-1) introduce the term environmental communication (i.e., "transfer of orientation, wayfinding (direction), and other information within the built environment, by means of signs and other communications devices or architectural features to enable people to reach destinations"), arguing that the built environment and its parts should function as a communication device. Such communication should begin at the outside of a building: the outside form is very instructive to the user, because it usually gives an impression of the building's internal spatial organization. Arthur and Passini mention two major aspects regarding the understanding of buildings: (1) a *spatial* aspect that refers to the total dimensions of the building (e.g., walls enclose space and elements such as an interior atrium break it up) and (2) a *sequential* one that considers a building in terms of its destination routes. Destination routes should eventually lead to so-called destination zones. These are groupings of similar destinations within buildings into clearly identifiable zones (Arthur and Passini 1992). In order to facilitate wayfinding to such destination zones the circulation system[5] should be of a form people can easily understand. It is further suggested that fewer decision points on any route and redundancy in wayfinding information are also facilitating effects. Based on an investigation about the nature of orientational problems users faced while traveling on the New York City subway, Bronzaft *et al.* (1976) suggested several improvements to be made in future design: consistent coding of information, applying structural details in a systematic and coherent fashion, presenting structure and operations of the system in different forms (i.e., to allow the user getting detailed information when needing it, but also seeing the entire system), and integrating colors as a type of coding for informational aids.

2.4 COMPUTER MODELS FOR WAYFINDING

In addition to empirical studies of performance (Section 2.3), cognitive wayfinding models have been investigated in what is referred to as *competence* literature. It includes simulations of spatial cognitive processes using computational models. Hirtle and Heidorn (1993) emphasize the importance of distinguishing between computational models of human cognitive processes and computational systems that perform the same task without paying much attention to human aspects. Cognitively based computer

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[5] "Circulation system: the overall horizontal and vertical pedestrian paths of a setting; circulation systems can be organized on a linear, central, composite, or network basis" (Arthur and Passini 1992 p.223)

models generally simulate a wayfinder that can solve route-planning tasks with the help of a cognitive-map-like representation. This map consists of learned landmarks and paths, and builds the foundation for navigation. The focus of these models is to find out how spatial knowledge is stored and used, and what cognitive processes operate upon it.

The TOUR model is considered the starting point for a computational theory of wayfinding (Kuipers 1978). It is a model of spatial knowledge whose spatial concepts are based mainly on observations by Lynch (1960) and Piaget and Inhelder (1967). With the TOUR model Kuipers simulates learning and problem solving while traveling in a large-scale urban environment. Besides dealing with states of partial knowledge his main focus of attention is the cognitive map which he defines as “the physically unobservable structure of information that represents spatial knowledge.” Kuipers takes three different metaphors (i.e., “map in the head”, “map like a network”, and “map like a catalog of routes”) for the cognitive map and combines them into one common framework. Knowledge in this cognitive map is divided into five categories: (1) routes (i.e., sequences of actions), (2) topological street network, (3) relative position of two places (i.e., vector within coordinate frame), (4) dividing boundaries, and (5) containing regions. This knowledge is represented through environmental descriptions, current positions, and inference rules that manipulate them (i.e., if a certain set of conditions is true, then the rules trigger some action). Different kinds of knowledge are stored in these representations and new information is assimilated. Because TOUR copes with incomplete spatial knowledge of the environment, it learns about it by assimilation of observations into the given structure. To describe orientation in the early TOUR model, eight headings at 45 degree intervals are used. But Kuipers points out that people do not actually use such numerical values when orienting themselves in the environment. A subsequent application to this computational model of the human cognitive map utilizes an approach to robot learning based on a hierarchy of types (i.e., sensorimotor interaction, procedural behaviors, topological mapping, and metric mapping) of knowledge of the robot’s senses, actions, and spatial environment (Kuipers and Levitt 1988). With this semantic hierarchy approach a computational model is built that expresses the complexity and modular structure of a nontrivial domain of human knowledge. It supports the position that a complex body of knowledge is not acquired by a single representation and learning algorithm but by a highly structured mechanism consisting of several distinct and interacting representations and learning algorithms.

Several other cognitively based computer models (e.g., TRAVELLER (Leiser and Zilbershatz 1989), SPAM (McDermott and Davis 1984), ELMER (McCalla *et al.* 1982)) have been developed to simulate learning and problem solving in spatial networks. A model of spatial learning that integrates concepts from both cognitive psychology and artificial intelligence was created by Gopal *et al.* (1989): NAVIGATOR represents basic components of human information processing[6], such as filtering and selecting (i.e., important landmarks), and forgetting. In the model, two views of a suburban environment—an objective and a subjective (i.e., cognitive) one—are complemented by cognitive processes relating to spatial learning and navigation. The cognitive map is modeled through a hierarchical network consisting of nodes, links, subnodes, and sublinks[7]. The goal of this computer model was to investigate how the process of extracting and using environmental information is conducted by the architecture of human information processing.

The focus of these computer models lies primarily in the creation and exploration of the cognitive map: how it is structured, what transitions occur during the learning process, etc. However, they do not tell the whole story of how people find their ways. Golledge (1992) argues that most of the computer models do not simulate the behavior of human wayfinders, because they fail to integrate asymmetric distances and directions[8]. Furthermore, these models do not include individual wayfinding criteria, such as minimizing travel time and/or distance, minimizing effort and/or stress, or minimizing the chance of getting lost by taking longer but more familiar routes. People also learn differently: instead of exploring a spatial network sequentially they choose sectors based on even a small piece of information (e.g., hypothesizing that the

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[6] The information processing framework is a dominant paradigm in cognitive psychology. Its goal is to analyze the structures and mental processes involved in the performance of a cognitive task.

[7] This approach is also called neurologically based information processing.

[8] It has been shown that people perceive distances differently depending on whether they are to or from a landmark.

destination is to the north). With their own approach Golledge *et al.* (1985) tried to overcome some of the limitations of other computational wayfinding models. Their model of route learning is based on four issues: (1) acquisition and representation based on episodic experience and subsequent generalization, (2) different types of knowledge and forms of representation, (3) systematic inaccuracies and distortions in the cognitive representation, and (4) behavioral errors associated with inaccurate and hierarchically organized knowledge. The conceptual model itself consists of the set of actions of the individual, the set of structures encoding knowledge about the task environment, the set of cognitive processes (i.e., perceiving, storing, retrieving, and reorganizing environmental knowledge) operating on the knowledge structures, and the set of control processes determining the interaction of the decision-maker with the environment. One result of the empirical analysis conducted to test the model showed that knowledge about salient wayfinding points along a route consists of four types of nodes. The origin and destination nodes establish the task environment. Cue and feature knowledge was found to be highest there. On the next hierarchical level there were second and third order nodes identifying key choice points for actions (e.g., a direction change). Next, there were lower order nodes needed to clarify the location of choice points (e.g., signaling a direction change). Finally, there were miscellaneous cues that could also be non-permanent features but had sufficient impact to guarantee recall for a specific task. Although with the inclusion of behavioral and representational errors this model seems to be an improvement over previous ones, Golledge (1992) later argued that more research on human understanding and use of space has to be done. He also mentioned the possibility of spatial knowledge not being well described by existing theories or models of learning and understanding.

3. IMAGE SCHEMATA

My body–the places it knew, so many places, ...
(Miller 1963)

In this chapter we discuss the concept of an *image schema* as the main component of our methodology. We explain their meaning, show examples, and describe their importance for people's structuring of wayfinding tasks. Finally, we show how image schemata relate to common-sense geographic knowledge and human wayfinding (Chapter 2). Image schemata are concepts people use to understand space (Johnson 1987). By using elements of human perception and cognition, such as image schemata, one can generate spatial representations that match better with people's real-world spatial interactions than models that are solely based on Euclidean geometry. Such representations form the basis for spatial information and design systems created to simulate real-world applications such as wayfinding tasks in a cognitively plausible way.

3.1 WHAT ARE IMAGE SCHEMATA ?

For a long time there has been a paradigm in science, called *Objectivism*, which assumes a fixed and determinate mind that is independent from reality. Objectivists assume that meaning consists only of relationships between abstract symbols and elements in real-world models. Therefore, correct reasoning is achieved by logical manipulation of such symbols and elements. This point of view obviously lacks a place for people, because the Objectivist's world stays the same, whether there are people in it or not. But in order to create computer systems that integrate human spatial concepts, it is necessary to understand what people grasp as meaningful. Johnson (1987) suggests that "meaning is always a matter of human understanding, which constitutes our experience of a common world that we can make some sense of" and that we should be concerned with "how real human beings reason and not with some ideal standard of rationality." He further argues that "any adequate account of meaning and rationality must give a central place to embodied and imaginative structures of understanding by which we grasp the world." Johnson proposes that people use recurring mental patterns to comprehend and structure their experience while moving through and interacting with the environment. He calls these patterns *image schemata*.

> *An image schema is a recurring, dynamic pattern of our perceptual interactions and motor programs that gives coherence and structure to our experience.*
>
> *...these image schemata are pervasive, well-defined, and full of sufficient internal structure to constrain our understanding and reasoning (Johnson 1987).*

Table 3.1 gives a selective list of Johnson's (1987 p.126) image schemata.

CONTAINER	BALANCE	COMPULSION
BLOCKAGE	COUNTERFORCE	RESTRAINT REMOVAL
ENABLEMENT	ATTRACTION	MASS-COUNT
PATH	LINK	CENTER-PERIPHERY
CYCLE	NEAR-FAR	SCALE
PART-WHOLE	MERGING	SPLITTING
FULL-EMPTY	MATCHING	SUPERIMPOSITION
ITERATION	CONTACT	PROCESS
SURFACE	OBJECT	COLLECTION

Table 3.1: Selective list of image schemata (Johnson 1987 p.126).

3.2 EXAMPLE IMAGE SCHEMATA

Image schemata are more abstract than mental pictures, because they can essentially be reduced to topology, and less abstract than logical structures, because they are constantly operating in people's minds while people are experiencing the world (Johnson 1987). An image schema can, therefore, be seen as a very generic, maybe even universal, and abstract structure that helps people establish a connection between different experiences that have this same recurring structure in common. The following examples are illustrative in this respect:

- Example 3.1: Tom is entering the building (Figure 3.1).
- Example 3.2: Tom is pouring coffee into a cup (Figure 3.2).

Figure 3.1: Large-scale containment.

Figure 3.2: Small-scale containment.

These experiences are obviously different from each other. Example 3.1 occurs in large-scale space, while example 3.2 happens in small-scale space. It is nevertheless possible to connect the two situations through the so-called CONTAINER schema. This image schema represents containment which people often face in their everyday lives. In example 3.1 Tom is experiencing the building based on the internal structure of the CONTAINER schema—a building has an inside, an outside, and a boundary. By crossing the boundary (i.e., entering the building through a door) Tom is moving from the outside into the inside of the building. In example 3.2 Tom is again experiencing a CONTAINER—a cup has an inside, an outside, and a boundary. By pouring coffee into the cup Tom is moving liquid from the outside into the inside of the cup. One can see that the CONTAINER image schema establishes an experiential connection between these two different situations. The common structure is that of an in-out orientation.

Image schemata (i.e., their internal structures) can also be *metaphorically*[9] projected from the physical to the nonphysical. One and the same image schema can be instantiated in different domains, if these domains are structurally related. The following examples show such structural relation:

- Example 3.3: Michael is going home from his office (Figure 3.3).
- Example 3.4: Michael wants to go the extra mile to get an A in this course.

Figure 3.3: The PATH schema in the physical.

Example 3.3 shows the so-called PATH schema in the physical. This image schema is built upon the following structure: a starting point (i.e., Michael's office), an endpoint (i.e., Michael's home), and a connection between these points (i.e., locations on Michael's way from his office to his home). Based on this internal structure the PATH schema can be metaphorically projected onto non-physical domains, such as the one shown in example 3.4. Michael's abstract purpose of getting an A is metaphorically expressed as a physical goal.

The previous examples show that image schemata and their metaphorical projections have sufficient internal structure to constrain people's meaning and reasoning. This is the reason why image schemata are important for the dynamic process

[9] Johnson (1987 p.xiv) describes metaphor "as a pervasive mode of understanding by which we project patterns from one domain of experience in order to structure another domain of a different kind."

of wayfinding: in order to perform a wayfinding task people need to understand spatial situations (i.e., grasp the meaning of spatial situations) and based on this understanding decide which way to go (i.e., reason about the correct way). Johnson (1987) elaborates on the case of walking:

> *When I walk, for example, I must recognize patterns in my environment to which I respond on the basis of the structures I perceive. It is true that* my body *does this responding, and I am not performing a rapid set of rule-governed calculations; yet, I must at least perceive certain structures which direct, shape, and help me to monitor my skillful responses, with varying degrees of adequacy (Johnson 1987 p.186).*

Image schemata help people to relate previous experiences with current environmental perceptions in order to understand the characteristics of a particular spatial situation. The dynamics of image schemata makes it possible to adapt to new situations immediately.

3.3 RELEVANCE OF IMAGE SCHEMATA FOR SPATIAL APPLICATIONS

The fundamental role that image schemata play in the design of GIS user interfaces and of GIS in general has been stressed by Mark (1989):

> *Optimal GIS interfaces will be based on the same image-schemata that are used when the person involved interacts directly with the real-world phenomena represented in the GIS (Mark 1989 p.551).*

In the case of wayfinding the importance of image schemata is equally evident. If space is to be designed to facilitate wayfinding, it is necessary to represent wayfinding tasks in the design process in the same way as people structure them in the real world. These tasks can then be tested within computer models of the particular space in order to evaluate if such space is well enough structured to facilitate wayfinding.

The relevance of image schemata for spatial applications was also shown by Freundschuh and Sharma (1996). In a pilot study they assessed the geographical content of children's narratives and investigated the relationship between locatives[10] and *spatial*

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[10] Locatives are words that describe relationships between places, e.g., in, on, under, and near.

image schemata[11]. One of their results was that books for different age levels utilized a standard set of locatives, suggesting the possibility to express most spatial relationships (i.e., spatial image schemata) with few locative terms. They also found indications that some image schemata (e.g., the CONTAINER schema) are more fundamental than others, demonstrating a possible developmental sequence in the building and comprehension of spatial image schemata.

Johnson claims that, although image schemata can be drawn as diagrams and represented propositionally, it is not possible to capture their continuous nature as structures of people's understanding. However, in order to use image schemata for measuring space complexity within spatial information and design systems, it is necessary to formally describe their internal structure and relationships. Formalizations of image schemata have used algebraic specifications (Kuhn and Frank 1991, Rodríguez and Egenhofer 1997). Kuhn and Frank employed the technique of algebraic specifications for the formalization of metaphors and image schemata in user interfaces. They argued that "formal approaches to design are mostly motivated by the need to evaluate design." This goes for the design of user interfaces as well as for the design of airports and other large-scale spaces.

3.4 IMAGE SCHEMATA RELATED TO COMMON-SENSE GEOGRAPHIC KNOWLEDGE AND HUMAN WAYFINDING

In Chapter 2 we described the areas of common-sense knowledge and human wayfinding, and reviewed empirical studies and cognitively based computer models of how people find their ways. Image schemata relate to common-sense knowledge—and particularly to Kuiper's definition of common-sense geographic knowledge (Section 2.1.1)—through the way people apply image-schematic structures to use the physical environment without concentrated effort (i.e., through common sense). For example, in order to follow a route from one place to another, people apply the PATH and SURFACE schemata. Image schemata can be seen as part of the topological information that is essential for common-sense reasoning (Section 2.1.2): relating image schemata to real-

[11] Most image schemata are related to space and, therefore, called spatial image schemata.

world situations and objects is clearly based on topological concepts (e.g., people can relate a building to the CONTAINER schema because they perceive its inside-outside structure). Image-schematic reasoning is also qualitative (Section 2.1.2) because people do not use absolute values—such as the exact position of an entrance within a coordinate system—in their everyday lives. Finally, formalizations of image schemata will contribute to the development of Naive Geography (Section 2.1.3): the result of our case study can be considered as part of a naive geographic model for the particular task of wayfinding in airports.

In his proposal to use the sense-making method for the investigation of human wayfinding processes (Section 2.2), Gluck (1991) calls for an exploration of the information needs—what information people need in order to understand their environment at a particular point in time. Image schemata offer a way to describe such an immediate grasp of meaning: in order to understand the world at a particular point in time people apply image-schematic structures to spatial situations.

The literature of performance and competence (Sections 2.3 and 2.4) offers many general principles and conditions for human wayfinding. It investigates how people learn about their environments and how they mentally organize spatial knowledge. Our methodology of structuring wayfinding tasks and space with image schemata contributes to the question of how people immediately understand and use their spatial environments. This is different from explaining how these environments are learnt: even when having a "perfect" cognitive map, people still have to make sense of spatial objects they perceive in order to know what to do with them. In this sense our approach does not contradict the idea of a cognitive map, or other wayfinding principles, but forms a necessary supplement within the area of environmental interaction.

4. A METHODOLOGY TO STRUCTURE WAYFINDING TASKS WITH IMAGE SCHEMATA

Imagination is more important than knowledge.
A. Einstein

In this chapter we present a methodology to structure wayfinding tasks and space according to elements of people's perception and cognition. It utilizes the concept of the image schema which was explained in detail in Chapter 3. Such a methodology allows for the development of spatial models that are closer to human perception and cognition of a real-world space than models based on Cartesian coordinate systems. This is important for the design of user-friendly environments that facilitate wayfinding. The methodology consists of four sequential stages (Figure 4.1): (1) a task sequence is formulated; (2) during interviews people describe their spatial experiences while performing a wayfinding task in the application space; (3) these interviews are analyzed and image schemata extracted; and (4) the extracted image schemata are used to structure the wayfinding task.

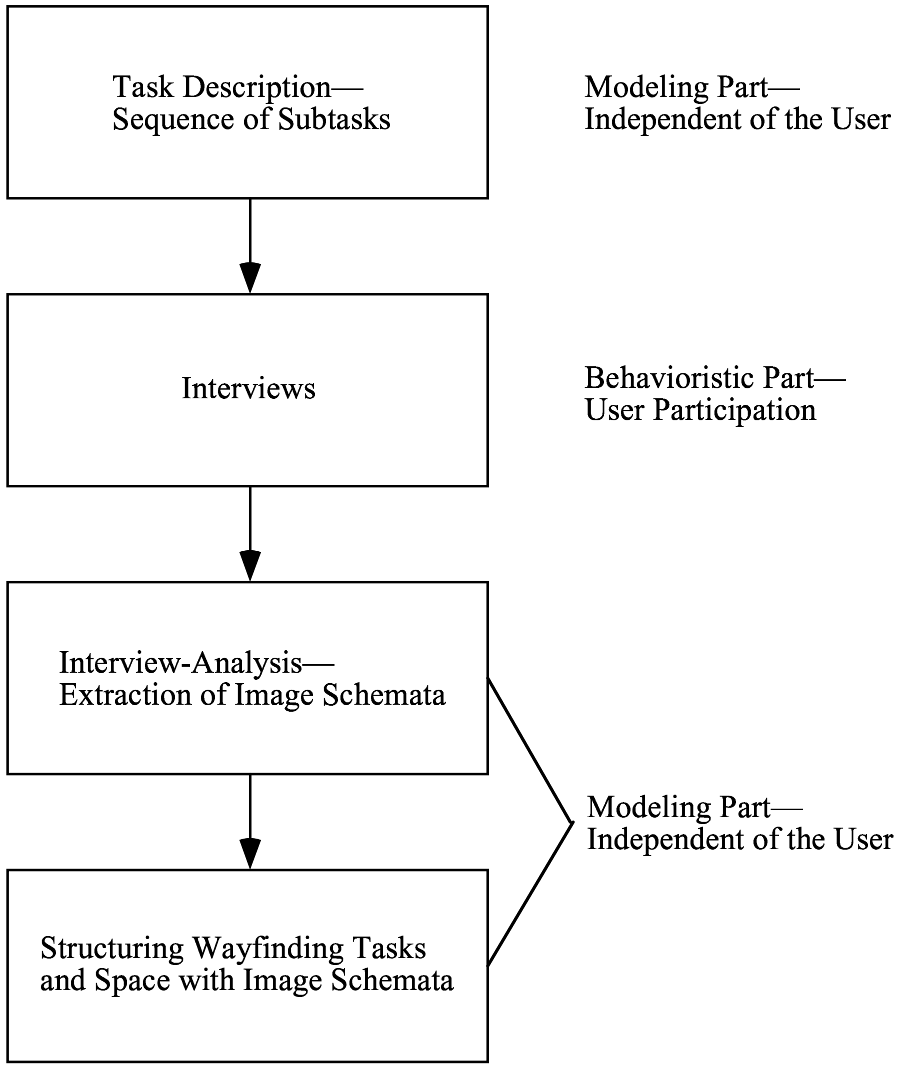

Figure 4.1: The four stages of the methodology to structure wayfinding tasks and space with image schemata.

4.1 TASK DESCRIPTION

An important aspect at this stage is the subdivision of tasks into sequences of subtasks. A *task* is defined as a process within a specific time frame and consists of a source (i.e., start) and a target (i.e., end). Tasks are composed of subtasks and are called *complex* if they are not atomic, i.e., cannot be subdivided into tasks. In the airport case study (Chapter 5) the timeline of a task is based on the subtasks people have to perform in a sequential order (e.g., checking in, moving through passport control, etc.).

4.2 INTERVIEWS

Interviewing is a method to record behavior (Agar 1996). Tobler (1976) suggested interviews as a means of recording mental maps. Although there has been the common view in artificial intelligence that expert knowledge can be much easier extracted than common-sense knowledge, Hayes (1985) states that basic intuitions are near the surface and relatively accessible by introspective interviewing. At this stage of the methodology we use interviews to record anticipated behavior of people interacting with a given environment, i.e., to record perceptual and cognitive space. During the interviews people describe their spatial experiences as they imagine performing a wayfinding task in the application space.

4.3 EXTRACTION OF IMAGE SCHEMATA FROM INTERVIEWS

The third step of the methodology consists of a systematic analysis of the transcripts of the interviews with the goal to extract the image schemata that people use to make sense of their environment while performing a wayfinding task. Language has been used for studying spatial cognition, because "grammar and syntax of a language, its lexicon and etymology, its semantics, pragmatics, and use all can provide valuable information and insights about human spatial cognition (Mark 1997)." Mark and Frank (1996) showed how image schemata can be deduced from natural-language expressions describing geographic situations. The image schema that has been in the speaker's mind while making a statement can be inferred from the preposition used (Mark 1989). The same approach was also used by Freundschuh and Sharma (1996) (Section 3.3). Our way of extracting image schemata from natural-language descriptions exploits the proposed connection to spatial locatives (i.e., prepositions) as well as semantic connotation.

In order to analyze and compare the extracted image schemata we use a semi-formal representation of them (Section 4.5 presents two examples of formal representations). We choose a representation in the form of predicates in which the predicate name refers to the image schema and the arguments refer to the object(s) that are involved in the image schema. Arguments can also be image-schematic structures themselves. Sequences of predicates are then also sequences of image schemata as observed and used by people. Some of the image schemata occur via metaphorical projections to describe non-spatial situations (Section 3.2). In the following section we present a short description of the extracted image schemata, the semi-formal structures applied to extract them, and examples for their occurrence in natural-language terms. We distinguish between *image schemata* and *orientational image schemata*.

4.3.1 IMAGE SCHEMATA

CONTAINER

A CONTAINER has an inside, an outside, and a boundary, and represents the idea of containment. In airports people apply the CONTAINER schema to buildings as well as to gates, and via metaphorical projection to signs.

- IN_CONTAINER (I, departure hall): "I am *in* the departure hall."

The CONTAINER schema is inferred from the preposition *in*. With reference to the departure hall the subject is either in or out.

- IN_CONTAINER (C51-62, range of gates): "C51 to 62 are *within* the range I'm looking for."

The CONTAINER schema is inferred from the preposition *within.* It is used metaphorically because "C51 to 62" are not physically contained within the "range of gates."

- CONTAINER (gate): "I *enter* the gate."

By moving from the outside to the inside of the gate the subject is *entering* a container.

- OUT_CONTAINER (I, waiting area): "I'm *outside* the waiting area."

LINK

People relate connected objects via LINKS. Such LINKS occur both in our spatial and temporal experience. Airport passengers try to establish visual LINKS between their current position and the location of the object they are looking for (e.g., a sign). LINKS (not necessarily visual LINKS) are transitive. For example, if a LINK exists between the passenger's position and a sign, and another LINK between the same sign and an object location, then there is a LINK between the passenger and the object.

- LINK (I, yellow signs): "I *see* the yellow signs."

A visual LINK between the subject and the yellow signs.

- LINK (ticket counter, ticket counter, ...): "All ticket counters are lined up in a row."

The ticket counters are perceived as connected objects.

- LINK (blue signs, signs): "The blue signs *refer to* the other signs."

There exists a semantic linkage between the blue sign and the other signs, therefore, the LINK schema is used via metaphorical projection.

- LINK (people, luggage): "People *with* luggage."

People are carrying their luggage, therefore, they are connected to it.

- LINK_ALONG (first#, last#, {first#-1, first#-2, ...}): "Numbers are decreasing."

The numbers are semantically connected. The LINK schema is used metaphorically.

- LINKED_BY (columns, ropes): "There're ropes between the columns."

  The ropes are perceived as spatial LINKS, connecting the columns.

PATH

The PATH schema is especially important for wayfinding tasks as people always move along PATHS. A PATH has a starting point, an endpoint, and a connection between them.

- PATH (I, ticket counter): "I *move to* the ticket counter."

The subject's current position is the starting point of the PATH, the ticket counter is the endpoint.

- PATH (I, people): "I *head towards* the people."
- PATH_ALONG (B1, B45, {B2...B44}): "Numbers are increasing. I *follow* B1 *along to* B2 to finally reaching B45."

B1 is the starting point of the PATH, B45 is the endpoint, and B2 to B44 are between them.

SURFACE

This schema is a trivial one and people need it all the time while standing or walking.

- SURFACE (hall): "The hall has got a clear open area to *walk*."
- ON_SURFACE (people, floor): "People are *walking*."

The fact that people are walking implies that there is a surface (i.e., the floor). People are *on* the floor.

- ON_SURFACE ("B", sign): "The sign has a 'B' *on* it."

  The SURFACE schema is used metaphorically because the "B" is not physically supported by the sign.

ATTRACTION

Johnson (1987 p.47) gives the following examples for experiencing the ATTRACTION schema in the physical: “A magnet draws a piece of steel toward itself, a vacuum cleaner pulls dirt into itself, and the earth pulls us back down when we jump.” While performing a wayfinding task people always seem to be *visually* attracted to specific features, such as signs and colors. Therefore, in all of our examples people use the ATTRACTION schema via metaphorical projection.

- ATTRACTED_BY (I, route): “Straight ahead looks the most direct route.”
- ATTRACTED_BY (I, railing): “The railing is the first salient clue.”
- ATTRACTED_BY (I, sign): “The sign catches the eye.”
- ATTRACTED_BY (I, yellow): “The yellow signifies it’s important.”

BLOCKAGE

BLOCKAGES are obstacles (e.g., walls or pillars) that stand in the way of PATHS and LINKS and, therefore, render wayfinding tasks more difficult.

- BLOCKED_BY (teller, people): “People *blocking* the teller.”
- BLOCKED_BY (LINK (I, unspecified objects), columns): “My view is *obstructed by* the columns.”

The visual LINK between the subject and some objects is blocked by columns.

MATCHING

Objects or colors can match with other objects or colors. The MATCHING schema is also used metaphorically: in order to know that they are on the right track or have arrived at the right gate, people match their cognitive information (i.e., knowledge in the head) with environmental information (i.e., knowledge in the world such as the content of signs).

- MATCHING (cognitive information “C53”, environmental information “C53”): “It tells me it’s boarding C53, so I have confirmation about that.”
- MATCHING (cognitive information, sign information): “I’m on the right path.”
- MATCHING (color-sign, color-previous sign): “It’s the *same color* as the sign I looked for previously.”
- MATCHING (gates, other gates): “The gates are *identical*.”

- MATCHING (PATH (I, gate C), PATH (unspecified location, boarding area)): "It looks like an official corridor that goes towards a boarding area for airplanes."

One physical path matches with a path that is in the subject's mind, therefore, the MATCHING schema is used via metaphorical projection.

ENABLEMENT

Johnson (1987 p.47) illustrates: "You feel able to move the chair *over to the corner*, or to lift the comb *up to your hair*." The criteria for using this image schema are a potential force vector and the absence of barriers or blocking COUNTERFORCES.

- ENABLE_TO (RIGHT_OF (PATH (I, unspecified location), I), I get full view): "I proceed to the right to get a full view."

"Moving to the right" represents a force vector and allows the subject to get rid of any barriers that block his/her view.

- ENABLE_TO (stairs, I go up): "I *can* go up stairs."

"Modal verbs, such as *can, may, must, could, might,* are verbs that pertain to our experience of actuality, possibility, and necessity." (Johnson 1987 p.48)

- ENABLE_TO (PATH (yellow sign, unspecified object), ON_SURFACE (wheelchairs, floor)): "The yellow sign indicates wheelchair access."

  The sign indication of wheelchair access implies that there is a path that enables handicapped people in wheelchairs to move along it.

MERGING

Objects can be combined to form bigger objects.

- MERGING_INTO (information signs, bar): "Information signs are blending into one big bar."

The MERGING schema is used metaphorically because the signs are only perceived as blending into one big bar; they are not physically merged.

SPLITTING

Objects can be split by, from, and into other objects. By using the SPLITTING schema people perceive or impose architectural structure which facilitates their sense-making of space.

- SPLIT_BY (room, gate signs): "The room is *divided by* gate signs."

- SPLIT_FROM (sign, other gates and signs): “The sign is *isolated from* other gates and signs.”
- SPLITTING_INTO (corridor, {LEFT_OF (corridor1, columns), RIGHT_OF (corridor2, columns)}): “I’m on the left side of the corridor.”

The subject perceives the corridor as split into two parts. One part is left, the other part right of the columns.

RESTRAINT REMOVAL

Sometimes a restraint (e.g., a barrier) has to be removed to allow the performance of a specific action.

- RESTRAINT_REMOVAL (BLOCKAGE (person)): “When the person moves then I’ll see the sign.”

FULL-EMPTY

Wayfinding in airports gets more difficult when the space is crowded. Therefore, this image schema has to be taken into account.

- FULL_OF (duty-free area, people): “It’s quite *crowded* here (i.e., in the duty-free area).”

A crowded area implies that it is full of people.

- EMPTY_OF (CONTAINER (space), unspecified objects): “It’s an *empty* space.”

SCALE

This image schema is based on the “more” or “less” aspect of human experience. People use the SCALE schema to understand quantitative amount and qualitative degree.

- MORE_THAN_IN (signs, sign1 + sign2, number): “I see *more* signs *than* B1 and B2.”

This SCALE schema represents a qualitative comparison of a number of objects.

- MORE_THAN_IN (FAR_FROM (COLLECTION (signs), I), FAR_FROM (sign, I), distance): “The sign is *far away* and another set of signs is *further* away.”

In this case the SCALE schema is used to compare relative distances.

- MORE_THAN_IN (ATTRACTED_BY (I, signage), ATTRACTED_BY (I, other things), intensity): “The signage offers a lot *more than* anything else.”

The SCALE schema is used via metaphorical projection to compare the intensities of experiencing two ATTRACTION schemata.

- MOST_OF (people): “*Most* people ...”
- LESS_THAN_IN (people at counter, people at other counters, number): “Counter with the *fewest* people.”

  The subject implies that there are less people at this counter than at other counters.

COLLECTION

People experience a COLLECTION as a sum of individual objects. A COLLECTION may form an area, such as a COLLECTION of gates forms a gate area. Groupings of similar destinations into zones facilitates wayfinding if these groupings are clearly identified (Arthur and Passini 1992).

- COLLECTION (ticket counters): “*All* ticket counters are lined up in a row.”
- COLLECTION (signs): “There’re *several* signs.”

PART-WHOLE

Wholes consist of parts.

- PART_OF_WHOLE (letters, sign): “The letters are *part of* the sign.”
- PART_OF_WHOLE (line, lines 51-65): “*One of* the lines 51 to 65.”

COMPULSION

People experience this image schema when they are being moved by external forces. In crowded airports passengers are sometimes being pushed along a PATH by other passengers.

- COMPELLED_TO_BY (I do unspecified action, people): “I do what other people are doing.”

In this case the COMPULSION schema is used metaphorically because the subject is not physically forced to perform an action.

- COMPELLED_TO_BY (PATH (I, unspecified location), LINK (I, ”A”)): “I notice the ‘A’ and I move off to a different view.”

  Again, the COMPULSION schema is used metaphorically. The subject does not look for gate A, therefore, he/she has to move and look for his/her gate.

COUNTERFORCE

This image schema “focuses on the head-on meetings of forces” (Johnson 1987 p.46).

- COUNTERFORCE_TO (people, I): "People are coming towards me."

This sentence can be interpreted as something (i.e., people) imposing a force against an action such as walking.

- COUNTERFORCE_TO (I checked in, PATH (I, check-in counters)): "I don't need to go there—I've already checked in."

  The COUNTERFORCE schema is used metaphorically because the counterforce is non-physical. A previously performed action serves as a counterforce to performing the same action again.

BALANCE

In all of the following examples the BALANCE schema is used metaphorically. Johnson (1987 p.85) refers to "common senses of balance as experienced in bodily movement and perception" and shows exemplar figures and paintings where "balance exists only in our perceptual activity" (Johnson 1987 p.99). A well-structured, balanced spatial design facilitates environmental interaction for users. The BALANCE schemata are subjectively deduced based on semantic connotation.

- BALANCE (ticket counters): "Again the space is such that it looks like all ticket counters are lined up in a row."
- BALANCE (signs): "We have clear yellow signs."
- BALANCE_BETWEEN (ceiling-structure, COLLECTION (gates)): "The ceiling-structure encompasses a series of gates."

CONTACT

The CONTACT schema occurs when objects are attached to each other.

- CONTACT (yellow shields, counters): "The yellow shields *at* the counters."

  The yellow shields are physically attached to the counters.

OBJECT

The OBJECT schema is a trivial one because people use it all the time to identify discrete entities in space. We don't use this image schema explicitly in the image-schematic descriptions.

- OBJECT (yellow sign), OBJECT (ticket counter), OBJECT (gate), etc.

4.3.2 ORIENTATIONAL IMAGE SCHEMATA

People use two different reference frames to locate themselves and objects while finding their ways in airports. The *egocentric reference frame* is based on their bodies and the *allocentric reference frame* is based on features of the environment (Levinson 1996, Kuhn and Blumenthal 1996). In order to establish such directional and orientational spatial context people superimpose *orientational image schemata* upon other image schemata (Section 4.3.1).

VERTICALITY

This image schema is missing in Johnson's list, but it is important for wayfinding in airports because many signs are near the ceiling. The VERTICALITY schema is structured by two points and a vertical (i.e., an up-down) dimension in-between them.

- IS_UP (signs, ticket counters): "There are signs *up above* the ticket counters."
- IS_UP (MOST_OF (signs), people's heads): "Most of the signs are *overhead*."
- IS_UP (LOW_OF (ceiling), PATH (I, CONTAINER (area)): "I have to duck *under* a low underpass and then out into a bigger area."

The subject implies that there is a low-ceiling structure on the way out into the bigger area.

- IS_UP ("Lufthansa", "SAS"): "SAS is a *sub*sidiary of Lufthansa."

The VERTICALITY schema is used metaphorically to express a commercial relation (i.e., a ranking) between two airlines.

- HIGH_OF (ceiling): "It's a *high* space."
- IS_DOWN (signs, ceiling): "Signs hanging from the ceiling."

It is implied that the signs are hanging *down* from the ceiling.

- LOW_OF (ceiling): "It's a *low* ceiling."

CENTER-PERIPHERY

In most of the cases the passenger functions as the center[12] and the surrounding environment is periphery. But sometimes the center is an object of the environment.

[12] "Our world radiates out from *our bodies* as perceptual centers from which we see, hear, touch, taste, and smell our world." (Johnson 1987 p.124)

- CENTER-PERIPHERY (I, unspecified objects): “I pan *around*.”

The subject is the center (i.e., egocentric reference frame) and looks at different objects in the periphery.

- CENTER-PERIPHERY (duty-free shops, hallway): “The hallway curves *around* the duty-free shops.”

  This example contains an allocentric reference frame because the duty-free shops (i.e., the reference) are objects of the subject’s environment.

NEAR-FAR

The NEAR-FAR schema plays a role when people have to go from one place to another or when they qualitatively compare distances.

- NEAR_FROM (I, sign): “I approach *closer* to the sign.”
- NEAR_FROM (desk, sign): “The desk *next to* the sign.”

The subject expresses relative closeness between two objects.

- NEAR (desk1, desk2): “There’s an opening *between* the desks.”

From the statement that there is an opening between the desks and the fact that in this case people have to go through security control it is inferred that the two desks are near each other.

- FAR_FROM (I, signs): “I can’t read the signs *at this distance*.”

The semantics of the sentence implies that the signs are far from the subject’s viewpoint.

- FAR_FROM (begin of corridor, end of corridor): “It’s a *long* corridor.”

FRONT-BACK

Although not included in Johnson’s list of image schemata, this seems to be an important orientational schema for wayfinding, e.g., “Having things always *in front of* me seems to be more useful.” and “If I don’t find the ‘C’, I go *back* and retrace myself.”

- IN_FRONT_OF (yellow signs, I): “I see the yellow signs *in front of* me.”
- IN_FRONT_OF (C-gates, sign): “The C-gates are *straight ahead from* the sign.”

In this example the subject imposes an allocentric reference frame based on an object of the environment (i.e., a sign). It is implied that objects straight ahead from the sign are in front of the sign.

- IN_BACK_OF (people, counters): “There’re people *behind* the counters.”

It is implied that objects behind the counters are in the back of the counters.

LEFT-RIGHT

This orientational image schema is also missing in Johnson's list. People use it frequently for qualitative descriptions of the positions of objects.

- LEFT_OF (even numbers, unspecified object): "The even numbers are *on the left*."
- RIGHT_OF (PATH (I, gate C), I): "*To the right* also gives me an option to go."

4.3.3 IMAGE SCHEMATA WITHIN DIFFERENT CONTEXTS

We use a number of symbols in combination with image schemata to distinguish between different contexts.

?"image schema" = Looking for a specific image schema.

- ?IN_CONTAINER (I, terminal 1): "I *want to* be in terminal 1."
- ?LINK (I, sign): "I'm *looking for* a sign."

The subject is trying to establish a LINK between his/her position and a sign.

- ?PATH (I, gate C57): "I'm *heading for* gate C57."

The subject is looking for a path that leads to gate C57.

- ?MATCHING (flight# or destination, environmental information): "I'm *looking for* something that matches the flight number or destination."

"image schema"? = Not sure about a specific image schema.

- IN_CONTAINER (I, "C")?: "I'm *not sure* if I'm in 'C'."
- PATH (I, end of terminal)?: "*Maybe* I won't have to walk the full length of the terminal."

no_"image schema" = Specific image schema does not exist.

- NO_LINK (I, letters): "I *can't read* the letters."
- NO_ON_SURFACE (people, SURFACE (escalator)): "The escalator is *unoccupied*."

An unoccupied escalator implies that nobody is standing on the surface of the escalator.

- NO_ATTRACTED_BY (I, sign): "The sign is subdued so I *ignore* it."

- NO_BLOCKED_BY (LINK (I, advertising billboards + navigation sign), plants + decorations): “The plants and decorations do *not interfere* with my view of advertising billboards and the navigation sign.”
- NO_IN_BACK_OF (people, counters): “There’re *no* people *behind* the counters.”
- NO_MATCHING (my gate, “A”): “Gate A is *not* my gate.”

future_”image schema” = An image schema that occurs at one of the next viewpoints (in most cases it occurs in combination with “image schema”? because people can only assume which image schema will occur at the next viewpoint but they cannot be sure of it).

- FUTURE_LINK (I, CONTAINER (room))?: “I can’t tell whether it opens up into a room.”

previous_”image schema” = An image schema that occurred at one of the last viewpoints.

- PREVIOUS_NO_LINK (I, ”gate A”): “Gate A wasn’t advertised *prior* to this.”

4.4 STRUCTURING WAYFINDING TASKS WITH IMAGE SCHEMATA

The previous sections explained the first three stages of our methodology to structure wayfinding tasks with image schemata: subdividing tasks into sequences of subtasks, interviewing people, and extracting image schemata from these interviews based on semi-formal structures. At this final stage of the methodology we use the semi-formal structures to build image-schematic representations of the wayfinding tasks. The potential of this approach is the incorporation of people’s cognitive aspects into engineering processes. In order to (re)organize an application space from the perspective of wayfinding, application users are interviewed, instead of designers who have the domain knowledge of the application. By analyzing user requirements and organizing common-sense knowledge (i.e., image schemata) the design process comes closer to the user and more semantics are added to the information already available. Transcript and image-schematic representation for one interview can be found in the Appendix. Transcripts and image-schematic representations for the remaining seven interviews can be downloaded from "ftp.spatial.maine.edu/pub/SIE/Thesis/Masters/Raubal1997/Interviews1-7/" (all files are Word6 for Macintosh).

4.5 TRANSLATION TO FORMAL REPRESENTATION

Our analysis and comparison of the extracted image schemata is based on a semi-formal representation. Implementing the methodology in spatial information and design systems requires a formal representation of image schemata. In the following section we show the semi-formal representation and two possible formal representations of one example, using the functional programming language Gofer (Jones 1991) and the logic-based programming language Prolog (Clocksin and Mellish 1984).

4.5.1 SEMI-FORMAL REPRESENTATION

Transcript	**Extracted Image Schemata**
"I go through passport control and head to the gates in the A-B-C-area."	LINK(I,passport control), PATH_ALONG(I,gates,passport control), CONTAINER(passport control), IN_CONTAINER(gates,A-B-C-area), ON_SURFACE(I,floor);

Table 4.1: Example of transcript and image-schematic representation.

4.5.2 FORMAL REPRESENTATION WITH GOFER

In Gofer we describe image schemata as functions of objects. In our example the different image schemata contain 1, 2, or 3 objects.

```
data IS = IS_Link | IS_PathAlong | IS_Container | IS_InContainer |
IS_OnSurface

data ObjT = I | PassportControl | Gates | Floor | ABC_Area

data IST = ISC IS [ObjT]
```

```
instance Eq ObjT where
     I == I = True
     PassportControl == PassportControl = True
     Gates == Gates = True
     Floor == Floor = True
     ABC_Area == ABC_Area = True
     _ == _ = False

composeIS :: [IST] -> [IST] -> [IST]
composeIS a b = a++b

hasObject :: ObjT -> IST -> Bool
hasObject o (ISC iT oo) = any ((==) o) oo

filterIS :: [IST] -> ObjT -> [IST]
filterIS iS o = filter (hasObject o) iS

createLink :: ObjT -> ObjT -> [IST]
createLink o1 o2 = [ISC IS_Link [o1,o2]]

createPathAlong :: ObjT -> ObjT -> ObjT -> [IST]
createPathAlong o1 o2 o3 = [ISC IS_PathAlong [o1,o2,o3]]

createContainer :: ObjT -> [IST]
createContainer o = [ISC IS_Container [o]]

createInContainer :: ObjT -> ObjT -> [IST]
createInContainer o1 o2 = [ISC IS_InContainer [o1,o2]]

createOnSurface :: ObjT -> ObjT -> [IST]
createOnSurface o1 o2 = [ISC IS_OnSurface [o1,o2]]
```

The image schemata that occur in our example are established through “create” functions:

```
t1 = createLink I PassportControl
t2 = createPathAlong I Gates PassportControl
t3 = createContainer PassportControl
t4 = createInContainer Gates ABC_Area
t5 = createOnSurface I Floor
```

The “composeIS” function is used to build sequences of image schemata. The result of this function are all image schemata that occur in our example:

```
t6 = composeIS (composeIS (composeIS (composeIS t1 t2) t3) t4) t5

? t6
[ISC IS_Link [I, PassportControl], ISC IS_PathAlong [I, Gates,
PassportControl],
 ISC IS_Container [PassportControl], ISC IS_InContainer [Gates, ABC_Area],
ISC
 IS_OnSurface [I, Floor]]
```

The “filterIS” function returns all image schemata that contain a specified object. Here, we ask for all image schemata that contain the object “I.” This is a way to see which image schemata are linked over one common argument.

```
t7 = filterIS t6 I

? t7
[ISC IS_Link [I, PassportControl], ISC IS_PathAlong [I, Gates,
PassportControl],
 ISC IS_OnSurface [I, Floor]]
```

4.5.3 FORMAL REPRESENTATION WITH PROLOG

In Prolog the extracted image schemata are described as first-order predicates. Different image schemata predicates are distinguished by different predicate names and have different arities (i.e., a different number of arguments). For example, the predicates of the image schemata LINK and PATH_ALONG could be expressed in general terms as follows:

```
i2(link,start,end).
i3(path_along,start,end,inbetween).
```

For the example in Table 4.1 the following predicates are created:

```
i2(link,i,passport_control).
i3(path_along,i,gates,passport_control).
i1(container,passport_control).
i2(in_container,gates,abc_area).
i2(on_surface,i,floor).
```

These predicates enable querying about such relations as "i2(Is,i,X)" or "i3(Is,i,X,Y)" in order to ask for image schemata that contain the object "I."

```
2 ?- i2(Is,i,X).

Is = link
X = passport_control ;

Is = on_surface
X = floor ;

3 ?- i3(Is,i,X,Y).

Is = path_along
X = gates
Y = passport_control ;
```

Additional rules in the form of predicates are necessary to describe composition of relations (Rodríguez and Egenhofer 1997). In order to show the property of transitivity we add another image schema predicate:

```
i2(link,passport_control,tom).
```

This is the rule for the concept of transitivity:

```
i2(link,A,C):-i2(link,A,B),i2(link,B,C).
```

Based on this rule the following query results in 3 links:

```
2 ?- i2(link,X,Y).

X = i
Y = passport_control ;

X = passport_control
Y = tom ;

X = i
Y = tom ;
```

The above shown formal representations using Gofer (Section 4.5.2) and Prolog (Section 4.5.3) serve only as a proof of concept. It seems that the algebraic concepts of Gofer and a relational approach of representing image schemata do not blend well. Prolog, on the other hand, should be more suitable to formally represent image-schematic structures, because relations and rules can be easily formulated. A query language such as the Structured Query Language SQL (Melton 1996) might be another useful approach to represent and query about image schemata.

5. Application of the Methodology to Wayfinding in Airports

The goal of the methodology developed in Chapter 4 was to establish a spatial representation for navigation tasks that comes close to human perception and cognition of a real-world space. In this chapter we demonstrate the usefulness of this methodology by applying it to a common wayfinding task in two different airports. We also propose a wayfinding model and use it to compare the complexity of the wayfinding task for both airports.

5.1 Interview Procedure

During the interviews subjects describe their spatial experiences with two simulated airport spaces (i.e., Vienna International Airport in Austria and Frankfurt International Airport in Germany) while orienting themselves and navigating through them.

5.1.1 Airport Spaces

Our goal of applying the methodology is to compare the complexity of two different airports in regard to people performing a common wayfinding task. We select one airport that is considered easy to navigate (i.e., Vienna) and another that is considered difficult to navigate (i.e., Frankfurt). This assessment is confirmed by combining our methodology with a wayfinding model.

The test site Frankfurt International Airport was selected based on the results of a questionnaire that had been distributed to 25 frequent flyers (age ranging from fifteen to sixty years, about half of them female and the other half male). We asked these people at what airports they had most difficulties in finding their way from the check-in counter to the gate. Frankfurt was mentioned most often, followed by London Heathrow.

Passengers also had trouble finding their way at Los Angeles Airport, Amsterdam, Atlanta, and Paris CDG (Table 5.1). As the main reasons for their answers people mentioned unclear and illogical infrastructures. Subsequent informal talks with the interviewees showed that most of them who had also been to Vienna International Airport found this airport easy to navigate. Therefore, we selected Vienna International Airport as the other test site.

Airport	**Counts**
Frankfurt (Germany)	9
London Heathrow (Great Britain)	7
Los Angeles (U.S.A.)	4
Amsterdam (Netherlands)	3
Atlanta (U.S.A.)	3
Paris CDG (France)	3

Table 5.1: Results of a questionnaire distributed amongst 25 frequent flyers. Subjects were asked at what airports they had most difficulties in wayfinding.

5.1.2 SIMULATION OF TASK

We used a sequence of color slides to simulate the route-following task from the departure hall (i.e., the check-in counter) to a specific gate in each of the chosen airports. Subjects were shown a sequence of 16 slides from inside Vienna International Airport and 21 slides from inside Frankfurt International Airport. We used color slides instead of pictures (Raubal *et al.* 1997) because these can be projected to a wall to give viewers a better impression of actually being involved in the environment tested. The slides were presented in a sequential order, featuring different situations that passengers have to face while performing the wayfinding task.

Goldin and Thorndyke (1982) compared actual and simulated information as alternative sources of environmental information and concluded that under some conditions, e.g., when the goal is to convey perceptual details, a film or slide presentation may provide as much detail as a live tour through the environment. Allen *et* *al.* (1978) suggested that a "presentation of slides separated by spatial intervals may closely parallel typical visual experience in large-scale environments" and used such procedure to assess the relationship between people's visual perception and spatial representation of an urban environment. Another experiment utilized slides for route simulation to prove the navigational aid of landmarks on street maps (Deakin 1996).

5.1.3 PROCEDURE AND SUBJECTS

The focus of this human subjects testing is to receive data for the existence of image schemata in wayfinding and not a thorough analysis of human behavior. Therefore, we use a simplified experimental setup with a small subject pool and color slides in lieu of actual navigation space.

During the interviews subjects are given the following task: "Imagine the following situation: you are a passenger at Vienna (Frankfurt) International Airport in Austria (Germany). You are about to board Austrian Airlines (Lufthansa) flight OS501 (LH4408) leaving at 11:35 (16:40) to New York (Lyon). Your gate number is C57 (B45). For check-in you can use any of the counters 51-65 (51-277). You are now standing in the departure hall, waiting to check in your luggage. Your task is the following: going from the departure hall to your gate."

Eight volunteers—four of them female, the other four male, each of them a native English speaker, and not all of them spatially educated—were shown and tested on the same task in both airports (Table 5.2). Half of the subjects saw the task inside Vienna International Airport first and the other half sees the task inside Frankfurt International Airport first. For every slide subjects had to answer the following two questions:

- What are the things and features you see on this picture and why did you choose them?
- How do you move on from here, referring to the things and features you noticed?

Subjects	Gender	Age	Profession	General airport-familiarity
subject 1	female	25	psychology student	not very familiar
subject 2	female	26	psychology student	fairly familiar
subject 3	female	40	engineer	familiar
subject 4	female	44	geography professor	very familiar
subject 5	male	26	engineering student	above average
subject 6	male	28	land surveyor	moderately familiar
subject 7	male	30	network manager	moderately familiar
subject 8	male	37	geographic engineer	very familiar

Table 5.2: Subjects tested.

5.2 VIENNA INTERNATIONAL AIRPORT

5.2.1 TASK DESCRIPTION

The task of going from the departure hall to the gate at Vienna International Airport consists of 3 subtasks that have to be performed in a sequential order (Table 5.3). People have to check in, move through passport control, and move through security control at the gate.

Task	Going from	Going to
task	departure hall	gate
subtask 1	departure hall	check-in counter
subtask 2	check-in counter	passport control
subtask 3	passport control	security control = gate

Table 5.3: Task and subtasks at Vienna International Airport.

5.2.2 INTERVIEWS

Subjects are asked to describe their spatial experiences while finding the way from the departure hall to their gate. The goal is to get on a flight to New York departing from gate C57. As an example we give the transcript for “moving through passport control” (i.e., end of subtask 2 and start of subtask 3) from one interview (Figure 5.1).

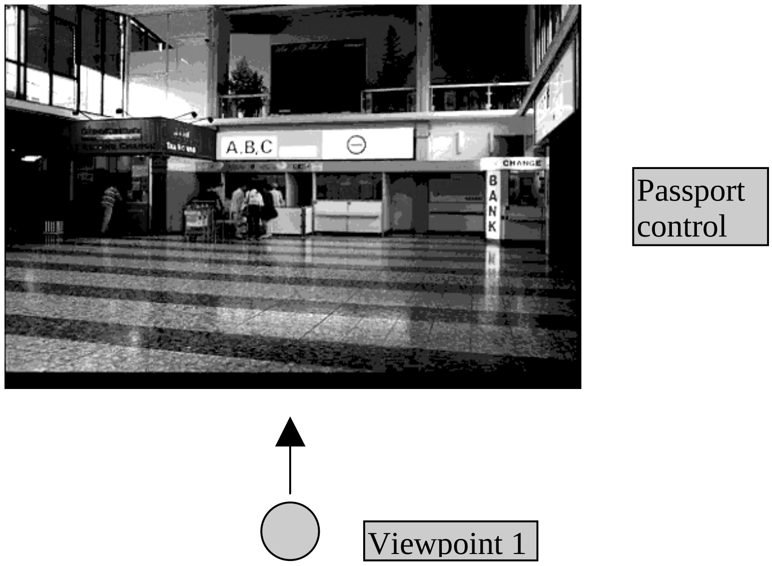

Figure 5.1: Moving through passport control at Vienna International Airport (slides 5, 6, 7, and 8).

Slide 5: Passport control.

> "I come out in a big taller area. I see an "A, B, C"-gate that says it's passport control. The yellow sign stands out against the rest of the airport signage. The "A" and "B" and "C" are prominent black on white. It doesn't say "departures" in that direction. I see an "A, B, C"-sign in the other direction off to the right. I go forward and queue up for passport control. I go through passport control and head to the gates in the A-B-C-area."

Slide 6: Duty-free area after passport control.

> "I see shops. It's well-lit and it's not claustrophobic. I see the sign that says I should go down that hall to go to gate A. That's not the direction I want to go. The aisle can't go very far. It disappears among the different shops."

Slide 7: Duty-free area after passport control.

> "It's an open space. I see the sign to the B-C-gates. I see information about the layout of the airport and flight information on the monitors. There's shops. They stand out against the back."

Slide 8: Duty-free area after passport control.

"I see lots of shops. I see a way to a sign that says "A, C." There's two ways to get to C. I see a flight-information-sign hanging from the ceiling. It's subdued so I ignored it. I'm looking for gate C, the general gate-C-area. I go down the shops-area in the center."

5.2.3 EXTRACTION OF IMAGE SCHEMATA FROM INTERVIEWS

Transcript	Extracted Image Schemata
"I come out in a big taller area."	IN_CONTAINER(I,area), MORE_THAN_IN(area,previous area, height);
"I see an "A, B, C"-gate that says it's passport control."	LINK(I,gate),LINK(I,"A,B,C"), LINK(I,"passport control"), MATCHING(gate,passport control);
"The yellow sign stands out against the rest of the airport signage."	LINK(I,yellow sign), ATTRACTED_BY(I,PART_OF_WHOLE (yellow sign,airport signage));
"The "A" and "B" and "C" are prominent black on white."	ATTRACTED_BY(I,"A,B,C"), ON_SURFACE(black letters,white ground);
"It doesn't say "departures" in that direction."	NO_LINK(I,"departures");
"I see an "A, B, C"-sign in the other direction off to the right."	LINK(I,RIGHT_OF(sign,unspecified object)),LINK(I,"A,B,C");
"I go forward and queue up for passport control."	IN_FRONT_OF(PATH(I,NEAR_FROM(I, passport control)),I), ON_SURFACE(I,floor);
"I go through passport control and head to the gates in the A-B-C-area."	PATH_ALONG(I,gates,CONTAINER (passport control)), IN_CONTAINER(gates,A-B-C-area);

Table 5.4: Transcript and image-schematic representation of slide 5 (passport control).

Transcript	Extracted Image Schemata
“I see shops.”	LINK(I,shops);
“It’s well-lit and it’s not claustrophobic.”	ATTRACTED_BY(I,light);
“I see the sign that says I should go down that hall to go to gate A.”	LINK(I,sign),LINK(I,hall), PATH_ALONG(I,gate A,SURFACE(hall));
“That’s not the direction I want to go.”	COUNTERFORCE_TO(LINK(I,”A”), PATH(I,gate A));
“The aisle can’t go very far.”	MATCHING(hall,aisle), PATH(begin of aisle,end of aisle), COMPELLED_TO(NO_FAR_FROM(begin of aisle,end of aisle));
“It disappears among the different shops.”	CENTER-PERIPHERY(aisle,shops), NEAR_FROM(shops,aisle);

Table 5.5: Transcript and image-schematic representation of slide 6 (duty-free area after passport control).

Transcript	Extracted Image Schemata
“It’s an open space.”	CONTAINER(duty-free space);
“I see the sign to the B-C-gates.”	LINK(I,sign),LINK(I,”B-C-gates”), PATH(sign,B-C-gates);
“I see information about the layout of the airport and flight information on the monitors.”	LINK(I,airport-layout-information), LINK(I,ON_SURFACE(flight information, monitors));
“There’s shops.”	LINK(I,shops);
“They stand out against the back.”	ATTRACTED_BY(I,shops), IN_BACK_OF(unspecified objects,shops);

Table 5.6: Transcript and image-schematic representation of slide 7 (duty-free area after passport control).

Transcript	Extracted Image Schemata
"I see lots of shops."	LINK(I,shops),FULL_OF(duty-free area, shops);
"I see a way to a sign that says "A, C.""	LINK(I,sign),PATH(I,sign),LINK(I,"A,C");
"There's two ways to get to C."	MERGING(PATH1(I,gate C),PATH2(I,gate C)),NO_MATCHING(PATH1(I,gate C), PATH2(I,gate C));
"I see a flight-information-sign hanging from the ceiling."	LINK(I,flight-information-sign), IS_DOWN(flight-information-sign,ceiling);
"It's subdued so I ignored it."	NO_ATTRACTED_BY(I,flight-information-sign);
"I'm looking for gate C, the general gate-C-area."	?LINK(I,"gates C");
"I go down the shops-area in the center."	CENTER-PERIPHERY(IN_FRONT_OF (PATH(I,A-C-gates),I),shops), IN_CONTAINER(shops,area), ON_SURFACE(I,floor);

Table 5.7: Transcript and image-schematic representation of slide 8 (duty-free area after passport control).

5.3 FRANKFURT INTERNATIONAL AIRPORT

5.3.1 TASK DESCRIPTION

The task of going from the departure hall to the gate at Frankfurt International Airport consists of 5 subtasks that have to be performed in a sequential order (Table 5.8). People have to check in, move through ticket control, move through security control, move through passport control, and go to the gate.

Task	Going from	Going to
task	departure hall	gate
subtask 1	departure hall	check-in counter
subtask 2	check-in counter	ticket control
subtask 3	ticket control	security control
subtask 4	security control	passport control
subtask 5	passport control	gate

Table 5.8: Task and subtasks at Frankfurt International Airport.

5.3.2 INTERVIEWS

Subjects are asked to describe their spatial experiences while finding the way from the departure hall to their gate. The goal is to get on a flight to Lyon departing from gate B45. As an example we give the transcript for one situation in the departure hall that people face during subtask 2 from one interview (Figure 5.2).

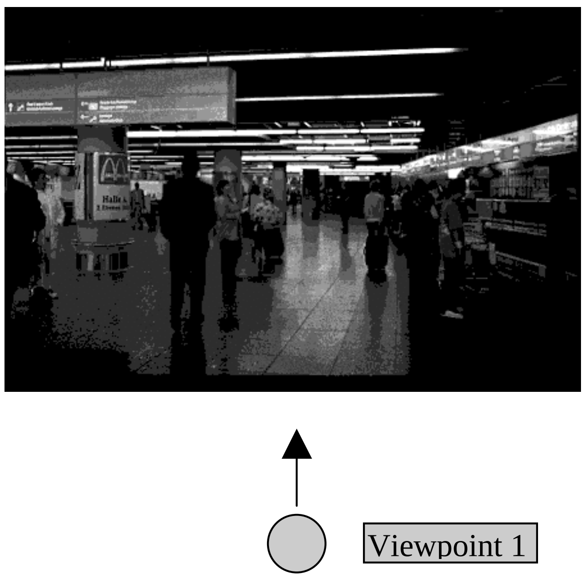

Figure 5.2: Part of the departure hall at Frankfurt International Airport.

Slide 5: Departure hall.

"I see stuff off to the right, I can't make out what it is. Phone booths or something like that. I see a sign hanging from the top. I'm in the wrong place. It's about baggage. I see advertising-signs. Way in the distance I see familiar blue signs. I see a "C" but I don't see anything else. I'm not sure where I'm going. I move forwards towards the blue indicator signs. I'm looking for a new reference point."

5.3.3 EXTRACTION OF IMAGE SCHEMATA FROM INTERVIEWS

Transcript	**Extracted Image Schemata**
"I see stuff off to the right, I can't make out what it is."	LINK(I,RIGHT_OF(unspecified objects,I)), NO_MATCHING(unspecified objects, cognitive information);
"Phone booths or something like that."	MATCHING(unspecified objects, phone booths)?;
"I see a sign hanging from the top."	LINK(I,sign),IS_DOWN(sign,ceiling);
"I'm in the wrong place."	IN_CONTAINER(I,place), NO_MATCHING(environmental information,cognitive information);
"It's about baggage."	LINK(I,"baggage");
"I see advertising signs."	LINK(I,advertising signs);
"Way in the distance I see familiar blue signs."	LINK(I,FAR_FROM(blue signs,I)), MATCHING(blue signs,previous blue signs);
"I see a "C" but I don't see anything else."	LINK(I,"C"), NO_LINK(I,other sign-information);
"I'm not sure where I'm going."	?PATH(I,my gate);
"I move forwards towards the blue indicator signs."	IN_FRONT_OF(PATH(I,blue signs),I), ON_SURFACE(I,floor);
"I'm looking for a new reference point."	?LINK(I,new reference point);

Table 5.9: Transcript and image-schematic representation of slide 5 (departure hall).

5.4 Wayfinding Model

In order to compare the complexity of the wayfinding task for Vienna and Frankfurt International Airports we use a simple wayfinding model (Figure 5.3) that takes two critical elements into consideration: *choices* and *clues*.

5.4.1 Choices

In our proposed wayfinding model we distinguish between points (i.e., viewpoints where slides were taken) where subjects have one obvious choice to continue the wayfinding task and points where subjects have more than one choice to continue the wayfinding task. Points with “choice = 1” are called *enforced decision points* while points with “choices > 1” are called *decision points*. The choices define the columns of the wayfinding model.

5.4.2 Clues

People need clues to make correct wayfinding decisions (i.e., how to proceed from viewpoints). We distinguish between *existing* (i.e., “clues”) and *non-existing clues* (i.e., “no clues”). Existing clues are divided into “good” clues (i.e., complete clues that enable people to decide about the correct continuation of their path) and “poor” clues (i.e., incomplete or misleading clues that do not enable people to decide about the correct continuation of their path). The clues define the rows of the wayfinding model.

CHOICE(S) / **CLUE(S)**		**CHOICE = 1** "enforced decision point"	**CHOICES > 1** "decision point"
CLUE(S)	"good"	O.K.	O.K.
	"poor"	O.K. "don't need clues" HESITATION "no confirmation"	PROBLEMS
NO CLUE(S)		O.K. "don't need clues" HESITATION "no confirmation"	PROBLEMS

Figure 5.3: Proposed wayfinding model.

There are six possibilities to combine choices and clues:

- “choice = 1” + “good clue(s)” => At an enforced decision point people are forced to continue in one direction. “Good” clues confirm that people are on the right track. Therefore, wayfinding is easy at these points.
- “choice = 1” + “poor clue(s)” => Even though there is only one way to proceed, people might hesitate to follow the way because “poor” clues do not reassure them that they are still on the right track.

- "choice = 1" + "no clue(s)" => Again, people might hesitate to follow the way because they have no confirmation of being on the right track.
- "choices > 1" + "good clue(s)" => At decision points people need "good" clues to choose the correct path. If clues are complete, easy to read, and easy to understand, wayfinding at those points is easy.
- "choices > 1" + "poor clue(s)" => Decision points with incomplete or misleading clues pose wayfinding problems for people.
- "choices > 1" + "no clue(s)" => Decision points without any clues form the worst scenario for wayfinding. At such points people are lost.

5.5 COMPARING WAYFINDING AT VIENNA INTERNATIONAL AIRPORT VERSUS FRANKFURT INTERNATIONAL AIRPORT

In this section we use the image-schematic representations and the proposed wayfinding model (Section 5.4) to provide evidence that the wayfinding task "going from the departure hall to the gate" is more complex in Frankfurt than in Vienna.

5.5.1 METHOD

In order to use the wayfinding model for comparison of the wayfinding task in Vienna and Frankfurt, the rows (i.e., choices) and columns (i.e., clues) of the model have to be evaluated for every viewpoint of the wayfinding task in both airports:

- Image schemata are used to decide whether a viewpoint is a decision point (i.e., choices >1) or an enforced decision point (i.e., choice = 1). This can be done by counting the different PATH schemata: a viewpoint qualifies as a decision point if there exist at least two different PATH schemata. If only one PATH schema occurs, then the viewpoint qualifies as an enforced decision point.
- Many clues can be found by looking at the different LINK schemata. Most often people establish visual LINKS to signs in order to perceive information. But clues might also be certain architectural features such as a hallway that is perceived and cognized as a funnel and, therefore, suggests moving forward (e.g., COMPELLED_TO_BY (move straight ahead, funnel)). The following rules (Table 5.10) help to infer clues.

Rule	Explanation
?LINK (I, ...) -> LINK (I, ...) => **clue**	"I'm looking for a link and there is a link."
?LINK (I, ...) -> NO_LINK (I, ...) => **no clue**	"I'm looking for a link but I can't find it."
LINK (I, ...) -> PATH (I, ...) => **"good" clue**	"I find a link and based on this link I find a path."
LINK (I, ...) -> NO_PATH (I, ...) => **"poor" clue**	"I find a link but it doesn't give me a path."

Table 5.10: Rules that help to infer clues from the image-schematic representation.

After evaluating the rows and columns of the wayfinding model for each viewpoint, points within "problem areas" are counted. The airport with the higher rating of points within "problem areas" is considered more complex for wayfinding. We show the final analysis for one interview (transcript and image-schematic representation for the whole interview can be found in the Appendix). Similar analyses were done for the other interviews. Transcripts and image-schematic representations for the remaining seven interviews can be downloaded from "ftp.spatial.maine.edu/pub/SIE/Thesis/Masters/Raubal1997/Interviews 1-7/" (all files are Word6 for Macintosh).

5.5.2 ANALYSIS FOR VIENNA INTERNATIONAL AIRPORT

Table 5.11 shows the analysis for Vienna International Airport. Each viewpoint is analyzed as in the following examples:

- **Slide 3:** This viewpoint represents a decision point because there are 2 paths (i.e., PATH (I, gate 55) and PATH (I, gate 54)). LINK (I, red check-in counters) represents a "good" clue because it results in a path to the check-in counters. But the subject can't figure out if "55" refers to the track (i.e., LINK (I, signs) + MATCHING ("55", track)?) and where to put his luggage (i.e., MATCHING ("55", LEFT_OF (luggage-conveyor-belt, counter 55))? + MATCHING ("55", RIGHT_OF (luggage-conveyor-belt, counter 55))?). These are 2 "poor" clues. Also, the counters are not with Austrian Airlines (i.e., NO_MATCHING (check-in counters, ”Austrian Airlines”)) which is interpreted as a missing link to Austrian Airlines. Based on the facts that the viewpoint is a decision point and there are 2 “poor” clues and 1 missing clue the subject does not know which way to go. Therefore, slide 3 represents a viewpoint that falls into the model category of “problems.”

- **Slide 5** (Figure 5.1): This viewpoint represents an enforced decision point because there is only one obvious way to go (i.e., PATH (I, NEAR_FROM (I, passport control))). One complete clue (i.e., LINK (I, gate) + LINK (I, ”A,B,C”) + LINK (I, ”passport control”) + MATCHING (gate, passport control) + LINK (I, yellow sign)) enables the subject to find the correct way. Therefore, there are no wayfinding problems at this viewpoint.
- **Slides 6, 7, 8** (Figure 5.1): This viewpoint represents a decision point because the subject has 3 paths to choose from (i.e., PATH (I, gate A) + PATH (sign, B-C-gates) + PATH (I, A-C-gates)). One “good” clue prevents the subject from choosing the wrong way (i.e., COUNTERFORCE_TO (LINK (I, ”A”), PATH (I, gate A))) and the other 2 “good” clues result in 2 correct paths (i.e., LINK (I, sign) + LINK (I, ”B-C-gates”) and LINK (I, sign) + LINK (I, ”A,C”)). The “poor” clue of a subdued flight-information-sign (i.e., LINK (I, flight-information-sign) + NO_ATTRACTED_BY (I,flight-information-sign)) does not prevent the subject from finding the correct path. Therefore, there are no wayfinding problems at this viewpoint.

Slide#	Paths	Good clues	Poor clues	No clues
1	1	1	0	1
2	1	1	0	0
3	2	1	2	1
4	2	2	1	1
5	1	1	0	0
6, 7, 8	3	3	1	0
9, 10	2	3	0	0
11	1	1	0	0
12	1	1	1	0
13	>1	2	0	0
14	1	1	0	0
15	1	1	0	0
16	1	2	0	0
Σ	**5 dp**	**20**	**5**	**3**

Table 5.11: Paths and clues for Vienna International Airport (viewpoints within problem areas are highlighted, dp = decision points).

5.5.3 ANALYSIS FOR FRANKFURT INTERNATIONAL AIRPORT

Table 5.12 shows the final analysis for Frankfurt International Airport. Again, each viewpoint is analyzed as in the following examples:

- **Slide 5** (Figure 5.2): It can be inferred from the image-schematic representation that this viewpoint represents a decision point: the subject mentions one path (i.e., PATH (I, blue signs)) and is also looking for a path to his gate (i.e., ?PATH (I, my gate)). The subject sees something to the right but cannot make out what it is (i.e., LINK (I, RIGHT_OF (unspecified objects, I)) + NO_MATCHING (unspecified objects, cognitive information)). He also sees a sign but concludes that he is in the wrong place (i.e., LINK (I,sign) + NO_MATCHING (environmental information, cognitive information)). Finally, he sees familiar blue signs in the distance. He can only make out a “C” on them but nothing else (i.e., LINK (I, FAR_FROM (blue signs, I)) + MATCHING (blue signs, previous blue signs) + LINK (I, ”C”) + NO_LINK (I, other sign-information)). Because there are only 3 “poor” clues the subject has to look for a new reference point (i.e., ?LINK (I, new reference point)). Therefore, slide 5 represents a viewpoint that falls into the model category of “problems.”

- **Slide 7:** The fact that the subject is trying to find another waypoint (i.e., ?LINK (I, waypoint)) serves as an indication that this viewpoint is a decision point. There is no “good” clue. The subject sees a lounge area but does not know if it is a general waiting area for all gate-B-flights (i.e., LINK (I, lounge area) + MATCHING (lounge area, general waiting area for gate-B-flights)?). Also, the subject cannot find his flight on the blue signs (i.e., LINK (I, blue signs) + NO_LINK (I, ON_SURFACE (my flight, signs))). These 2 “poor” clues and the fact that the subject cannot find a waypoint places the viewpoint of slide 7 in the model category of “problems.”
- **Slide 19:** This viewpoint represents an enforced decision point because the architectural features suggest only one obvious way to go (i.e., PATH (start of funnel, end of funnel)). Although the subject does not notice any signs at first (i.e., NO_LINK (I, signs)) and then sees a “poor” clue (i.e., LINK (I, sign) + LINK (I, ”44-unspecified #”) + FAR_FROM (sign + ”44-unspecified #, I)), there are 2 “good” clues serve as confirmations to the subject for continuing in this direction: the subject sees a corridor (i.e., LINK (I, corridor)) and posts that present a funnel (i.e., LINK (I, posts) + LEFT_OF (COLLECTION (posts), funnel) + RIGHT_OF (COLLECTION (posts), funnel)) that suggests moving forward. Therefore, the subject has no wayfinding problems at this viewpoint.

Slide#	Paths	Good clues	Poor clues	No clues
1	2	2	0	0
2	1	3	1	1
3	2	3	0	0
4	2	1	1	0
5	>1	0	3	0
6	3	1	1	0
7	>1	0	2	1
8	2	2	0	1
9	2	3	0	0
10	1	2	0	0
11	1	2	1	0
12	1	3	0	0
13	1	2	0	0
14	1	1	1	0
15	2	4	1	0
16	1	3	0	1
17	2	3	0	0
18	1	1	0	0
19	1	2	1	1
20	1	0	2	1
21	1	3	0	1
Σ	**10 dp**	**41**	**14**	**7**

Table 5.12: Paths and clues for Frankfurt International Airport (viewpoints within problem areas are highlighted, dp = decision points).

5.5.4 Proof of Hypothesis and Results

The analysis done in Section 5.5 showed strong evidence for proving both parts of the hypothesis:

- *Representing wayfinding tasks at airports through image schemata is an appropriate method to determine the critical elements (i.e., the choices and clues) of a wayfinding model*.

We established rules to infer choices and clues from semi-formal image-schematic structures and applied them to representations of a wayfinding task at two different airports. The result is the number of paths (i.e., choices), and existing and missing clues for each viewpoint of the wayfinding task.

- *These elements account for the complexity of the wayfinding tasks as rated by travelers*.

The wayfinding task "going from the departure hall to the gate" has a higher rating of points within "problem areas" at Frankfurt International Airport (2) than at Vienna International Airport (1). This result indicates that the chosen wayfinding task is more complex at Frankfurt International Airport than at Vienna International Airport. Other outcomes from the analysis reinforce the truth of this statement:
- Frankfurt has more decision points (10) than Vienna (5). At decision points people have to choose from different paths which usually makes wayfinding more difficult than at enforced decision points (Section 2.3). Therefore, the wayfinding task is more complex in Frankfurt.
- The sum of all "poor" clues totals 14 in Frankfurt and only 5 in Vienna.
- The sum of all missing clues totals 7 in Frankfurt and only 3 in Vienna.

Some possible errors made during the different stages of the methodology may have had an influence on the final results. First of all, the viewpoints where the slides were taken had been chosen on a subjective basis: whenever the photographer saw a new view, he took a slide. Different viewpoints and camera angles might result in different transcripts and, therefore, in different image-schematic representations. Second, descriptions of spatial experiences seemed to depend heavily on the background of the interviewees. For example, geographers gave a richer and more detailed description of space than psychologists who focused mainly on the description of signs. Such bias translated directly into the image-schematic representation. Finally, misinterpretation might have been another source leading to errors in the counts of choices and clues.

Subjects may have misinterpreted—for example, perceiving a vertical dimension when there was none—or missed important clues in their description. In addition, misinterpretation has to be viewed in the light of the interpreter: image schemata were also deduced based on semantic connotation and in some situations there was no clear-cut rule of which image schema to choose for a particular transcript. To maintain overall consistency we kept a database into which we wrote every deduced image schema and also the transcript from which the image schema was deduced. This insured systematic analysis because by looking up previous records of the database, the same image schemata were deduced from identical or similar transcripts. In order to decrease the number of possible errors one could refine the rules and setup for each stage of the methodology. Sensitivity of counts to errors could be measured by doing statistical tests on the final results.

6. SUMMARY, CONCLUSIONS, AND FUTURE WORK

6.1 SUMMARY

This thesis presented a methodology to structure wayfinding tasks and space with image schemata. These experiential patterns are part of people's perceptual and cognitive processes and help them to understand spatial environments. In order to demonstrate the methodology we applied it to wayfinding in airports. Image schemata were extracted from interviews and then used to build semi-formal knowledge-representations for a wayfinding task in two different airport spaces. In particular, we combined the methodology with a proposed wayfinding model to compare the complexity of a specific wayfinding task for Vienna International Airport in Austria and Frankfurt International Airport in Germany. Our main argument was that an image-schematic representation of the application space matches better with people's real-world spatial interactions than geometric (e.g., coordinate-based) models, which neglect people's perceptual and cognitive processes.

6.2 CONCLUSIONS

The work presented in this thesis leads to the following conclusions:

- People use a variety of image schemata to structure their wayfinding tasks in airports. Many image schemata are metaphorically projected and, therefore, metaphorical projections play an integral part in the descriptions and sense-making of space.
- The application of our methodology to comparing the complexity of a particular wayfinding task within two different airport spaces shows that the use of image schemata is a powerful method to describe human spatial cognition related to navigation tasks.

- Sequences of image schemata are sufficient to describe wayfinding tasks in spatial environments at an abstract level. In order to fully describe wayfinding processes the image-schematic structures have to be enriched with relevant wayfinding principles that can be found in the literature (Section 2.3).
- The integration of image schemata into the design process helps to identify architectural problems (with regard to wayfinding) prior to construction. The design process of easier-to-navigate spaces must take care of constraints, such as necessary LINKS and PATHS at different viewpoints. This can be done automatically by using semi-formal image-schematic structures (i.e., ?LINK (I, ...) -> LINK (I, ...) needed or ?PATH (I, ...) -> PATH (I, ...) needed).

6.3 FUTURE WORK

Several directions for future work regarding the representation of human cognitive concepts in spatial information systems remain open and some research questions have to be answered.

- In order to represent image schemata in spatial information and design systems, they have to be formalized. Attempts to formalize the CONTAINER and SURFACE schemata have already been made (Kuhn and Frank 1991, Rodríguez and Egenhofer 1997), but in order to represent and simulate complex processes such as wayfinding, a more comprehensive set of image schemata must be formalized in an integrated algebra. Such formalizations should also take the force dynamics of image schemata into consideration.
- The demonstration of our methodology is only based on a few interviews. A more sophisticated and extended experimental design is needed to verify the cross-cultural universality of image-schematic representations. Instead of using slides to interview people about their spatial experiences, human-subjects testing may be done in real-world application space. As pointed out by Allen *et al.* (1978) and Deakin (1996), the results of testing people's spatial perceptions with a sequence of slides may not be equal to their perceptions while walking through the actual environment. Furthermore, many of the stresses of navigating in an airport, such as overcrowdedness or timetrouble, were missing in our test-setup. During the

interviews subjects were not put under time control in order to cut out the stress factor. Therefore, the length-of-description variable could not be determined. Such a variable might have an influence on people's wayfinding behavior. Also, interviews should be done for different spatial environments, such as public transport buildings, hospitals, or libraries.

- Which image schemata are connected and how?

Our analysis shows that many image schemata are not experienced in isolation, but are correlated with other image schemata—represented as tightly coupled image-schematic blocks. For example, the LINK, PATH, and SURFACE schemata are used together most of the time: "I move to the ticket counter." implies that there exists a LINK between the subject's position and the ticket counter (i.e., a PATH); the activity of moving affords a SURFACE. Such image schemata are linked over common arguments, e.g., "I" (egocentric reference frame), PATH (*I*, ...), ON_SURFACE (*I*, floor). These *superimpositions* of schematic structures (Johnson 1987 p.125) occur, because it is difficult to fully express a spatial situation using only one pattern. More research has to be done on which image schemata are used within block-structures and how they are connected.

- Which image schemata are relevant for the comparison of wayfinding tasks?

One might look for a percentage-relation between important and unimportant image schemata used in the descriptions. LINKS and PATHS seem to be the most important image schemata for wayfinding tasks. First, people perceive spatial features via LINKS, then they decide where to go via PATHS. Image schemata like ON_SURFACE seem to be trivial and, therefore, of minor importance for the model. They are complemented by orientational and directional image schemata (e.g., LEFT_OF, IN_FRONT_OF) and other image schemata (e.g., BLOCKAGE, COUNTERFORCE).

- How are image schemata related to affordances?

  The term *affordance* was first introduced by Gibson (1979) who investigated how people perceive their environment. Gibson described the process of perception as the extraction of invariants from the stimulus flux and called these invariants affordances. Affordances are what environments and objects offer people to do. Therefore, they create potential activities for users. Affordances play a key role in an experiential view of space (Lakoff 1988, Mark and Frank 1996) because they offer a user-centered perspective.

Kuhn (1996) applied the theory of affordances to spatialized user interfaces. Affordances of physical space are mapped to abstract computational domains through spatial metaphors in order to bring human-computer interaction closer to people's experiences with real-world objects. Kuhn groups spatial affordances into four categories—affordances for (1) an individual user (e.g., move), (2) a user and an individual entity (e.g., objectify), (3) a user and multiple entities (e.g., differentiate), and (4) groups of users (e.g., communicate)—, reflecting different task situations. In order to know what passengers can do at an airport (i.e., what airport space affords to its users) one should find out what spatial affordances the architecture of an airport can offer for people's wayfinding. Examples for each of Kuhn's categories in relation to airport space are "moving from check-in counter to the gate", "navigating through the airport", "perceiving a sign", "interpreting a sign", "entering the departure hall", "searching for an emergency exit", "checking in at the check-in counter", "differentiating gates", "mentally organizing the hierarchy of signs", "communicating with other people at the airport", and "cooperating" (e.g., help finding each other's way).

As the literature on wayfinding models does not discuss important features like "being lost", there are no descriptions of negative affordances such as "getting lost." However, it is also important to find out about these negative affordances. If their causes—which are highly correlated to the causes of human (wayfinding) errors (Norman 1988)—could be found, it should in many cases be possible to alter the design of a particular space to get rid of its negative affordances.

Affordances seem to be closely related to image schemata because both of these concepts help people to understand a spatial situation in order to know what to do. The following two examples from Section 3.2 show the connection between image schemata and affordances: "Tom is entering the building." shows an experience with the concept of containment. *To enter* is an affordance of the object building and, therefore, based on the CONTAINER schema. "Michael is going home from his office."

shows the PATH schema. The path from his office to his home affords Michael to walk, therefore, motion is based on the PATH schema. The relation between image schemata and affordances was also pointed out by Kuhn (1996). Some of his examples are: perceiving is based on the OBJECT schema, motion is based on the PATH schema, place and store are based on the SURFACE and CONTAINER schemata. Therefore, affordances might be operational building blocks of image schemata. It remains to be seen whether they provide a basis for structuring wayfinding tasks and how this compares to the use of image schemata.

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APPENDIX

The following section presents transcript and image-schematic representation for one interview with regard to slides taken at Vienna International Airport in Austria.

Transcript	Extracted Image Schemata
Slide 1	
I see a large sign with flight information. I see crowds of people. I see a sign for terminal 2. I don't see "Austrian Airlines." There's the check-in counters. My gate is 51 to 65. I go forward and to the right. I'm looking for a short line to be in. Even though it's high it's a crowded space.	LINK(I,sign),LINK(I,flight information); LINK(I,people),FULL_OF(departure hall, people); LINK(I,terminal-2-sign); NO_LINK(I,"Austrian Airlines"); LINK(I,check-in counters); ?LINK(I,MATCHING(check-in counters, "51-65")); IN_FRONT_OF(PATH(I,unspecified location),I), RIGHT_OF(PATH(NEAR_FROM(I,unspecified location),check-in counters), NEAR_FROM(I,unspecified location)), ON_SURFACE(I,floor); ?LINK(I,LESS_THAN_IN(people in line,people in other lines,number)), IN_CONTAINER(I,line); HIGH_OF(ceiling);

Slide 2

It has opened up. I see the check-in counters. They are not as crowded as they were before. Gate 55 is the place to check in. I proceed forward and to the right. I go up to counter 55 or some place around there. I can check in at a particular set of check-in counters. I'm looking for those. I'm looking for short lines. I notice the yellow sign that says something about gates.

CONTAINER(departure hall),
LESS_THAN_IN(FULL_OF(departure hall, people),PREVIOUS_FULL_OF(departure hall, people),scale);
LINK(I,check-in counters);
LESS_THAN_IN(IN_FRONT_OF(people,check-incounters),PREVIOUS_IN_FRONT_OF(people,check-in counters),number);
LINK(I,gate 55),?PATH(I,gate 55);
IN_FRONT_OF(PATH(I,unspecified location),I),
RIGHT_OF(PATH(NEAR_FROM(I,unspecified location),check-in counters),NEAR_FROM(I, unspecified location)),ON_SURFACE(I,floor);
PATH(I,NEAR_FROM(I,gate 55)),CENTER-PERIPHERY(gate 55,unspecified location),
PATH(I,unspecified location);
ENABLE_TO(cognitive information
IN_CONTAINER(my counter,counters 51-65),
PATH(I,IN_CONTAINER(counter, counters 51-65)));
?LINK(I,IN_CONTAINER(counter, counters 51-65));
?LINK(I,LESS_THAN_IN(people in line, people in other lines,number));
LINK(I,yellow sign),LINK(I,gate-information);

Slide 3

I notice bright red counters. These are with Swiss Air and not with Austrian Airlines. I check in at gate 55 or 54. I read the signs. Does the “55” refer to the track? Do I put my luggage on the left or on the right?

LINK(I,red check-in counters);
MATCHING(check-in counters,”Swiss Air”),
NO_MATCHING(check-in counters,”Austrian Airlines”);
PATH(I,gate 55), PATH(I,gate54),
ON_SURFACE(I,floor);
LINK(I,signs);
MATCHING(“55”,track)?;
MATCHING(“55”,LEFT_OF(luggage-conveyor-belt,counter 55))?,
MATCHING(“55”,RIGHT_OF(luggage-conveyor-belt,counter 55))?,
ON_SURFACE(luggage,luggage-conveyor-belt);

Slide 4

I see half of a sign up in the upper right. I head for gate C57. I don't see where C is. I see the "Austrian-Airlines"-check-in counters. I don't need to go there—I've already checked in. It's a low ceiling. I have to duck under a low underpass and then out into a bigger area. I look around. I look at that sign. If it doesn't provide me anything I'll go in underneath to the other side and look around. There's a sign off to the left. It blends in with the other yellow signs.

LINK(I,PART_OF_WHOLE(rest of sign,sign)), IS_UP(sign,unspecified object), RIGHT_OF(sign,unspecified location);
?PATH(I,gate C57);
NO_LINK(I,"C");
LINK(I,check-in counters), LINK(I,"Austrian Airlines");
COUNTERFORCE_TO(I checked in, PATH(I,check-in counters));
LOW_OF(ceiling);
IS_DOWN(PATH(I,IN_CONTAINER(I,area)), LOW(ceiling)),ON_SURFACE(I,floor), LINK(I,CONTAINER(area));
CENTER-PERIPHERY(I,unspecified objects), COLLECTION(LINKS(I,unspecified object));
LINK(I,sign);
COMPELLED_TO_BY({PATH(I, CONTAINER(area)), CENTER-PERIPHERY(IN_BACK_OF(I, underpass),unspecified objects), COLLECTION(LINKS(IN_BACK_OF(I, underpass),unspecified object))}, NO_LINK(I,sign-information)),
IN_BACK_OF(CONTAINER(area),underpass);
LINK(I,LEFT_OF(sign,unspecified object));
MATCHING(sign,other yellow signs);

Slide 5

I come out in a big taller area. I see an "A, B, C"-gate that says it's passport control. The yellow sign stands out against the rest of the airport signage. The "A" and "B" and "C" are prominent black on white. It doesn't say "departures" in that direction. I see an "A, B, C"-sign in the other direction off to the right. I go forward and queue up for passport control. I go through passport control and head to the gates in the A-B-C-area.

IN_CONTAINER(I,area), MORE_THAN_IN(area,previous area,height);
LINK(I,gate),LINK(I,"A,B,C"),LINK(I, "passport control"),MATCHING(gate,passport control);
LINK(I,yellow sign), ATTRACTED_BY(I,PART_OF_WHOLE(yellow sign,airport signage));
ATTRACTED_BY(I,"A,B,C"), ON_SURFACE(black letters,white ground);
NO_LINK(I,"departures");
LINK(I,RIGHT_OF(sign,unspecified object)), LINK(I,"A,B,C");
IN_FRONT_OF(PATH(I,NEAR_FROM(I, passport control)),I),ON_SURFACE(I,floor);
PATH_ALONG(I,gates,CONTAINER(passport control)),IN_CONTAINER(gates,A-B-C-area);

Slide 6

I see shops. It's well-lit and it's not claustrophobic. I see the sign that says I should go down that hall to go to gate A. That's not the direction I want to go. The aisle can't go very far. It disappears among the different shops.

LINK(I,shops);
ATTRACTED_BY(I,light);
LINK(I,sign),LINK(I,hall),PATH_ALONG(I, gate A,SURFACE(hall));
COUNTERFORCE_TO(LINK(I,"A"),PATH(I, gate A));
MATCHING(hall,aisle),PATH(begin of aisle, end of aisle), COMPELLED_TO(NO_FAR_FROM(begin of aisle,end of aisle));
CENTER-PERIPHERY(aisle,shops), NEAR_FROM(shops,aisle);

Slide 7

It's an open space. I see the sign to the B-C-gates. I see information about the layout of the airport and flight information on the monitors. There's shops. They stand out against the back.	CONTAINER(duty-free space); LINK(I,sign),LINK(I,"B-C-gates"), PATH(sign,B-C-gates); LINK(I,airport-layout-information), LINK(I,ON_SURFACE(flight information, monitors)); LINK(I,shops); ATTRACTED_BY(I,shops), IN_BACK_OF(unspecified objects,shops);

Slide 8

I see lots of shops. I see a way to a sign that says "A, C." There's two ways to get to C. I see a flight-information-sign hanging from the ceiling. It's subdued so I ignored it. I'm looking for gate C, the general gate-C-area. I go down the shops-area in the center.	LINK(I,shops),FULL_OF(duty-free area,shops); LINK(I,sign),PATH(I,sign),LINK(I,"A,C"); MERGING(PATH1(I,gate C),PATH2(I,gate C)), NO_MATCHING(PATH1(I,gate C),PATH2(I, gate C)); LINK(I,flight-information-sign), IS_DOWN(flight-information-sign,ceiling); NO_ATTRACTED_BY(I,flight-information-sign); ?LINK(I,"gates C"); CENTER-PERIPHERY(IN_FRONT_OF(PATH(I, A-C-gates),I),shops),IN_CONTAINER(shops, area),ON_SURFACE(I,floor);

Slide 9

I see the yellow direction-signs. There's no "C" in this direction so I give it up quick. I notice the "A" and the arrow and I move off to a different view.

LINK(I,yellow direction-signs);
IN_FRONT_OF(NO_LINK(I,"C"),I),
COMPELLED_TO_BY(I give up direction, NO_LINK(I,"C"));
LINK(I,"A"),LINK(I,arrow),
COMPELLED_TO_BY(PATH(I,unspecified location),LINK(I,"A")),ON_SURFACE(I,floor),
NO_MATCHING(LINK(unspecified location, unspecified object),LINK(I,"A"));

Slide 10

The yellow direction-signs show up against this scene. I see the "C" to go forward. Beneath the sign I see directions to gates C51 to 62 which include my gate. I move straight on from here. I'm getting used to looking for the yellow signs.

LINK(I,yellow direction-signs),
ATTRACTED_BY(I,yellow direction-signs);
LINK(I,"C"),IN_FRONT_OF(PATH("C", gates C),"C"),SURFACE(floor);
LINK(I,"gates C51-62"),LINK(I,arrow),
IN_CONTAINER(my gate,"C51-62"),
IS_DOWN("gates C51-62"+arrow,sign);
IN_FRONT_OF(PATH(I,my gate),I),
ON_SURFACE(I,floor);
ATTRACTED_BY(I,yellow signs),
?LINK(I,yellow sign);

Slide 11

This is a brightly-lit corridor. It's not claustrophobic. I see the yellow sign in the distance urging me on. It's a long walk straight up the corridor.

LINK(I,corridor),ATTRACTED_BY(I,light);
MORE_THAN_IN(CONTAINER(corridor), CONTAINER(previous areas),openness);
LINK(I,FAR_FROM(yellow sign,I)),
COMPELLED_TO_BY(PATH(I,yellow sign), LINK(I,yellow sign)),ON_SURFACE(I,floor);
IN_FRONT_OF(PATH(I,FAR_FROM(my gate, I)),I);

Slide 12

I see the “C51 to C62”-sign. There’s a lot of information-signs coming up and they’re blending all into one great big bar. Informational signs for duty-shops and blank informational signs are blending in to things I need to find my way. The reflectance of the floor is distracting. It adds to the amount of yellow in the scene and makes it hard to pick out information signs. I go straight forward up to that space I can see. I move up closer to the signs to examine them.

LINK(I,sign),LINK(I,”C51-C62”); FULL_OF(corridor,information-signs), FAR_FROM(information-signs,I),LINK(I,bar), MERGING_INTO(information-signs,bar); LINK(I,duty-shop-information-signs), LINK(I,blank information-signs), MERGING(duty-shop-information-signs,blank information-signs,direction-signs); LINK(I,floor),ON_SURFACE(reflectance, floor),ATTRACTED_BY(I,reflectance); COUNTERFORCE_TO(FULL_OF(corridor, yellow),?LINK(I,information-signs)), IN_CONTAINER(yellow,corridor); IN_FRONT_OF(PATH(I,NEAR_FROM(I, CONTAINER(space))),I),LINK(I, CONTAINER(space)),ON_SURFACE(I,floor); ENABLE_TO(PATH(I,NEAR_FROM(I, information-signs)),LINK(I,information-signs));

Slide 13

There's a lot of gate-signs. I'm close to one that indicates "52 to 62." I'm looking for gate 57. I have to go up. The gates branch off. There's a lot of direction. Way in the distance I see a "C54 to 61." That's where I'm heading—off to the center. I pass the sculpture.	LINK(I,gate-signs),FULL_OF(corridor, gate-signs); LINK(I,"52-62"),NEAR_FROM(I,"52-62"); ?LINK(I,"gate 57"); IN_FRONT_OF(PATH(I,gate 57),I), ON_SURFACE(I,floor); SPLITTING(gates); FULL_OF(corridor,directions); LINK(I,FAR_FROM("C54-61",I)); IN_FRONT_OF(PATH(I,"C54-61"),I), CENTER-PERIPHERY("C54-61",unspecified objects); LINK(I,sculpture),PATH_ALONG(I,"C54-61", sculpture);

Slide 14

I see a large number of gates. I see my 57-gate in the center. The gate-signs are above the head of the crowd. The ceiling has come in low. My goal is straight ahead towards the center. I have to go to the right and around those posts. I have to avoid a passenger-lounge-area.	LINK(I,COLLECTION(gates)); LINK(I,gate 57),CENTER-PERIPHERY(gate 57, other gates); LINK(I,gate-signs),IS_UP(signs,heads), LINK(I,COLLECTION(people)); LINK(I,LOW_OF(ceiling)); IN_FRONT_OF(LINK(I,gate 57),I); COMPELLED_TO(RIGHT_OF(PATH(I,gate 57), unspecified object)),ON_SURFACE(I,floor), LINK(I,posts),CENTER-PERIPHERY(posts, PATH(I,gate 57)); LINK(I,passenger-lounge-area), COMPELLED_TO(RESTRAINT_REMOVAL(BLOCKED_BY(PATH(I,gate 57),passenger-lounge-area)));

Slide 15

The gate-areas and gate-counters. It’s a big open space. I see the passenger-lounge off to each side of the gates. There’s a large sculpture in the middle. I go off to the right to gate C57.	LINK(I,gate-areas),LINK(I,gate-counters); IN_CONTAINER(gate-areas+gate-counters, space); LINK(I,passenger-lounge), LEFT_OF(passenger-lounge,gates), RIGHT-OF(passenger-lounge,gates), NEAR_FROM(passenger-lounge,gates); LINK(I,sculpture), CENTER-PERIPHERY(sculpture, CONTAINER(space)); RIGHT_OF(PATH(I,gate C57),sculpture), ON_SURFACE(I,floor);

Slide 16

I see a gate. It’s a single-entry-point—I go straight through. There’s a loading-area beyond.	LINK(I,gate); PATH_ALONG(I,IN_CONTAINER(I,passenger-lounge),single-entry-point), ON_SURFACE(I,floor); LINK(I,loading-area),IN_BACK_OF(loading-area,gate),FAR_FROM(loading-area,I);

The following section presents transcript and image-schematic representation for one interview with regard to slides taken at Frankfurt International Airport in Germany.

Transcript	**Extracted Image Schemata**
Slide 1	
I see check-in gates. I notice two levels in the airport. There's an escalator near the check-in area. I see a monitor for flights off in the distance. I see a couple of signs, some say "A." I don't see signs for B which is my gate. I go to the check-in counter.	LINK(I,check-in gates); LINK(I,level1),LINK(I,level2),IS_UP(level2, level1),IN_CONTAINER(levels,airport); LINK(I,check-in-area), LINK(I,NEAR_FROM(escalator,check-in-area)); LINK(I,FAR_FROM(flights-monitor,I)); LINK(I,COLLECTION(signs)), LINK(I,COLLECTION("A")); NO_LINK(I,PART_OF_WHOLE("B",signs)), MATCHING(B,my gate); PATH(I,check-in counter), ON_SURFACE(I,floor);

Slide 2

I see a number of gates. I see a "do-not-enter"-sign and I don't see an "enter"-sign. I see the counter folks. I see signs indicating particular classes of flights, I see "business class." It looks like SAS is a subsidiary of Lufthansa. I don't see an entrance marked. I go up to right along that blue strip and wait for a counter to open. I'm looking for some "where-to-go" from here. I'm looking for obvious entrances. The yellow shields at the counters are eye-catching.

LINK(I,COLLECTION(gates));
LINK(I,sign),LINK(I,"do-not-enter"),
NO_LINK(I,"enter");
LINK(I,counter-staff);
LINK(I,signs),PART_OF_WHOLE("flight classes",signs),LINK(I,"business class");
IN_CONTAINER("SAS","Lufthansa"),
IS_UP("Lufthansa","SAS");
NO_LINK(I,entrance);
LINK(I,blue strip),PATH_ALONG(I,unspecified location,blue strip),NEAR_FROM(unspecified location,blue strip),ON_SURFACE(I,floor),
LINK(I,COLLECTION(counters)),
?RESTRAINT_REMOVAL(PART_OF_WHOLE(closed counter,COLLECTION(counters)));
?LINK(I,directional information);
?ATTRACTED_BY(I,entrances);
LINK(I,yellow shields),CONTACT(yellow shields,counters),ATTRACTED_BY(I,yellow shields);

Slide 3

I notice the blue signs hanging from the ceiling that have “B, C, D, E” marked on them. I see the word “departures” but I saw the large letters first. I notice the icon. I see the escalator up. I see the sign for gates-B-area, the arrow pointing to the direction. I look high on the ceiling for information. I head forward towards that sign. When I pass under the sign I look for something to point off to the right. I follow that group in front of me.	LINK(I,blue signs),LINK(I,ceiling), IS_DOWN(blue signs,ceiling), LINK(I,”B,C,D,E”), ON_SURFACE(“B,C,D,E”,blue signs); LINK(I,”departures”),ATTRACTED_BY(I, ”B,C,D,E”); LINK(I,icon); LINK(I,escalator),PATH_ALONG(unspecified location1,unspecified location2, SURFACE(escalator)),IS_UP(unspecified location2,unspecified location1); LINK(I,gates-B-sign),LINK(I,arrow), PATH(gates-B-sign,gates B); ?LINK(I,NEAR_FROM(information,ceiling)), HIGH_OF(ceiling),SURFACE(ceiling); IN_FRONT_OF(PATH(I,gates-B-sign),I), ON_SURFACE(I,floor); IS_DOWN(PATH(I,unspecified location),gates-B-sign), ?LINK(I,RIGHT_OF(PATH(IS_DOWN(I,gates-B-sign),unspecified object),I)); LINK(I,IN_FRONT_OF(COLLECTION(people), I)), COMPELLED_TO_BY(I follow people,people going);

Slide 4

I’m in the big part of the airport. I see a big departure-board, a lot of advertising. There’re some kiosks off to the left. I see the “McDonald’s”-sign. I see this “check-in for” but it’s so crowded with information that I ignore it. I look at the departure-board. I go under the departure-board and find a new path. I look for my flight, confirm the gate. I look for a B-direction to go. I see a “B” and an arrow pointing in some direction but it’s difficult to see.

IN_CONTAINER(I,departure hall), PART_OF_WHOLE(departure hall,airport); LINK(I,departure-board),LINK(I,advertising), FULL_OF(departure hall,advertising); LINK(I,LEFT_OF(COLLECTION(kiosks), unspecified object)); LINK(I,“McDonald’s”-sign); LINK(I,”check-in for”),LINK(I,information), FULL_OF(“check-in for”,information), NO_ATTRACTED_BY(I,”check-in for”); -; PATH(I,IS_DOWN(I,departure-board)), ON_SURFACE(I,floor),?PATH(IS_DOWN(I, departure-board),unspecified object); ?LINK(I,my flight),?MATCHING(cognitive gate-information,board-gate-information); ?PATH(I,B-gates); LINK(I,”B”),LINK(I,arrow),PATH(“B”, B-gates),NO_LINK(I,direction of arrow), FAR_FROM(arrow,I);

Slide 5

I see stuff off to the right, I can't make out what it is. Phone booths or something like that. I see a sign hanging from the top. I'm in the wrong place. It's about baggage. I see advertising-signs. Way in the distance I see familiar blue signs. I see a "C" but I don't see anything else. I'm not sure where I'm going. I move forwards towards the blue indicator signs. I'm looking for a new reference point.

LINK(I,RIGHT_OF(unspecified objects,I)), NO_MATCHING(unspecified objects, cognitive information);
MATCHING(unspecified objects,phone booths)?;
LINK(I,sign),IS_DOWN(sign,ceiling);
IN_CONTAINER(I,place), NO_MATCHING(environmental information, cognitive information);
LINK(I,"baggage");
LINK(I,advertising-signs);
LINK(I,FAR_FROM(blue signs,I)), MATCHING(blue signs,previous blue signs);
LINK(I,"C"),NO_LINK(I,other sign-information);
?PATH(I,my gate);
IN_FRONT_OF(PATH(I,blue signs),I), ON_SURFACE(I,floor);
?LINK(I,new reference point);

Slide 6

I see a big blue familiar gate-B-sign. I see a yellow cart being driven towards me so I get out of the way. A look at my ticket confirms that sign indicates towards where I want to go. It tells me to go off to the left. I don't see where my next waypoint is off to the left. I go up to the sign and go to the left. I check on the other side of the signs to see if they mean I have to go downstairs, because there's escalators. I get used to following blue signs. Off to the left I see A, B, C's and D, E's.

LINK(I,blue gate-B-sign),
MATCHING(blue sign,previous blue signs);
LINK(I,cart),PATH(cart,I),ON_SURFACE(cart, floor),COUNTERFORCE_TO(cart,PATH(I, unspecified location));
MATCHING(ticket-information,sign-information);
LEFT_OF(PATH(blue gate-B-sign,gates B),blue gate-B-sign);
NO_LINK(I,LEFT_OF(waypoint, blue gate-B-sign));
PATH(I,NEAR_FROM(I,blue gate-B-sign)), LEFT_OF(PATH(NEAR_FROM(I,blue gate-B-sign),unspecified object),blue gate-B-sign), ON_SURFACE(I,floor);
PATH(IN_FRONT_OF(I,blue gate-sign), IN_BACK_OF(I,blue gate-B-sign)), ?LINK(I,IN_BACK_OF(information, blue gate-B-sign)),LINK(I,escalators), PATH_ALONG(I,unspecified location, SURFACE(escalator))?, IS_DOWN(unspecified location,I);
ATTRACTED_BY(I,blue signs), PATH_ALONG(I,my gate,blue signs);
LINK(I,LEFT_OF(COLLECTION("A,B,C", "D,E")),unspecified object);

Slide 7

I see a food-service-area off in the distance and a lounge area for people waiting for flights. I don't know if this is a general waiting for all gate-B-flights. The blue signs are referring to the signs above them. I don't see the flight there. There's no green light indicating that it's boarding. I do a 360 and look at my surroundings to find another waypoint.

LINK(I,FAR_FROM(food-service-area,I)),
LINK(I,lounge area),
IN_CONTAINER(people,lounge area);
MATCHING(lounge area,general waiting for gate-B-flights)?;
LINK(I,blue signs),LINK(I,signs),
IS_UP(signs,blue signs),LINK(blue signs, signs);
NO_LINK(I,ON_SURFACE(my flight,signs));
NO_LINK(I,MATCHING(green light,"plane is boarding"));
CENTER-PERIPHERY(I,unspecified objects),
?COLLECTION(LINKS(I,unspecified objects)),
?LINK(I,waypoint);

Slide 8

The blue signs stand out in the airport. I see the blue gate-B-sign indicating some place off to the right. I go that way. I cross out of the shops-area that I'm in. I don't see the hallway that I go off. I go forward and to the left to get underneath the sign and look for the next indicator. There's an information booth. If I get too confused, I'll go there.

ATTRACTED_BY(I,blue signs), IN_CONTAINER(blue signs,airport); LINK(I,blue gate-B-sign), RIGHT_OF(PATH(blue gate-B-sign,B-gates), blue gate-B-sign); RIGHT_OF(PATH(I,B-gates),blue gate-B-sign),ON_SURFACE(I,floor); PATH(IN_CONTAINER(I,shops-area), OUT_CONTAINER(I,shops-area)); NO_LINK(I,hallway),PATH_ALONG(I, gates B,hallway); IN_FRONT_OF(PATH(I,unspecified location),I), LEFT_OF(PATH(I,IS_DOWN(I,blue gate-B-sign)),unspecified location),?LINK(I,indicator); LINK(I,information booth); PATH(I,information booth)?;

Slide 9

I see the corridor I need to move into. I see the "terminal-2-via-skyline." Further down I see the terminal-B-forward-arrow-sign. They stand out against the gray-green of the walls. I head straight down that way. I'm cued in to the rectangular signs that say "B."

LINK(I,corridor),PATH(I,IN_CONTAINER(I, corridor)),ON_SURFACE(I,floor); LINK(I,"terminal-2-via-skyline"); LINK(I,FAR_FROM(terminal-B-sign,I)), LINK(I,FAR_FROM(arrow,I)), IN_FRONT_OF(PATH(terminal-B-sign, B-gates),terminal-B-sign); ATTRACTED_BY(I,blue signs), LINK(I,gray-green walls); IN_FRONT_OF(PATH(I,gates B),I); ATTRACTED_BY(I,rectangular B-signs);

Slide 10

I see the "B"-sign. I go down and take a left. I notice the "access for passengers only"-sign. I'm getting into a security area.	LINK(I,sign),LINK(I,"B"); IN_FRONT_OF(PATH(I,unspecified location1), I),LEFT_OF(PATH(I,unspecified location2), unspecified location1),ON_SURFACE(I,floor); LINK(I,sign), LINK(I,"access for passengers only"); PATH(I,IN_CONTAINER(I,security area));

Slide 11

I see a lot of blue information-signs. Down in the distance I see the blue B-sign. This is a security-or-ticket-check-point. I don't know how to interpret the icon. I notice the tunneling past the check-point. They have a computer terminal covering their entire body. This is a restricted-flow-area. I proceed forward.	LINK(I,information-signs), FULL_OF(area,blue information-signs); LINK(I,FAR_FROM(blue B-sign,I)); LINK(I,security-check-point)?, LINK(I,ticket-check-point)?; LINK(I,icon),NO_MATCHING(icon, cognitive information); LINK(I,check-point), IN_BACK_OF(CONTAINER(tunnel),check-point),PATH(start of tunnel,end of tunnel), SURFACE(tunnel); LINK(I,computer terminal),BLOCKED_BY(employee's body,computer terminal); BLOCKED_BY(PATH(OUT_CONTAINER(people,tunnel),IN_CONTAINER(people, tunnel)),small entrance); IN_FRONT_OF(PATH(I,my gate),I), ON_SURFACE(I,floor);

Slide 12

This is a security-checkpoint. The glass walls and the prominent “B”-sign. There’re different classes of check-in. I go straight through security.	LINK(I,security-checkpoint); LINK(I,glass walls),LINK(I,B-sign), ATTRACTED_BY(I,B-sign); LINK(I,check-in-classes), SPLITTING(check-in-classes); IN_FRONT_OF(PATH_ALONG(I,unspecified location,CONTAINER(security)),I), ON_SURFACE(I,floor);

Slide 13

I’m in a wide open space. I see the “B”-sign. I don’t see any qualifications that it’s only for certain gates so it takes care of everything. I move forward and turn left down that corridor.	IN_CONTAINER(I,wide space); LINK(I,B-sign); NO_LINK(I,PART_OF_WHOLE(“certain gates”,”B-gates”)),PATH(B-sign,all B-gates); IN_FRONT_OF(PATH(I,unspecified location),I), LEFT_OF(PATH_ALONG(I,gates B,corridor), unspecified location),ON_SURFACE(I,floor), LINK(I,corridor);

Slide 14

I notice individual gate signs off to either side of the corridor. It's a long walk to gate B45. The gates don't alternate with odds on one side and evens on the other. The ceiling is lower, a more constricted space. There's a group of signs down the way. Maybe I won't have to walk the full length of the terminal. It branches. I proceed on straight down the hall and check whether I'm going to branch one direction or the other.

LINK(I,COLLECTION(gate-signs)), LINK(I,corridor),LEFT_OF(gate-signs, corridor),RIGHT_OF(gate-signs,corridor); PATH(I,FAR_FROM(gate B45,I)), SURFACE(corridor); LEFT_OF(NO_LINK_ALONG(first gate#,last gate#,only odd#),corridor), RIGHT_OF(NO_LINK_ALONG(first gate#,last gate#,only even#),corridor); LOW_OF(ceiling),NEAR_FROM(LEFT_OF(unspecified object,corridor),RIGHT_OF(unspecified object1,corridor)); LINK(I,FAR_FROM(COLLECTION(signs),I)); PATH(I,FAR_FROM(end of terminal,I))?; SPLITTING(terminal); IN_FRONT_OF(PATH_ALONG(I,gate B45, SURFACE(hall)),I),ON_SURFACE(I,floor), ?MATCHING(PART_OF_WHOLE(direction, directions),PATH(I,gate B45));

Slide 15

There's more visual clutter with the posts and posters. I see the "gate-B"-sign indicating gate B45 is that way. I see a sign for non-EU nationals—that's me. I'm coming to another checkpoint. I go forward and hang to the left. There's a different queue for non-EU's. There's a different path where gates 60 and above go off. There's only one direction to be going. There's no indication of direction on the line-up signs.	LINK(I,posts),LINK(I,posters), FULL_OF(CONTAINER(area),posts+posters); LINK(I,gate-B-sign),PATH(gate-B-sign, gate B45); LINK(I,sign),LINK(I,"non-EU nationals"), MATCHING(sign-information,cognitive information); LINK(I,checkpoint),PATH(I,checkpoint); IN_FRONT_OF(PATH(I,unspecified location1), I),LEFT_OF(PATH(I,unspecified location2), unspecified location1),ON_SURFACE(I,floor); LINK(I,queues),SPLITTING(queues), NO_MATCHING(queue for non-EU's, other queues); SPLITTING(PATH(I,B-gates)), NO_MATCHING(PATH(I,gates B-below 60), PATH(I,gates B-above 59)); MATCHING(one direction,PATH(I,gate B45)); LINK(I,line-up-signs),NO_LINK(I, ON_SURFACE(direction,line-up-signs));

Slide 16

I see the passport-control-sign. I see queues I need to approach. The gates are beyond this point. It’s hard to see beyond this point. I approach the counter. I go right down the middle.

LINK(I,sign),LINK(I,”passport control”);
LINK(I,queues),COMPELLED_TO(PATH(I, queues));
IN_BACK_OF(gates,counter);
?LINK(I,IN_BACK_OF(unspecified object, counter));
LINK(I,counter),PATH(I,counter),
ON_SURFACE(I,floor);
CENTER-PERIPHERY(IN_FRONT_OF(PATH(I, unspecified location),I),counters);

Slide 17

It opens up and I see a lot of gate information. The signs in the center are prominent. Gate A is advertised but it wasn’t prior to this. So it must be that you have to exit out and go all the way back to the main turn. I see duty-free shops. Gate B45 is off to the left. I go past the kiosk and off to the left.

CONTAINER(duty-free-area),
LINK(I,COLLECTION(gate-information));
LINK(I,signs),CENTER-PERIPHERY(signs, unspecified objects),ATTRACTED_BY(I,signs);
LINK(I,”gate A”),PREVIOUS_NO_LINK(I, ”gate A”);
COMPELLED_TO_BY(PATH_ALONG(“gate A”, gates A,{OUT_CONTAINER(person,duty-free-area),FAR_FROM(main turn,person)}),
LINK(I,”gate A”)),
ON_SURFACE(person,floor);
LINK(I,duty-free shops);
LEFT_OF(PATH(signs,gate B45),signs);
LINK(I,kiosk),
LEFT_OF(PATH_ALONG(I,gate B45,kiosk),I),
ON_SURFACE(I,floor);

Slide 18

I see the gate-sign. There's duty-free shops. I head straight down. This is a more open area.	LINK(I,gate-sign); LINK(I,duty-free shops); IN_FRONT_OF(PATH(I,gate B45),I), ON_SURFACE(I,floor); MORE_THAN_IN(CONTAINER(area), CONTAINER(previous area),openness);

Slide 19

I see lots of seats. I see a corridor. The posts present a funnel. There's a linear orientation to this space—it suggests moving forward. I don't see any signs. Way in the distance I see a "44-to-something"-sign. I proceed down this corridor.	LINK(I,COLLECTION(seats)); LINK(I,corridor); LINK(I,posts),PATH(start of funnel, end of funnel),SURFACE(funnel), LEFT_OF(COLLECTION(posts),funnel), RIGHT_OF(COLLECTION(posts),funnel); IN_FRONT_OF(PATH_ALONG(I, end of funnel,SURFACE(funnel)),I); NO_LINK(I,signs); LINK(I,sign),LINK(I,"44-unspecified #"), FAR_FROM(sign+"44-unspecified #,I); PATH_ALONG(I,FAR_FROM(sign,I), ON_SURFACE(I,corridor));

Slide 20

I notice the usual foreground to background. I see people with luggage-carts. I see counters but I don't see anybody at the counters. I see an information kiosk. I do a 360 and take in the whole scene. I don't see crowds of passengers that indicate a boarding area. Behind that person's head is a "B." I step to one side to see what it says down that way. Then I'm able to see if that's a particular gate designator. I look off to the left and right to get more detail. I proceed down past the guys with the luggage carts.

LINK(I,NEAR_FROM(unspecified objects,I)),
LINK(I,FAR_FROM(unspecified objects,I));
LINK(I,people),LINK(people,luggage-carts);
LINK(I,counters),
NO_LINK(I,NEAR_FROM(people,counters));
LINK(I,information kiosk);
CENTER_PERIPHERY(I,unspecified objects),
?COLLECTION(LINKS(I,unspecified objects));
NO_LINK(I,FULL_OF(area,passengers)),
NO_MATCHING(FULL_OF(area,passengers),
boarding area);
LINK(I,person's head),LINK(I,"B"),
IN_BACK_OF("B",person's head);
NEAR_FROM(unspecified location,I),
ENABLE_TO(LEFT_OF(PATH(I,unspecified
location),I),LINK(I,FAR_FROM(information,
I))),ON_SURFACE(I,floor);
ENABLE_TO(RESTRAINT_REMOVAL(
BLOCKAGE(person's head)),MATCHING("B",
gate designator)?);
?LINK(I,unspecified objects),
LEFT_OF(unspecified objects,I),
RIGHT_OF(unspecified objects,I);
IN_FRONT_OF(PATH_ALONG(I,unspecified
location,{people,luggage carts}),I);

Slide 21

I see a crowd. Centered is gate B45 which is my goal. People have a lot of luggage. I don’t know if there’s luggage check-in. I get in the queue and go to the counter.	LINK(I,people),FULL_OF(gate-area,people); LINK(I,gate B45),CENTER-PERIPHERY(gate B45,people),MATCHING(environmental gate-information,cognitive gate-information); LINK(people,COLLECTION(luggage)); LINK(I,luggage-check-in)?; LINK(I,queue),PATH(I,queue),ON_SURFACE(I,floor),LINK(I,counter),PATH(I,counter);

BIOGRAPHY

Martin Raubal was born in Vienna, Austria on September 11, 1968. He received his high school diploma with honors from the Stiftsgymnasium in Melk, Austria in 1986. After serving in the Austrian Army he entered the Technical University of Vienna in 1987. Between 1987 and 1990 Martin worked for the Austrian Surveying Agency for several months. In 1991 and 1992 he traveled to the U.S.A., Australia, and New Zealand. While in Sydney, Australia, he studied English at the Cambridge English Language Centers and received a diploma. After returning to Austria he worked part-time as a surveyor from 1993 - 1995 and received the “1st Diploma” in Surveying Engineering in March 1995. In 1995 and 1996 Martin worked as a Teaching Assistant at the Department of Geoinformation, Technical University Vienna.

In the fall of 1996 he entered the master’s degree program at the University of Maine in the department of Spatial Information Science and Engineering where he also worked as a Research Assistant. In 1996 and 1997 he has authored and co-authored four research papers published in conference proceedings and journals.

Martin is a candidate for the Master of Science degree in Spatial Information Science and Engineering from the University of Maine in December, 1997.