Towards Audio-tactile You-are-here Maps: Navigation Aids for Visually Impaired People

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Abstract: Gaining survey knowledge of a complex spatial environment has proven to be facilitated by so-called You-are-here maps (YAH maps). These maps present an abstraction of the surrounding of the current location in the world with a clear marking of the map-readers' own position. Research on cognition and psychology has identified design factors that contribute to the usefulness and usability of such maps. With these recommendations YAH maps are usually designed as visual medium for visually capable people. In this paper we discuss these analyses of visual YAH maps and their transfer to tactile YAH maps useful for blind and visual impaired people. Aside from the sensory layer of modalities, we focus on the representational layer of modalities, especially on the interaction of spatial and verbal representations, which is the basis for designing one promising type of audio-tactile YAH maps for visually impaired people.
Keywords: You-are-here maps, navigation, audio-tactile maps

1 Introduction

Although navigating in large-scale environments is a common human behavior, people need assistance in finding their way at least in some cases of complex—and in particular of 'unknown'— spatial environments. There exists a wide spectrum of methods navigating agents can get access to other people's knowledge and experience relevant for reaching the destination in question (cf. Habel, 2003; Habel & Eschenbach, in preparation). For example, (1) they can ask someone for direction-giving, (2) they can use a map, or (3) they can ask someone to lead them to the goal. The cases (1) and (2) are based on the use of external—verbal or pictorial—representations of knowledge and experience that are useful or even essential to reach the goal. These cases are examples of "instructed navigation". In contrast to this, cases of type (3), in which navigating agents perform nearly the same movement as their guides at nearly the same time—we call this "guided navigation"— could in principal be based on observing the guide's navigation behavior only, i.e. the use of external representations can even be peripheral.[1] *Navigation*—as used in this paper referring to goal-directed movement in space—includes two major components (Montello, 2005): *locomotion*, the movement of the agent's body adjusted to input of the perceptually accessible environment, and *wayfinding*, goal-directed movement based on higher cognitive modules, as memory, planning and reasoning.[2]

Whereas verbal instructions for navigation, i.e. route instructions, are typically specified with respect to one specific origin A and one specific destination B, standard maps are multipurpose means for spatial problem solving: A city map—for example—is an external representation that can be used by people in finding their way from a large number of origins A to a large number of destinations B, i.e., the class of origins A and the class of destinations B span up a variety of potential way finding problems (Klippel, Tappe & Habel, 2003). *You-Are-Here maps* (YAH maps), that are specifically made to give an overview of the proximate environment of a location, have an intermediary status: they are co-localized with the navigator, and thus they are one-origin maps, but they enable navigation to a variety of destinations B.[3] People walk up to YAH maps to orientate themselves. These maps are typically installed at junctions or other main decision points and thus they enable people to localize themselves in a depictive representation of the environment, namely in the map. Furthermore, by using these maps people are enabled to find specific locations they look for and to plan next actions to reach their destinations (Levine, 1982; O'Neill, 1999; Klippel, Freksa & Winter, 2006).

The 'intermediary status' of YAH maps mentioned above can also be seen from the perspective of the navigation process. Using a YAH map connects the past and the future of the navigation task in question: the navigator has one segment of a route (successfully) passed, *now* she uses the YAH map, and after that, she will continue on the route and—hopefully—reach the destination.

Since You-Are-Here maps are proven means for successful navigation in complex buildings (e.g., malls, hospitals, etc.) and in out-door environments (such as, parks, zoos, university campuses, etc.) this type of external representations is also a candidate to be provided for visually impaired people. Whether specifically designed YAH maps can or will be useful for visually impaired people, is currently an open question, which can not be answered in this paper. For starting off examining this topic it is important to consider—at least—the following aspects of YAH maps for visually impaired people:

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1 Modern technology has provided different types of devices for 'guided navigation', such as *car navigation systems* or *navigation aids for visually impaired people* (Loomis, Golledge, Klatzky & Marston, 2006).

2 Unfortunately, the terminology with respect to *navigation* and *wayfinding* is not consistent in the field of spatial cognition. Loomis, Golledge, Klatzky and Marston (2006, p. 179) take an opposite perspective in using *wayfinding* as a higher concept, based on the functions of *sensing* and *navigating*.

3 In a quasi-formal manner these types of wayfinding means can be characterized as follows: verbal route instructions are *1 x 1 wayfinding means*, city maps are *n x n wayfinding means*—assuming that the class of potential origins is the same as the class of potential destinations—and YAH maps—used in the principal sense—are *1 x n wayfinding means.*

i. Are YAH maps for visually impaired people useful or helpful in the times of GPS and guiding systems or have new technologies made maps superfluous as navigational means?
ii. How have YAH maps for visually impaired people to be designed and realized? What sensor modalities and representational modalities can be used to substitute visual perception in realizing YAH maps for visually impaired people?
iii. How differ the requirements between subgroups of visually impaired people, e.g. blind people – people with residual sight, congenitally blind people – early blind people – late blind people? What types of YAH maps, i.e. YAH maps with specific properties and assistance performances, are appropriate for which subgroups?[4]

Since it is generally accepted (see Golledge, 1999), that high wayfinding competence is grounded on different types of spatial knowledge, namely on landmark knowledge, on route knowledge as well as on survey knowledge, systems for guided navigation—e.g. GPS-based guiding systems or talking-sign systems—have to be evaluated with respect to their focusing primarily on landmarks and routes. Burnett and Lee (2005) and Parush, Ahuvia and Erev (2007) argue that car navigation systems have negative effects on the acquisition of the spatial knowledge of their users. In our opinion by providing YAH maps, visually impaired people can be guided in wayfinding and simultaneously be supported in acquiring survey knowledge (cf. Ungar, 2000). In particular in environments visited regularly—as campuses, malls etc.—this would be advantageous for visually impaired people since this could lead to an increase of self-dependency. [The detailed empirical analysis of the acquisition of survey knowledge by tactile YAH will be performed in a future phase of our research.]

Almost all design guidelines for visual You-are-here maps (e.g., Klippel, Freksa & Winter, 2006), are grounded on explicit prerequisites and implicit assumptions, which are essentially based on how people handle visual representations. But these conceptions cannot be applied to people who are visually impaired, e.g. when assuming that the access to the representation (i.e. the map) is instant, and the handling of the representation (e.g. the search for an artifact) is of no burden. Since visually impaired people have to employ different strategies for tasks incorporating a map than users of visual maps do, the recommendations for the design of YAH maps must be reconsidered when designing YAH maps for visually impaired people. The design criteria must be accustomed to the special needs of the target group. The combination of multiple representational modalities is one approach to communicate spatial knowledge to visually impaired people. The aim of the present paper is to discuss some basic principles for designing and realizing YAH maps for visually impaired people when incorporating the interaction of spatial and language representations as some form of multimodality.

In the remainder of the paper, we will give an overview in the use of tactile maps and what specific challenges are encountered when considering their use by visually impaired people (Section 2), then we will investigate the existing recommendations

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4 In the present paper we will use the term "visually impaired people" on the superconcept level; in other words, we will not differences between the subgroups and their specific requirements on tactile map or assistance systems mentioned in item (iii).

for designing YAH maps concerning the multimodal approach (Section 3), and finally we will cast a view into future research in this area (Section 4).

2 From Tactile Maps to Audio-tactile Maps

Whereas visually non-impaired people have direct visual access to their environment—including YAH maps—visually impaired people have to use other strategies. Their impairment holds two challenges. Firstly, visually impaired people have a harder time to build up a representation of the environment. They have no far-reaching sense to exactly and directly get to know what the world in some distance is like. Some have learned to use other senses, e.g. the olfactory or the audio sense, with high perfection to supplement deficits in vision. They can sense traffic lights or pedestrian crossings from specific audio patterns emitted by signalization devices. But even with these capabilities it is not possible to build up a full survey-like representation of larger environments, e.g. of a whole park or the configuration of a street. Maps as external representations of the environment can be used by visually impaired people in substituting the direct access to the environment. Maps hold the advantage that destinations not directly perceivable by the visually impaired can be grasped via a projection into a representation space directly accessible for visually impaired people. But this bears a second problem.

While the access to maps for the visually capable is instant, i.e. with one view the map is perceived as one entity including the relations of its parts, maps for visually impaired people have to be accessible via other sensory modalities, in particular using tactile sensation. Such maps for visually impaired people—called *tactile maps*—can be classified into two cases: Firstly, maps which are physically realized on different media using lines and dots with varying degrees of elevation, explored by the map-reader using one (or two) fingers; these maps are currently produced mainly using thermoform and microcapsule paper.[5] Secondly, there are ‘digital maps’ accessible via *tactile interfaces*—as force-feedback devices, vibrating mouse, etc.—or via *audio-tactile interfaces*, which give feedback to the user in form of sounds or language or any additional source of information (in this case further devices, e.g. touch-screens can be used).[6] For using tactile maps (of any type), the exploration process, which provides a stream of input data, needs high attention and thus it takes much time and high effort. This is true even when considering the low resolution of a tactile map compared to a visual map.

A tactile map cannot be of the same precision as a visual map, as the tactile sense cannot provide the same resolution as the eye. A bigger map could counterbalance this, but the map has to be usable. With limited space, it cannot represent the same amount of information because a tactile map needs to be coarser to be perceptible. Special design considerations have to be taken into account to suite the users’

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5 A detailed discussion of different types of *tactile* or *haptic maps* as well as of the strategies and processes of comprehending these types of maps is beyond the limitations of the present article (see for an overview: Rowell, J., & Ungar, S. (2003a, 2003b, 2003c).

6 On the relevance of combining tactile maps with audio information, in particular verbal descriptions, see, for example: Siekierska and Müller (2003).

perception. The discrimination of each piece of content as unique entity in the map must be preserved. For example, every line has to be perceivable as entity and must not be display in such a close proximity that it might be accidentally mixed with others by the map-reader. Therefore, crossing lines to not touch each other and around each line there normally is a gap of free space so that the map reader is not confused when following a line with his fingers. Discrimination in the visual domain can be achieved with more approaches than in the tactile domain. For example, map entities could differ in 6 properties: in color (that is: hue, saturation, and brightness), in size, in shape, in texture. The tactile presentation in a map for the visually impaired is limited to three: size, shape, texture. Mapmakers can use these dimensions to encode information and build a representation of space via the map.

The limitation in dimensionality, the general smaller resolution in tactile maps and the different nature of exploring the map pose general challenges to design of You-are-maps for the visually impaired. The substitution of information into other representational modalities like language could be one solution when thinking about the usage of You-are-here maps for the visually impaired (cf. Golledge, Marston & Costanzo, 1997). Steyvers and Kooijman (2008) showed that visually impaired people can successfully use verbally presented route information as well as survey information in constructing cognitive maps of environments, even if they are not as efficient as normally sighted people. Audio-tactile maps, which allow a multi-modal co-comprehension of tactilely perceived and verbally presented information, are a promising way to diminish some restrictions of tactile maps (contrasted to visual maps). In particular the division of labor between the sensor modalities, tactile vs. auditory, on one layer, and the representational modalities, map vs. language, on the other layer, should give audio-tactile maps perceptual an conceptual advantages compared to monomodal maps or descriptions (on visual maps combined with verbal descriptions, see Habel, 2003; Brunye, Rapp & Taylor, 2008.)

3 You-are-here Maps for Visually Impaired People: Principles and Design Criteria

In this section we consider some specific requirements for an augmentations of YAH maps usable for visually impaired people, i.e. tactile or audio-tactile YAH maps. This discussion is based on three thorough analyses of ‘standard YAH maps’, i.e. YAH maps designed to be perceived visually, namely the seminal papers by Levine (1984) and O’Neill (1999), and the evaluation of design criteria by Klippel, Freksa and Winter (2006). We will focus in particular on criteria for and properties of standard YAH maps that have to be changed, to be cut out or to be added in the case of tactile or audio-tactile variants. The following two subsections are organized parallel to Klippel, Freksa and Winter’s (2006) presentation of general principles of good map design and specific ones for You-are-here maps.

3.1 General Principles of Good Map Design

Completeness: The requirement to represent all the information that is necessary to enable orientation and wayfinding in the environment holds true for tactile maps as well. Nevertheless the representational characteristics and the level of detail of the representation have changed. Some implicit information that was conveyed through the visual layout of graphical entities has to be converted into other external representations to be usable for the visually impaired map-reader. Classes of entities in the environment can successfully be specified and grouped by color-coding, for example, this can be used in maps for shopping malls to determine types of shops or visualize the area of restaurants and cafes. The use of verbal descriptions provided by audio-tactile maps can assist the visually impaired map-reader in getting corresponding information. This type of substitution of visually represented information is essential in map-based wayfinding for visually impaired people in general, since non-visual *qualia* play the leading role: Landmarks are no longer of visual nature, but of auditory, olfactory or haptic nature. Big buildings in a distance might not be that interesting as landmarks any more (maybe only to ask for it when on the way), but sources of noise (e.g. traffic lights) or specific patterns (e.g. a fountain) become more important and should be represented in the map. Without these landmarks, visually impaired people would have problems in wayfinding.

Additionally, verbal descriptions of the map and the environment transmitted via the acoustic channel provides the visually impaired map-reader with further information, e.g. about the extension of the map (what is the size of the area is shown) and the content of the map (what is the special purpose) without the need to explore it in its full existence. This information provided before the reader accesses the map will support her in building up her survey knowledge. In the phase of detailed exploration of the map, it is essential that map-readers find all information that is relevant for their navigation task. Audio-tactile maps, in which verbal comments about the region touched by the fingertip as well as of map-neighboured regions are given, can assist map readers in their map exploration and learning task.

Semantic Clarity: Entities used in a map need to have a unique meaning – this is true both for visual and for tactile maps. But the realm in tactile map is often that there is consistent, unambiguous information about different entities, but not in the sense of iconic signage. In a map for visually impaired people it is questionable if the resemblance with a visual representation of an object as symbol is truly useful, e.g. a railroad track line. Conceptual symbols (like e.g. a stippled line) and attached explanation would probably be more useful to the map-reader (on tactile symbols, see, McCallum, Ungar & Jehoel, 2006). These explanations should not only hold local information about what the entity represents (e.g. to identify the stipple line as railroad track) but what relationships the represented object has in the world (e.g. the start and the end of the railroad track, stations on it and where they are). In maps for the visually impaired people, syntactical clarity seems to be more important than semantic clarity regarding the entity itself. But semantic information about the global relation of the represented object to other objects promises to be helpful to the map-reader.

3.2 Special Design Criteria for YaH Maps

Global and local placement: Richter and Klippel (2002) describe a graph-theoretic method for computing successfully preferred placement for YAH maps in two-dimensional outdoor environments. Their evaluation procedure takes mainly the complexity of the environment, in particular, the complexity of the path-structure, into consideration. For finding an optimal place for a YAH map it is important to distinguish those parts of the environment that are perceivable during using the map, from those that are not perceivable.[7] But this grouping is drastically different for seeing and visually impaired people. Therefore global placement of YAH maps for visual impaired people requires further studies.

Local placement of a You-are-here map should be non-ambiguous in the environment, e.g. not in the middle of an intersection that is symmetric. The map should be placed in a distinct asymmetrical part of the environment. When transferring these guidelines to You-are-maps for visually impaired people some more considerations have to be made. Symmetric and asymmetric now means to the perception of the visually impaired! While visually able people move freely and can detect the next You-are-here map from far away, visually impaired people usually orientate themselves along walls of buildings or along some edges (e.g. on a sidewalk, distant to the car movement). When placing the You-are-here maps it should happen according to the usual movements of visually impaired people (e.g. at walls they move along). As they cannot detect the existence of a You-are-here map from far away, some special markings on the ground should lead their way to the map. Once arrived at the map, the orientation of the map should support the map-reader. In difference to the visual You-are-here maps, tactile maps should be presented in a horizontal way (like on a table). In this way, the exploration with the fingers is facilitated as holding the arms down (onto a the map) instead of up (to touch the vertical map) is easier in the long run because the blood stays in the fingers and they do not become numb.

Correspondence: Klippel et al. (2006) see "establishing a correspondence between the represented information and the information that is perceptible" as a primary design requirement for YAH maps. As mentioned above, what is perceivable by visually impaired people differs severely from that what the seeing person perceives visually. In particular, self-localization of visually impaired people with respect to the YAH map can not be grounded on direct perception of distant landmarks.

In other words, and here we come back to the metaphor of YAH maps bridging the past and the future of the navigation task, visually impaired people cannot directly perceive the paths they have used and the landmarks they have passed, and they also cannot directly perceive the paths they have to go and the landmarks they have to consider in wayfinding. Nevertheless, they possess knowledge about the paths they have gone to the YAH map, and this has to be used for self localization and for establishing the correspondence between the path they have gone and its representation in the map (cf. Loomis, Klatzky, Golledge & Philbeck (1999) on navigation and path integration). Since the primary base for self localization by

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7 In the Richter-Klippel approach (2002) this classification can—in principle—be considered by setting of parameters.

visually impaired map-readers is their locomotion—on a more or less horizontal plane—a horizontal YAH map should also be preferred, as there is a 1:1 correspondence between the exploration of the tactile map and the locomotion in the environment (Note: this assumption has to be tested empirically).

The characteristic constituent of a YAH maps is the You-are-here symbol, which has a predominant weight in a visual map, so that it can be found easily when looking at the map. Given the mode of linear exploration with the fingers in a tactile map as opposed to instant holistic perception with the human visual system, the premier role of the You-are-here symbol has to be realized by a representation with corresponding properties in tactile maps. This could be performed by leading the user from a prominent *entrance point* on the frame of the map—distinguished by its location or by sonification—using specific meta-lines to the YAH symbol.

4 Conclusion and Future Research

You-are-here maps, which are successful aids in wayfinding for "seeing people", seem also promising as navigation aids for visually impaired people. In the present paper we described some aspects of traditional YAH maps, which have to be adapted to the requirements of visually impaired people. The redesign process, which is based on substituting visual perception by tactile perception, leads to tactile YAH maps. Additionally we propose—beyond the level of *sensory substitution*—a second level of substitution, namely *representational substitution*: whereas maps are *visual-spatial representations* of the environment, audio-tactile maps that provide verbal descriptions are *multimodal representations* integrating *spatial* and *propositional representations*.[8]

Following this goal of designing adequate audio-tactile YAH maps, we focus on two research areas: (1) tactile YAH maps of different types of physical realization as well as of different *graphical inventories* and *representation conventions,* (2) multimodal, audio-tactile YAH maps providing natural language descriptions and instructions. Methodologically, the research will cover empirical research on comprehension of YAH maps, on cognitive mapping using YAH maps and on wayfinding based on YAH maps, on the one hand, and the design and the realization of prototypical audio-tactile YAH maps, on the other hand.

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8 The findings of Giudice, Bakdash and Legge (2007) and of Brunye, Rapp and Taylor (2008) strongly support this proposal.

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