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SPATIAL ASPECTS OF TASK-SPECIFIC WAYFINDING MAPS

A representation-theoretic perspective

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Abstract. Ways of guiding people from a given location to specific other locations are discussed. Different classes of wayfinding tasks are distinguished. Various parameters that influence the suitability of certain wayfinding aids for specific wayfinding tasks are identified. Maps are compared with verbal route descriptions and the respective advantages of the two wayfinding aids are discussed. Spatially presented wayfinding aids, specifically schematic maps, are considered in more detail. The question of how to decide on a suitable level of abstraction for map representations is addressed. Different ways of simplifying wayfinding are considered. An approach to systematic investigation and design of wayfinding systems is proposed.

1. Wayfinding

Finding specific locations in the environment is one of the most essential abilities of agents like human beings, animals, and autonomous robots. Finding one's way requires knowledge about the environment (McDermott and Davis, 1984; Passini, 1984). This knowledge may refer to specific facts about a given environment or it may refer to general relationships that hold in a larger class of environments or even in all spatial worlds.

Specific spatial knowledge usually is directly acquired by exploring the environment and memorizing landmarks and their relationships. General spatial knowledge also can be acquired by gaining direct experience about spatial configurations and by making inferences about general patterns. Alternatively, abstractions from reality may be formed on the basis of observed or hypothesized regularities and general knowledge may be derived on this more abstract level.

The spatial realm has the special property that abstractions of a physical environment can be represented rather naturally in such a way that spatial relations in the environment are mapped into spatial relations in the abstract representation. In this way, we can obtain particularly concrete abstractions in which spatial relations can be treated just as if they were relations in the real environment (Freksa, 1997).

In this paper, we address the issue of designing spatial environments and wayfinding maps in such a way that human beings – or other cognitive agents – can easily find their way. This spatial design problem touches on issues of architecture and spatial cognition. We will identify a variety of dimensions related to the cognitive process of wayfinding and discuss how these dimensions can be taken into consideration in designing customized wayfinding tools.

The paper is organized as follows: In the remainder of this section we introduce the wayfinding task as a process that involves the communication of spatial knowledge and that causes cognitive effort and therefore requires support for reducing this effort. Section 2 discusses different classes of aids that can support wayfinding. Graphical and verbal aids are considered in section 3 in more detail as two approaches to supporting wayfinding. Section 4 addresses the wayfinding problem from a representation-theoretic perspective and section 5 discusses how this perspective can be used for a systematic approach to designing wayfinding aids. Section 6 discusses the role of the environment in the wayfinding task and section 7 presents an outlook on the development of tools for designing task-specific wayfinding aids.

1.1. COMMUNICATING SPATIAL KNOWLEDGE

Besides through personal experience from a real environment or from an abstract representation of space, spatial knowledge can be communicated from one agent to another agent. For the purposes of the present paper, we shall consider two types of communication: (1) communication by means of (propositional) language, and (2) communication by means of (analogical) spatial representations (Habel, 1990).

Propositional languages include natural languages and formal languages. A main feature of propositional languages is their generality: in principle, propositional languages are powerful enough to describe arbitrary concrete or abstract relationships – whether these relationships can be realized in the physical world or not, and whether they are consistent to one another or not. Another feature of typical propositional languages is their linear structure: natural languages and most formal languages have a natural sequential structure that defines the canonical order of presentation.

In contrast, analogical spatial representations are constrained by severe restrictions: as a consequence of the analogicity of spatial representations, physically impossible spatial relations and inconsistent sets of relations can not be represented. Furthermore, spatial representations usually are conveyed in a 2- or 3-dimensional spatial medium and do not have a natural linear representation structure. Although they may be converted into linear sequential structures by systematic traversing strategies, these conversions do not preserve the full spatial analogicity that makes them so special (Larkin and Simon, 1987).

1.2. WAYFINDING SUPPORT

Autonomous agents – in particular human beings – have general wayfinding abilities (Board, 1978). With these abilities, ways to a given destination typically can be found eventually without extraneous help. However, external information about the specific wayfinding situation may simplify the wayfinding task.

Different wayfinding situations require different support. Support is not for free: a certain effort is required to generate situation-adequate support and to communicate it to the waysearcher. Thus, in determining adequate wayfinding support for a given situation, we first must understand what kind of wayfinding situation we are looking at. A wayfinding situation involves:

- at least one search object in a given environment,
- at least one starting position for the search process,
- at least one search instance,
- at least one possible route,
- at least one waysearcher, and
- zero or more external supporters.

Wayfinding situations can be characterized as:

- simple or complex search situations and
- time-critical, space-critical, or uncritical search situations,

and we can distinguish

- well-informed or uninformed searchers and
- smart or helpless searchers.

Furthermore,

- cultural dispositions,
- sensory abilities,
- orientation abilities, and
- individual mobility

may influence the choice of an appropriate way. Each of these conditions may differ for a specific wayfinding support situation. We will look at the different conditions in more detail to analyze the design situation for the wayfinding support we want to provide.

1.3. COST OF FINDING ONE'S WAY

We will look at wayfinding situations from a perspective of cognitive processing and economy. It is not obvious which types of efforts should be considered as contributing to the wayfinding cost. Surely, wayfinding is easier (and less costly) in a structured orderly environment than in an unstructured heterogeneous world. In our culture, environments containing paved roads may support a given wayfinding task better than jungles that are difficult to penetrate. Converting a jungle into an environment with paved roads, however, is costly. Should we count the cost of converting an environment as wayfinding cost?

As the present paper is written in the context of design, we will have to take into account such expenses. Design of adequate wayfinding support does not stop at the status quo of the environment. To the cost of wayfinding contribute

- cost of preparing the way to be found,
- cost of planning the decisions to be taken for finding the way, and
- cost of executing the wayfinding plan.

Some of these expenditures are spent by the waysearchers, some by the supporters. Part of the design task will be to determine a suitable dividing line between the tasks of the two groups.

1.4. CLASSES OF WAYFINDING SITUATIONS

Not all of the expenses incurred in finding one's way can be attributed to a single wayfinding event. Rather, the cost of preparing the way in support of the wayfinding task must be distributed to all wayfinding events that benefit from or are impeded by the preparation of the way. Accordingly, the planning cost must be distributed to all wayfinding events that benefit from or are impeded by the plan.

The evaluation of a wayfinding support system for a specific problem domain requires the evaluation of the entire set of different situations to be handled and must take into account the number of situations it has to support. Conversely, when designing a wayfinding support system, we must estimate the cost and usefulness in different situations and compare possible solutions to possible alternatives.

2. Customized Wayfinding Support

In everyday communication we select from quite a variety of methods to support someone to find his or her way. The selection of an appropriate method depends on the specific situation.

2.1. SUPPORT FOR FINDING A SINGLE ROUTE

For example, we may give someone a verbal description of the decisions to be taken along the route orally, when we expect the waysearcher to search the way immediately thereafter and when the decisions to be taken are not too complex. When we must fear that the waysearcher might use a different reference system for interpreting our verbal description, we may enrich the description by pointing out an unambiguous spatial reference and anchor the description to this common reference system.

When the waysearch is not supposed to take place immediately, we may prefer to write down the description to make sure no important details get lost in memory until the description is used. When we are not able to point out a reliable reference landmark (e.g. due to restrictions in visibility), we may enrich the verbal description by drawing a sketch map indicating landmarks that can be identified during the search procedure. A written route description may be chosen also for another reason than the one given above: when the instruction needs to be given to several users it may be more economical to write down the description once and provide a copy of it to each of the waysearchers.

2.2. SUPPORT FOR FINDING A CLASS OF ROUTES

Verbal descriptions are economical when there is only one route that is taken by all users. However, when everybody has the same destination but approaches from a different direction, everyone would need a different description. In such situations it makes sense to provide a map that contains the different approach routes. The map may take more effort to provide than the verbal description of a single route; but it is of more general use as it serves to find the way on different routes. Accordingly, when we want to support finding different destinations from a given location, it makes sense to provide a map (McEachren, 1995).

Now let's look at an additional dimension: someone desires support for a yet unspecified route, e.g. support for finding an arbitrary route in an unknown city. It would be quite a burden if the waysearcher had to carry along verbal descriptions of all the routes one may possibly want to take. Not to speak about the effort and cost in producing these descriptions! Again, the more general but less supportive device of a map is an adequate choice in such a situation, in most cases.

But also note that the map does not provide the same type of support as the verbal description does. While the verbal description contains the decisions to be taken in precompiled form, the map must be analyzed and interpreted in more depth to identify potential landmarks and decision points. In this sense, a map supports the waysearcher to a lesser extent than a verbal description does. The freedom of specifying a route to be taken spontaneously must be bought at the expense of gaining less support.

2.3. REDUCED GENERALITY FOR ENHANCED EFFECTIVITY

Perhaps the device ‘map’ is unnecessarily general for a specific problem class like wayfinding? After all, maps are useful for all sorts of other tasks as well. Indeed, for navigating in a city we do not need many of the aspects that may be found on a general reference map. In other words: for the class of wayfinding tasks, we want to have maps that are general wrt. the particular ways to be found but we do not need maps that are general wrt. other feature dimensions (Barkowsky and Freksa, 1997).

The obvious solution is to abstract from those types of information in a map that do not support the wayfinding process. The interesting question that arises is: Which features, relations, structures, and other properties support the wayfinding process and which impede the process?

3. Combining Advantages of Maps and of Verbal Descriptions

Maps derive their basic structure from the spatial structure of the geographic world while verbal descriptions derive their structure from conceptual categories and linguistic structures (cf. Tversky and Lee, 1998). While the structure of maps allows us to directly derive spatial relations that are relevant for wayfinding tasks in the real environment, verbal route descriptions explicitly address decisions to be taken in terms of meaningful notions familiar to the user. To evaluate the contribution of different types of wayfinding support technologies, we will provide a computational account of the different information structures.

3.1. MAPS AS ANNOTATED AERIAL PHOTOGRAPHS

From a user’s perspective, what is the difference between an aerial photograph and a corresponding map? An aerial photograph can be viewed as a recording of spatial relations between meaningless entities taken from a bird’s eye perspective. While the recorded light intensities by themselves do not tell anything about the entities they refer to, their spatial relations tell much about the spatial relations of the corresponding entities in the reference world. As these spatial relations are extremely important for dealing with a large class of tasks including wayfinding tasks, maps are produced that reflect exactly those spatial relationships.

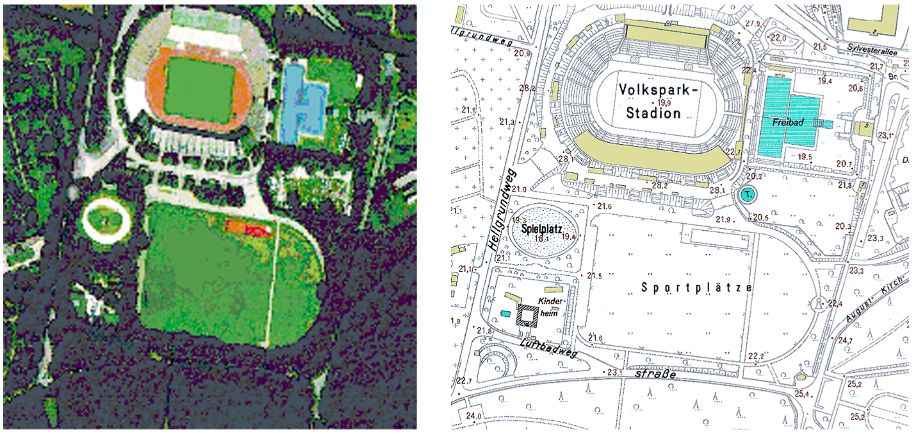

Figure 1. *Aerial photograph and a corresponding map section.*

In addition to spatial relationships, maps represent knowledge about depicted entities. Thus, maps can be viewed as interpreted aerial photographs, where sets of meaningless picture elements are replaced by symbols and the symbols correspond to meaningful entities in our concept-oriented view of the world. The spatial relationships of the symbols maintain the spatial relationships of the original picture elements wherever possible. As symbols use shape and other spatial features for visualization on maps, a representational conflict arises, and exact spatial symbol-picture correspondence is violated (Barkowsky and Freksa, 1997).

Depending on the class of tasks to be performed, maps symbolize different entities and different conceptual aspects of the depicted domain. In this way, maps can be generated with wayfinding tasks in mind and the interpretation of features can be carried out with regard to this class of tasks. Thus, computational effort invested in the production of the map relieves the waysearcher from cognitive effort in finding the way, as many decisions with regard to the conceptual structure of the world that are relevant for the wayfinding task already have been taken.

3.2. VERBAL DESCRIPTIONS AS SPECIFIC COMPILED PLANS

Verbal route descriptions prepare the wayfinding process beyond structuring the domain for a class of tasks. They contain instructions like ‘turn left at the next intersection’ that refer to specific decisions that must be taken along the route. Cognitive effort is invested here to derive a plan for the specific route, leaving for the waysearcher only the task of identifying landmarks and spatial relations in the real environment and to instantiate the precompiled decision.

In verbal route descriptions, the representation of spatial relations is reduced to a minimum. Spatial relations, which are represented in maps intrinsically, are reduced to a sequence of locations on the specific route in verbal descriptions. This usually makes it impossible to generalize from specific route descriptions to a larger class of wayfinding tasks.

3.3. SCHEMATIC MAPS AS GENERIC COMPILED PLANS

An ideal support for solving a given class of tasks would be a map-like structure that features just those aspects of the domain that are relevant to this class of tasks and prevents other features from distracting from a straightforward solution of the task. Like in the verbal description, attention would be focussed on decision points and on the alternatives that may exist in the given problem class (Berendt, Barkowsky, et al., 1998).

There are two types of representations that can be considered hybrids of maps and verbal descriptions in the sense described above: schematic maps and sketch maps. Schematic maps are derived from maps by relaxing spatial and other constraints; on a qualitative level, certain spatial relations are still preserved. In schematic maps, typically more spatial relations are maintained than in sketch maps and schematic maps are more complete wrt. the entities depicted, but there is no crisp boundary between the two types of representations.

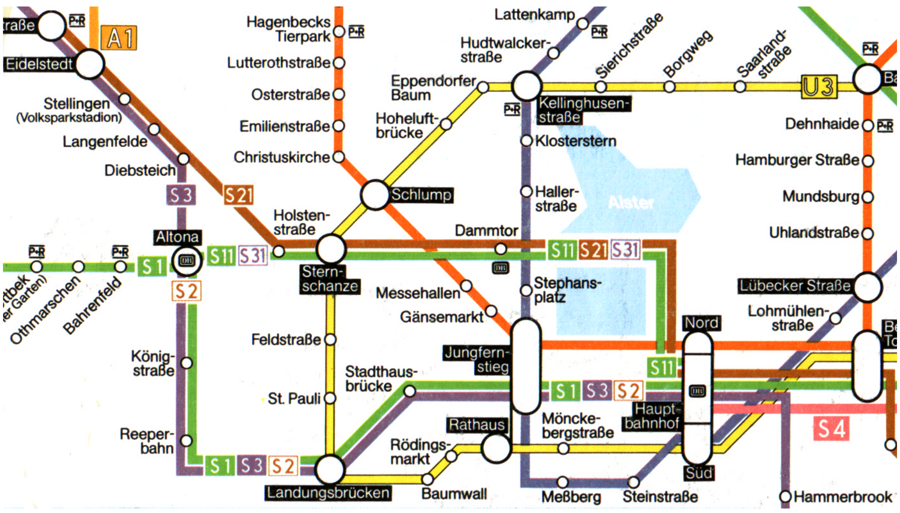

Figure 2. *Section from the schematic public transportation network map of Hamburg.*

Schematic maps like public transportation network maps can be considered precompiled general wayfinding plans that stop short of verbalization. Routes can be derived more easily than from more general maps but certain spatial and other relations cannot be derived (Berendt, Rauh, et al. 1998). Schematic maps are simplified versions of more general maps in such a way that those aspects, which would be captured in a verbal wayfinding description, are emphasized and other aspects are neglected. For a selected route it does not take much effort to verbalize the resulting plan and get easy to follow support for finding the way.

Everybody knows from their own experience that there are good schematic maps and bad schematic maps. Sometimes, transportation network maps that are transparent and easy to use for novice users are replaced by maps that are considered superior by the designers and inferior by the users. As yet, we have no cognitive theory that allows us to evaluate advantages and disadvantages of different spatial information support systems and to systematically determine an optimal trade-off between competing design criteria.

3.4. SKETCH MAPS AS CUSTOMIZED COMPILED PLANS

The other hybrids of maps and verbal descriptions, sketch maps, are sequentially generated much like verbal route descriptions (Habel and Tappe, in press) and are visualized using map elements. Sketch maps frequently are generated to enhance verbal descriptions by spatial features and are typically derived from verbal descriptions (cf. Suwa et al., 1998). They serve as customized wayfinding aids that are specifically suitable to find one particular location.

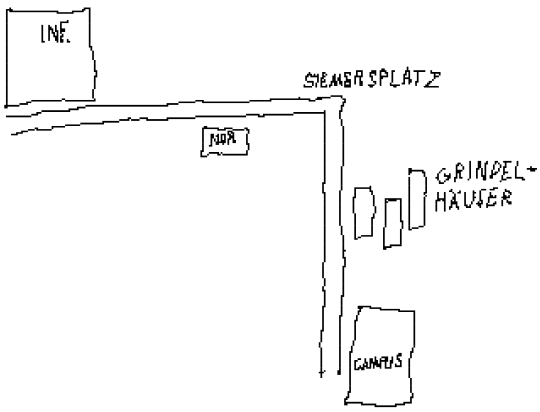

Figure 3. *Sketch map for finding a specific location from a given starting point* (from Habel and Tappe, in press).

4. A Representation-Theoretic Account of Wayfinding

As many other cognitive tasks, wayfinding tasks are carried out partly in the physical environment and partly in the domain of cognitive representation. The parts carried out in the physical environment are – from a cognitive perspective – primitive. But the relations in the physical environment are the ones that count; they give meaning to the structures and operations in the cognitive representation. The structures and operations in the representation of the environment are the ones that can make an agent intelligent; they are the ones that help the waysearcher find a good solution cognitively, i.e. relying more on mental processes than on physical action (Downs and Stea, 1977; Thorndyke and Hayes-Roth, 1982; McDermott and Davis, 1984).

Representation theory describes the correspondences between a represented world and the relations in this world on one hand, and a representing world and the relations in this representing world on the other hand (Palmer, 1978; Furbach et al., 1985). In the case of a wayfinding task, the represented world is the environment in which the way must be found. Among the relations in the represented world are the spatial relations that exist in the environment. The representing world is the map or the verbal route description. The relations in the representing world are spatial relations and designations in the map and designations and linguistic relations in the verbal route description, respectively.

4.1. THE WAYFINDING TASK IN THE ENVIRONMENT

The environment as well as the perception and the conception of the environment determine the structure of a wayfinding problem (Gärling and Golledge, 1989). Conceptual solutions to real world problems are only useful if they can be linked correctly to the respective real world situation. Thus, the perception and motor abilities of an agent will determine the appropriateness and usefulness of the conceptual counterpart.

Wayfinding is a rather down to earth task intrinsically connected to a specific spatio-physical structure of a given environment. Practical abilities for wayfinding have developed on a low perceptual level before higher-level cognitive shortcuts could emerge. It is plausible to assume that spatially organized cognitive structures took over the task of solving inherently spatial tasks.

A crucial aspect in solving cognitive tasks in a meaningful way is to get straight the correspondence relation between the environment (where the solution of the task matters) and the representation (where the solution is computed). The correspondence relation can be very simple when similar or identical operations can be performed in the representation as in the real environment.

4.2. THE WAYFINDING TASK IN THE COGNITIVE DOMAIN

In our wayfinding example we distinguish the problem domain, in which the problem solution can be applied, from the representation domain, in which the solution is derived. The representation domain may consist of a human brain or a computer. In our example it includes an external tool: the verbal description and/or the map.[1]

We will now focus our attention on the representation domain where most of the cognitive processes are carried out. This is the place where structures perceived in the environment and conceptual structures developed in cognitive processes meet. It is the place where action sequences in the physical environment can benefit from processing conceptual structures. These two types of structures manifest themselves in the structure of our external tool that supports the wayfinding process.

We may have a basically spatial structure in form of a map; this structure has a strong correspondence to the physical environment and is therefore particularly useful for an action-type reasoning process. Or we may have a basically conceptual structure in form of a description; this structure may have strong correspondence to our abstract reasoning and is particularly useful for a concept-driven reasoning process (Freksa, 1991). The narrower we can make the gap between these two extremes, the better should become the cognitive support we can provide for wayfinding. Schematic maps can be viewed as an attempt to bridge the gap between the physical and the conceptual structures.

4.3. COGNITIVE CORRESPONDENCE BETWEEN THE ENVIRONMENT AND ITS REPRESENTATION

The representational mapping relevant for easily solving wayfinding tasks roughly looks as follows: the aspects of the environment that are conceptually critical for the wayfinding task are mapped into a schematic map. The schematic map organizes symbols corresponding to these critical aspects in a structurally simple scheme. The spatial arrangement of the symbols corresponds on a qualitative level to the spatial arrangement of the real entities represented by the symbols. In this way, concepts relevant to the cognitive wayfinding process are spatially linked to the corresponding entities in the real environment and can easily be identified.

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[1] We can ignore here that the brain / computer and the external tool happen to be part of the environment, as well.

5. Schematic Map Design as Solving a Representation-Theoretic Optimization Problem

Why can maps be much more effective for spatial problem solving than verbal descriptions? Not only the structural correspondences to the depicted environment but also the inherent spatial constraints of the map support the inference processes. When a specific spatial task is solved using a map, a whole range of alternatives becomes apparent as spatial inference processes operate on the map. These alternatives have an obvious correspondence to real-world situations and alternatives without such correspondence are not considered. The space can be realistically explored by operating on its representation.

When employing maps for wayfinding, three major tasks are involved:

- selecting the relevant aspects in the world to be represented,
- selecting a suitable structure for the inferences to be made, and
- interpreting the result of the inferences.

These tasks correspond to the relations described in representation theory. Designing a good map for wayfinding involves finding a good configuration of choices for fulfilling these three requirements.

5.1. SELECTING THE RELEVANT ASPECTS

In designing a wayfinding system, we must decide which aspects of the environment are crucial and must be emphasized, which aspects require precision and must be truthfully preserved, and which aspects should be ignored to provide the best support for the task. To take the right decisions, we need a cognitive theory about the absolute and relative relevance of different aspects of the world for solving the wayfinding task (Tversky, 1993). Cognitive theories typically involve empirical evidence and a computational model. With regard to cognition, the interpretation of empirical evidence with respect to a cognitive theory may be particularly tricky, as different individuals may employ different strategies to solve the same problem.

5.2. SELECTING A SUITABLE STRUCTURE FOR INFERENCE

The most important design decision for a wayfinding support system already has been taken when deciding in favor of a map as representational medium. This decision implies that spatial relations in the environment are modeled by spatial relations in the representation. When we decide to employ schematic maps (rather than topographic maps) certain relations in the map will be distorted in favor of a greater transparency of the aspects relevant for the task. As a consequence, certain spatial relations will not be faithfully represented and the inferences may be become more complicated.

Determining a cognitively adequate compromise between a 'faithful' and a schematic map representation for a given class of tasks presents an interesting and difficult challenge that is related to the area of diagrammatic reasoning in artificial intelligence (Glasgow et al., 1995). Such a compromise reflects a trade-off between spatially presented information and conceptually presented information. In fact, there may be no compromise which will be agreed upon as 'best compromise' by everybody, as there are individual preferences for dealing either with spatially represented information or with conceptually / propositionally represented information. A completely different way of integrating spatial and propositional information is possible, of course: faithful maps could be used in conjunction with fully propositional descriptions, for certain applications (Mijksenaar, 1999).

5.3. INTERPRETING THE RESULTS OF INFERENCES

The third major step to be performed when using representations for solving problems is the interpretation of the inferences performed in the representation medium, i.e. the translation of the 'insight' achieved in terms of meaningful entities in the world. The more we deviate from spatially faithful representations and move towards schematic representations of the world, the less we can rely on the validity of the spatial inferences we can make. For symbolic and schematic descriptions of the world we need completely different inference rules than for spatial descriptions; therefore, the transition from a purely spatial representation to a schematic form is a representation-theoretic and cognitive challenge (Berendt, Barkowsky, et al., 1998).

6. Redesigning the Interface between the Environment and its Representation

So far, we assumed that wayfinding support requires finding a good representation of the existing environment 'as is'. But as the structure of the wayfinding task is determined to a large extent by the spatial structure of the environment, changing just this structure, i.e. by redesigning the environment, can also support wayfinding. From the representation-theoretic perspective, changing the structure of the environment will lead to a different structure in the representation as well. Therefore the abstract wayfinding procedure may become simpler.

Modifying the environment is a well-known approach to change its functionality in environmental and city design. With respect to wayfinding there are different structuring principles which support a systematic wayfinding procedure (Lynch, 1960; Passini, 1984).

6.1. SYSTEMATIC SPATIAL STRUCTURES SUPPORT WAYFINDING

An obvious spatial structuring approach that supports wayfinding is a hierarchical scheme. Hierarchical structuring schemes may be applied in different ways to structure space. For example, a city may be structured in districts, quarters, blocks, houses, apartments, rooms, etc. In the domain of routes, we may have freeways, highways, mayor and minor city streets, pedestrian routes, etc. that can be well distinguished by their mere appearance.

Our world knowledge tells us that roads of the prior type will lead to more distance places while roads of the latter type are more local. This knowledge – together with the hierarchical structure – will help us to select appropriate routes. At the same time, exploiting the different levels of the hierarchy helps to keep the structural complexity of the routes low and the route descriptions simple.

It is much easier to obtain a suitable hierarchical scheme when environments are organized top-down, i.e. from the global to the local level, rather than bottom-up. For example, a large designed city like Paris with large places that serve as high-level nodes in the traffic network may be much easier to navigate in than smaller cities that grew without a structured design.

6.2. IRREGULARITIES IN THE WORLD SUPPORT WAYFINDING

It is important to note that it is not necessarily the regularity of hierarchical structures that simplifies wayfinding – although regularity also can be quite helpful (Levine, 1982). While regularities support the use of general world knowledge (e.g. with regards to types of roads and relations between different types), irregularities support the use of specific knowledge (e.g. with regards to particular places on a given level of the hierarchy).

In architecture, certain established principles seem to get forgotten, every once in a while. The irregularity principle, for example, seems to have been forgotten in European post World War II architecture. Large city complexes were designed and built in such a way that it was not possible to distinguish one block of buildings from the other, one floor level from another, or one apartment from another. This regularity was considered a feature rather than a bug of the design, at that time (cf. Alexander, 1965).

To overcome the problem of missing irregularity it sometimes suffices to place unique objects as landmarks at certain places and to avoid symmetries in doing so to make sure no new spatial regularities are getting introduced.

6.3. SYSTEMATIC ANNOTATIONS SUPPORT WAYFINDING

In section 5.2 we discussed ways to support wayfinding on the conceptual representation level. In sections 6.1 and 6.2 we discussed ways of modifying the world *per se.* Now we will describe how we can transfer conceptual structures about the environment directly into the environment.

Typically, we consider names and numbers not as parts of the world but as information about the world. In the representation-theoretic framework, they are parts of our conceptual structure on the representation level. Both, names and numbers, can be structured rather naturally: there is a strict correspondence between natural numbers and a sequential order; names can be structured according to a variety of principles, on the surface level by alphabetic order or on a deeper level by correspondence to complex semantic structures.

Such conceptual structures can be mapped back from the conceptual representation into the environment. For example, street names and house numbers can be placed systematically in the environment in such a way that the underlying conceptual structure supports orientation and wayfinding in this environment. The support acts in two ways: (1) our conceptual knowledge about numbers and namable concepts helps us infer the location of numbered or named places directly in the world; (2) the conceptual knowledge also helps us find places in an external representation of the world, especially a map, and to establish the correspondence between the external representation and the depicted environment.

Conversely, there is a great potential to prevent wayfinding successfully, when the systematicity of the structure is violated in the world, in its representation, or in the correspondence relation between the world and the representation. An example for this was the defense strategy of Czech people during the Russian invasion in 1968. The people displaced street signs in the city of Prague to confuse the invasion troops. Even though the environment itself was not redesigned and the spatial structures of the city and of the external representations stayed the same, orientation became extremely difficult for the invaders. A wrong label or a bad label seems to have a much stronger negative effect on wayfinding than no label at all.

7. Towards a Tool Box for Designing Task-Specific Schematic Maps

We discussed a variety of factors influencing cognitive aspects of wayfinding from a representation-theoretic perspective. Some of the principles for designing good support systems for wayfinding harmonize well, others conflict with one another to some extent. For successful application of these principles it is desirable to know whether and how these and additional principles could be integrated in a design support system for constructing wayfinding maps.

The state of knowledge about the relative role of these and other principles suggests an formal analysis of the wayfinding process and the development of an experimental computerized tool comprising interacting modules that implement these principles. This tool could be used to explore ways of systematically combining different aspects of schematic map design, to create schematic maps of different flavor, and to empirically investigate the effects of variations in design on human participants.

While many of the insights collected for this paper are trivial and appear obvious, the quality of wayfinding aids in everyday practice is rather low. We believe that the formalization and computer implementation of results from cognitive psychology, visual design, cartography, computer science and other disciplines may provide a great potential for advancing interdisciplinary cooperation in this area (Gero and Sudweeks, 1998; Zwaga et al., 1999). In our experience, terminological and other starting problems in interdisciplinary work may best be overcome by discussing concrete working models. They help in setting common ground on the basis of phenomena that will lead to common conceptions.

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