You-Are-Here Maps: Wayfinding Support as Location Based Service

Kai-Florian RICHTER & Alexander KLIPPEL

University of Hamburg

Vogt-Kölln-Str. 30, 22527 Hamburg, Germany

{richter, klippel}@informatik.uni-hamburg.de

ABSTRACT

Wayfinding support is a basic and important location based service. Today, this kind of service is mostly provided by solidly installed, static means. Of these means maps ideally support wayfinding, as it is possible, for example, to use one map for many visitors with many different destinations. A special kind of maps—You-Are-Here maps—is especially suited if design and placement criteria are carefully taken into account. In this paper we present a computational model that allows for determining those locations within an environment where maps function efficiently as location based wayfinding support. The model is based on findings in spatial cognition and, particularly, on research on You-Are-Here maps. The results of these fields of research have been analyzed to obtain operationable criteria for a prototypical system that calculates the placement of You-Are-Here maps for a given bounded outdoor environment. Even though the model is designed for 'classical' wayfinding support it already offers functionalities for current technological developments, i.e. electronic and mobile wayfinding systems.

1. WAYFINDING SUPPORT AS LOCATION BASED SERVICES

In the light of new mobile information technologies like Personal Digital Assistants (PDAs), the Global Positioning System (GPS), and other mobile transmission standards it is getting constantly easier to provide location based services (LBS) to people acting in an environment. These services include, for example, information on interesting sights, location dependent news on traffic, weather or events, or advertisements for facilities located nearby.

One of the most basic and at the same time most important services is supporting wayfinding processes. Orientation in an unknown environment is a critical factor for successfully arriving at a specified destination and requires usually external knowledge sources.

Kai-Florian Richter, Alexander Klippel (2002). You-Are-Here Maps: Wayfinding Support as Location Based System. In J. Moltgen, A. Wytzisk (Eds.), GI-Technologien für Verkehr und Logistik. Beiträge zu den Münsteraner GI Tagen, Vol. 13, IfGI Prints.

For car navigation commercial systems exist that help drivers find their way to a destination; for environments where people typically are on foot—like public buildings, convention centers, a university campus, or parks—these systems are still a matter of research (e.g., Baus et al., 2001; Malaka & Zipf, 2000). Officially provided wayfinding support in such environments, in opposition for instance to paper city maps, is usually solidly installed and static.

Arguments for 'Classical' Wayfinding Support

There are several technical and psychological reasons why solidly installed, static support is to prevail. From a technical perspective there are difficulties like providing everywhere a sufficiently stable connection between a transmitter of a localization signal and the receiving device; the costs to build an infrastructure that allows for such a service is rather high and, thus, needs to be re-financed via charges imposed on the users—something they do not accept yet. Furthermore, PDAs and other devices capable of services for mobile, electronic wayfinding support are not common enough by now.

From a psychological perspective disadvantages of mobile electronic wayfinding support include, for instance, that the actual environment may be too complex to be adequately depicted on small displays PDAs or mobile phones offer. Among other things this hinders people gaining survey knowledge, which is the most complex kind of spatial knowledge and allows for the most inferences. Additionally, users may not want or be able to have their mobile devices turned on all the time and have to look at them for wayfinding information. Finally, as users may feel dependent on these devices, it reduces their acceptance.

Maps as Wayfinding Support

Two basic types of solidly installed, static wayfinding aids can be distinguished: maps and direction signs. While information provided by direction signs is normally faster to process than information represented in maps, these signs are problematic for the following reasons: signs show directions, not routes, i.e. at every decision point[1] a new sign is needed; using a sign, just the direction to one destination can be shown resulting in an extra sign for every destination; signs are one way, i.e. following signs to one destination does not necessarily allow for finding the way back using the same signs; self localization and acquiring survey knowledge is

[1] At least at every decision point that requires a direction change.

much more difficult when people depend solely on direction signs in wayfinding (cf O'Neill, 1999)[2].

Maps on the other hand are approved means for supporting wayfinding processes in an environment (MacEachren, 1986; Freksa, 1999): they allow to depict routes to different destinations, i.e. it is sufficient to provide one map instead of many signs at a given location; they show routes instead of directions, there is no need to provide a new map at every decision point; provided the map is sensibly positioned (cf. next section) self localization using a map is easy; maps ideally support acquiring survey knowledge (e.g. Freundschuh, 1991), hence, when using maps people do lose their dependence on wayfinding support earlier.

On the other hand an analysis of maps used for wayfinding support reveals many design mistakes, as for the design of proper wayfinding aids a good understanding of the wayfinding process itself is necessary (cf. Arthur & Passini, 1992). Typically, this process consists of four sub-tasks: 1. Orientation, 2. Choosing the route, 3. Keeping the right track, 4. Discovering the objective (e.g., Downs & Stea, 1977; Daniel & Denis, 1998). Good wayfinding aids support all four of these tasks.

Towards a Computational Model

In this paper we outline a computational model for the identification of places at which maps function efficiently as location based wayfinding support. The model is based on findings in spatial cognition, especially research on cognitive maps (e.g., McNamara, 1991; Hirtle & Heidorn, 1993) and on landmarks (e.g., Sorrows & Hirtle, 1999), on constructive and interpretative processes on aspect maps (Berendt et al., 1998), and, in particular, on You-Are-Here maps (Levine, 1982).

The next section reviews shortly research on YAH maps. We then present the computational model that allows for identifying locations important for wayfinding; the relevant criteria are introduced and it is shown how they can be combined in a model that is used to determine the locations. In section 4 we discuss an example; the model is applied to calculate locations for the placement of YAH maps on a university campus. Finally, we present some ideas on further research and possibilities to use the algorithm in mobile contexts.

---

[2] There are signs that allow for self-localization, for example signs at the borders of states or cities or labels at buildings stating their number or function, e.g. 'library'.

2. You-Are-Here Maps: A Short Review

As stated above maps are good means to support wayfinding processes. A special kind of maps used is You-Are-Here (YAH) maps (Levine, 1982; O'Neill, 1999). These maps are solidly installed in the environment—usually vertically attached on walls or signposts—and contain a You-Are-Here symbol. This symbol indicates on the map the location where in the environment the map is positioned. The symbol significantly eases self-localization as it obviously indicates ones position within an environment.

Levine (1982) identified design and positioning criteria to enhance a YAH map's suitability for aiding wayfinding. O'Neill (1999) resumed the original work and extended the requirements for YAH maps resulting in the following list:

- Provision of signs and labels in the environment and correspondingly on the map: this eases the mapping between what is seen on the map and what is seen in the environment itself. If signs and labels seen on the map can be detected in the environment, relating features of the map to features of the environment is straightforward. Thus, self-localization as well as orientation and choosing the route become much simpler.
- Inclusion of architectural cues and natural landmarks: YAH maps should be designed such that architectural cues and natural landmarks are included and that the shape of the paths drawn in the YAH map relates to the actual shape of the paths found in the environment. As these are important cues in people's wayfinding behavior this eases map use and reinforces learning the environment's layout.
- Placement of YAH maps near entrances of an environment and at decision points: these are the locations in an environment where people (re)orient themselves and, thus, need support for their decisions.
- Placement of YAH maps near asymmetrical parts of an environment: this facilitates to locate the map within the environment. An asymmetrical part of an environment is easily identified on the map as its layout combined with the YAH symbol shown on the map provides many cues for its location. Therefore, the location of the map in the environment becomes non-ambiguous.
- Use of a complex YAH symbol: a complex YAH symbol shows, along with the location of a map in the environment, an orientation, which is the viewing direction of the user. This significantly eases orientation at the corresponding location and determining the path to the destination as, again, relating map features to features in the environment is

facilitated; alignment (see next paragraph) and the orientation of the complex YAH symbol should correspond to each other.

- Alignment of the map and environment: if a map is aligned with the environment the relation *top* in the map corresponds to the relation *in front of* of the user viewing the map. Hence, a corresponding relative reference system is established in which the relations 'left' and 'right' are the same in the map and in the viewed environment; this greatly helps mapping what is seen on the map to what is seen in the environment (see also Shepard & Hurwitz, 1984).
- Redundancy: combining the principles mentioned above allows for easy self-localization, orientation and determination of the path to the destination (see also Hirtle, 2000).

Especially map alignment has been subject to further research (e.g. Shepard & Hurwitz, 1984; Warren & Scott, 1993). Apart from the YAH symbol this is the most important criterion for the construction of good YAH maps; people usually expect YAH maps to be aligned and they use them accordingly (Levine et al., 1984). Thus, non-aligned YAH maps significantly complicate the wayfinding process[3].

Still many YAH maps found in environments are often not adequately designed. Sometimes the YAH symbol is missing and, often, these maps are not properly aligned. Figure 1 shows a typical example: this map can be found on the island Wangerooge in the northwest of Germany. While a YAH symbol is provided and, thus, simple perceptual processes accomplish self-localization, the map is not aligned; determining a route to take is, therefore, unnecessarily aggravated.

[3] This is the main reason why people tend to rotate maps they hold in their hands when using them for orientation tasks.

Fig. 1: A YAH map as found on Wangerooge.

3. A Computational Model to Identify Relevant Locations for You-Are-Here Maps

In this section we present a computational model to identify relevant locations in wayfinding support with YAH maps. To build this model we analyzed research on spatial cognition, especially the results stated in the previous section, to obtain operationable criteria needed to automatically determine relevant locations. First, we shortly elaborate the term ‘relevant location’. We then explain the derived criteria and, finally, we give an overview of the computational model.

What is a Relevant Location for a YAH Map?

Solidly installed wayfinding support in an environment should not be placed arbitrarily. First of all, it needs to be placed along paths as visitors are expected to use them while moving through an environment. Decision points, i.e. points along a route that require a decision on a direction to take, play a crucial role in wayfinding (Denis, 1997). As soon as a decision for one direction is taken at such points there are no further planning problems until the next decision point is reached; there is no need to change the decision. Therefore, maps should be positioned near decision points (cf. previous section). Wayfinding support in-between decision points would come unexpected and usually be significantly less useful than support at decision points.

The term ‘relevant location’ can be further restricted. Obviously maps are needed at the entrances to an environment as visitors orient themselves at these points and determine their destination and the route to their destination, respectively. But, since a human’s capacity for processing information is limited (cf. Miller, 1956), it is usually impossible or would take too much time to remember all necessary decisions along a route. Hence, additional maps are needed at some decision points along the route. Thus, as will be explained in greater detail below, the relevance of a location for its use in wayfinding support depends on its relevance for finding the way along the respective routes to a destination in an environment.

Criteria to Determine Relevant Locations

The two-dimensional layout of paths in an environment is essential for wayfinding (O’Neill, 1991a). Its complexity and, consequently, the complexity of routes[4] is an important factor to decide on the relevance of locations for wayfinding support with maps. O’Neill (1991b) uses the concept of InterConnection Density (ICD) to determine the complexity of a route. The ICD is calculated by averaging the complexity of every (decision) point of a route, which is the number of branches, i.e. the number of connections of one point in a route graph. This, however, is too restricted for placing maps efficiently in the environment as wayfinding support. Therefore, in our approach we extended the concept of route complexity by the following parameters:

- Length of a route: obviously, it is easier to follow a short route than a long one. Apart from the fact that typically—even though not necessarily—fewer decisions need to be taken on a short route, it takes less time to reach the destination and, therefore, the information on the decisions does not need to be remembered for a long time. Visitors can make these decisions with greater confidence and, thus, need less support in finding their way.
- Overall number of decision points: at each such point visitors must decide on the direction to take; they must remember the decision due at this point that they previously identified on a map. Since potentially, at each decision point a visitor might take a wrong direction, routes that pass many decision points are harder to follow than those that just pass a few.

[4] The term *route* is used to denote a behavioral pattern that emerges when a chosen path within a network is actually travelled.

- Number of necessary turns: even if a route passes many decision points it can be easy to follow it if no changes in direction are necessary. Additionally, if turns to take can be grouped, like 'twice left, then three times right', remembering these turns is facilitated as some form of chunking can be performed and, thus, the number of items to be kept in mind is reduced. Therefore, the number of necessary turns plays a crucial role for the complexity of a route. Other forms of chunking, i.e. combining elementary route segments to higher order route segments, like 'turn right at the third intersection' can reduce the complexity as well, especially when landmarks are employed (cf. Klippel et al., 2002).
- Number of branches at a decision point: coming to a decision point with just two possible directions, remembering the direction to take is usually much easier than at a decision point at which three different possibilities to turn left and four to turn right exist. Thus, the number of branches at a decision point has to be taken into account when calculating the complexity of a route.

Furthermore, landmarks play a crucial role in wayfinding (e.g., Sorrows & Hirtle, 1999). Landmarks are prominent features in an environment; maps used as wayfinding aids should be designed such that landmarks are easily identifiable especially at decision points that require a direction change (cf. Lee et al., 2002). Then it is possible for a visitor to relate decisions on directions to take to a landmark and, while moving along the route, use landmarks as wayfinding support, i.e. it is possible to keep a specific previously remembered relation between oneself and the landmark which greatly eases following the route. Thus, as long as a landmark is visible, no other wayfinding support may be needed (Golledge, 1999). By now, landmarks are only partially taken into account in our model; they are used as prominent features that might serve as sub-goals in a route to a destination.

When actually placing a map at a location, local features have to be taken into account. The map must be positioned such that it is instantly detectable, that it can be readily looked on, and—as it greatly eases localization of the map and oneself, respectively—ideally, it should be positioned in an asymmetrical part of the environment. Thus, when positioning a map, a position around a decision point is searched for that can be perceived from some distance, is passed by most visitors that encounter this decision point, and is easily accessible. Additionally, it should be possible to orient the map adequately relative to the environment, i.e. most of the depicted environment on the map should be above the YAH symbol.

Finally, when determining the relevance of a location, the relevance of other locations has to be considered. Since maps allow for determining the entire route to a destination and not just the currently required direction, it is possible to provide efficient wayfinding support with significantly less aids than by installing direction signs. To account for this, maps should be placed just at the most relevant locations of a given part of the environment, i.e. the computational model should minimize the number of maps installed while still ensuring efficient wayfinding support. Therefore, a location should be rejected as being important if a location nearby is deemed more relevant than the one given.

The Computational Model

Figure 2 gives an overview of the model; each step is described in further detail below. The general idea is to, first, calculate for each specified route in a given environment those locations where maps efficiently function as wayfinding support and, second, to subsume all locally determined locations to those that are globally needed for the whole environment.

A specification of the environment's features, such as buildings or roads, serves as data for the model. This data must be provided such that the features and their geometry are identifiable, for example, any vectorial description of the environment as offered by many geographic information systems (GIS) is appropriate.

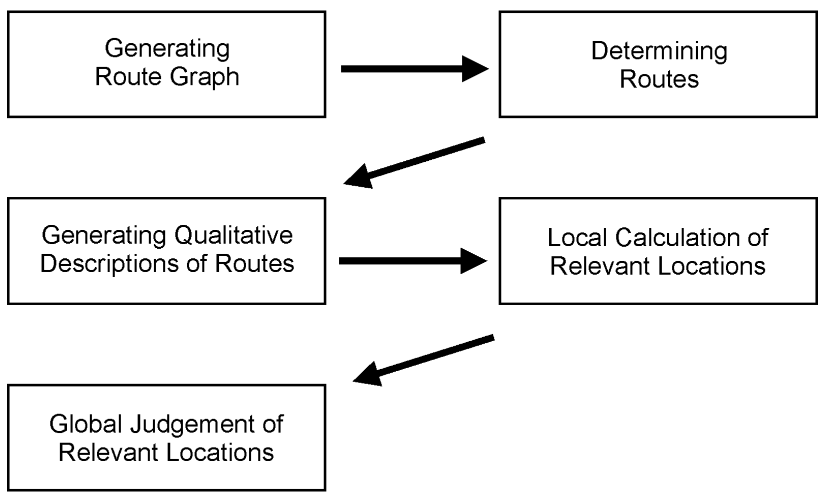

Fig. 2: Overview of the computational model.

Computing the relevant locations starts off by constructing a route graph of a given environment. The graph is based on the environment's system of paths; it reflects the structure of this system, but—as it only consists of nodes and edges—the complexity of the data to work on is significantly reduced. In order for the graph to be similar to the system of paths it is not sufficient to include decision points and destinations as nodes. Moreover, all points that contribute to the shape of the system need to be integrated as nodes in the route graph. The easiest way to achieve this is to build nodes from all points that make up the geometrical shape of the paths.

In the next step, routes are identified in the route graph. To restrict the number of routes and, consequently, the computational costs, only routes between distinguished destinations and between entrances and destinations are calculated. Destinations on a university campus, for example, include lecture halls or the library. A route is assumed the shortest connection between the two nodes that represent the destinations in the route graph. The routes' calculation is based on the algorithm by Dijkstra (1959), the length of the respective path-fragments are used as weights for the graph's edges.

The complexity of a route and, finally, the relevance of a location is calculated in three steps: first, all identified routes, that initially consist of a simple sequence of all nodes passed, are transformed in descriptions that consist only of decision points, qualitative distance information between two decision points, and qualitative turning information at a decision point; second, the qualitative information is weighted according to its contribution to the complexity and, if a certain threshold is reached, the respective node is marked as a relevant location; third, after the number of all marked nodes is reduced to those nodes that are globally relevant, the placement of YAH maps is performed in the initial feature-based map-like representation, i.e. the marks are transferred back from the nodes to the locations in the map that they represent.

Initially, a route description contains all nodes that have to be passed in order to get from the start node to the end node, i.e. from one destination to another; this is purely ordering information without any directional or metrical information. As many of these nodes are just present in the graph to ensure similarity of shape, they are not as such important for the complexity of a route. The information that these nodes provide is, therefore, abstracted to a qualitative description. Only start nodes, end nodes, and all nodes in-between that represent decision points are left over. The qualitative information comprises the distance between two decision points and turning information at a decision point. The qualitative (walking) distance is calculated by adding up the weights of all edges that are between decision points as these weights are derived from the length of the respective path-fragments of the route. The qualitative turning information depends on the angle between the last edge leading to a remaining node and the first edge going out of the node (see Fig. 3). This reflects the change of direction at a corresponding location a visitor performs while following a route. We use five different distance relations and eight different direction relations to qualitatively describe the route.

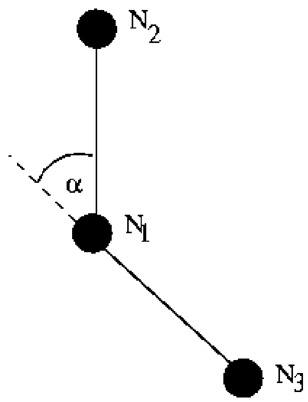

Fig. 3: Example for the calculation of the direction between two nodes.

For each qualitative route description the qualitative relations are weighted using the criteria stated in the last subsection. Distance and turning information are weighted independently according to their contribution to the route's complexity. For example, turning at a decision point is deemed more complex than keeping the direction, i.e. walking straight ahead. The weights are added to a counter that is compared to a threshold. This threshold is one of the parameters of the presented model. Setting a low threshold leads to a higher number of placed YAH maps while setting a high one leads to fewer maps. If the counter is greater than the threshold, the node that the distance and direction relation refer to is marked as a possible location for a YAH map and the counter is reset. This is done for all previously determined route descriptions. As a consequence, all nodes that are relevant for wayfinding support on each respective route are now marked.

But as these typically results in far more possible locations than necessary in a given environment, all marked nodes need to be evaluated globally. Each marked node is judged according to its relevance for wayfinding support when looking at the environment taken as a whole, i.e. its relevance for the network of routes. A relevance measure for each marked node is set up and the results are compared. The criteria used for this comparison include: the number of routes passing a node; the number of possible directions at a node; the kind of (decision) point a node represents, for example, entrances to an environment are deemed more important than crossings; the potential location for a YAH map relative to other potential locations.

For the comparison regions in the environment are defined. They reflect the area around decision points where visitors are believed to definitely remember their previously determined decisions. In a given region just the node with the highest measure keeps its mark, all other marks are removed. The size of these regions is another parameter of the model. As just one mark is kept in a region, the size of the regions directly affects the number of marked locations remaining in an environment; small regions lead to more kept marks since the environment is divided in more regions. The nodes that remain marked are those representing points in the environment where maps efficiently function as wayfinding support. Around these points an area that encloses possible positions of a map is determined. The last step is to decide on the position and orientation of the maps.

The next section illustrates the computational model just described. Based on this model we have built an application that determines an efficient placement of YAH maps in an outdoor environment using a vectorial representation (Richter, 2001).

4. AN EXAMPLE: PLACING YOU-ARE-HERE MAPS

We chose all criteria used in the model that are relevant for the placement of YAH maps and implemented them. We, thus, built a prototypical system that computes for a given environment locations critical for wayfinding and, as such, candidates for wayfinding support.

In the following, we present a sample calculation for the Informatics campus of the University of Hamburg. Taking up the description of our model in the last section we exemplify the necessary steps towards a placement of YAH maps. We start off with a vectorial representation of the geometry of the environment's features. The left part of figure 4 shows a map-like presentation of this data. From this data the route graph is extracted. To further reduce complexity this graph is schematized using the algorithm of Barkowsky et al. (2000); this algorithm ensures that after schematization the initially extracted graph stays similar in structure to the system of paths, as can be seen in figure 4 on the right side.

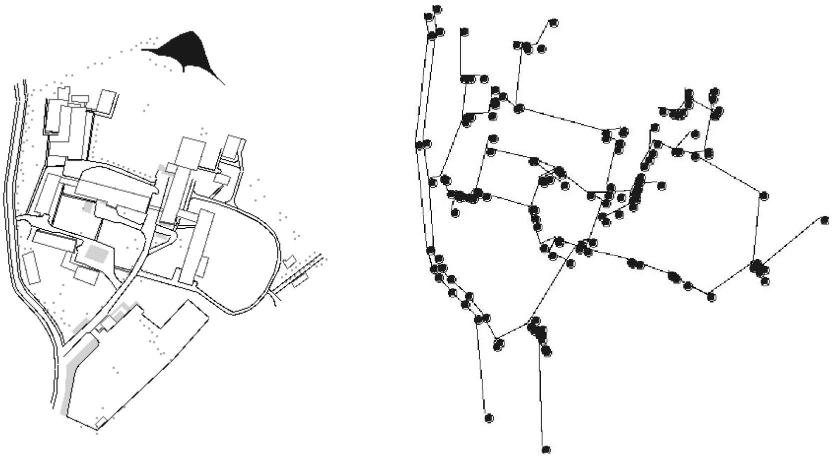

Fig. 4: A map of the university campus and its corresponding route graph.

Next all routes in the route graph are determined. These are then transformed to a qualitative description removing all nodes that are neither a destination nor a decision point. Additionally to all crossings, i.e. all points where a visitor needs to decide on the direction to take, entrances to the environment and to buildings count as decision points. Even though these points are not decision points visitors may need and expect wayfinding support there. For every route description all relations are weighted and nodes are marked according to the algorithm described above. This results in a great number of marked nodes as can be seen on the left side of figure 5. The right side shows the remaining marked nodes after the relevance of each marked node is judged globally.

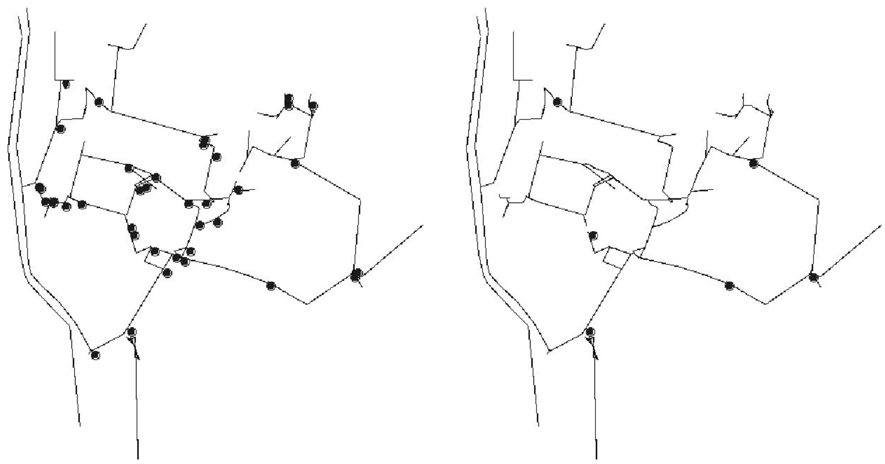

Fig. 5: Locally marked nodes (left) and the remaining globally marked nodes (right).

At every point that corresponds to a marked node we determine the actual position and orientation of a YAH map. The map's orientation is determined based on the number of routes passing the point. The resulting placement can be seen in figure 6 (left); on the right side we present a sample YAH map, its design is kept very simple. We inserted a complex YAH symbol at the corresponding location and aligned the map according to its previously determined orientation relative to the environment. Designing better YAH maps is one possible extension of our system and subject to further research.

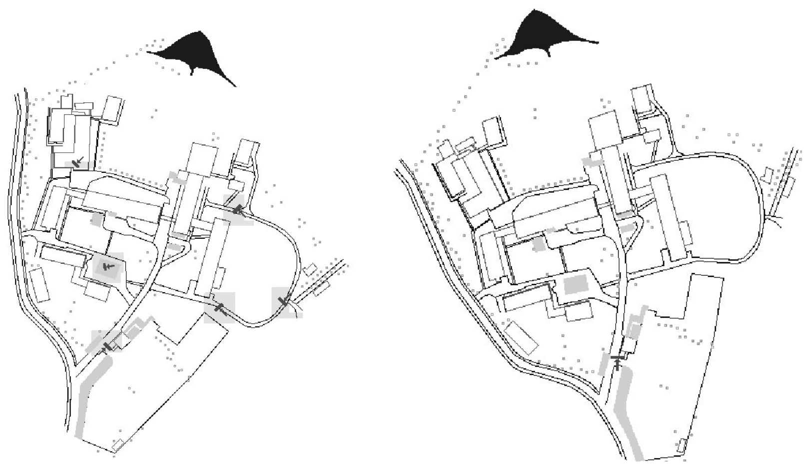

Fig. 6: Placement of YAH maps in the environment (left) and a simple example map (right).

5. YOU-ARE-HERE MAPS AND MOBILE INFORMATION SYSTEMS

Even though the model and especially the presented application originally are designed for 'classical' wayfinding support they already provide aids for current technological developments.

For example, systems that present routes to a user in information booths (Baus et al. 2000; Krüger et al., 2000) can benefit from our model. First, it is possible to determine a placement of such booths in an environment just as it is possible to determine a location for YAH maps. Criteria specific for such means of wayfinding support can be easily integrated in our model. Second, the presentation of routes in such booths can be enhanced. After locations that are important for wayfinding have been determined special attention can be given to them while presenting a route; this is especially helpful if additional information booths are placed at other locations.

Even without information booths this model can be applied in contexts where visitors use PDAs for wayfinding. Though it is impossible to present an adequate overview map of an environment on small screens PDAs offer presenting a map of the immediate surrounding environment is possible. Most of the times visitors do not need that much detail as it is harder to process than directional cues like, for example, arrows and—since they carry the wayfinding support with them—visitors can always get help. But just using directional cues do not allow visitors to reorient themselves; they get no help on where in the environment they are at any given moment. Therefore, the wayfinding process can be enhanced if at relevant locations an overview of the surrounding is presented. These locations can be determined using our model. This, then, supports visitors in reorienting and, consequently, in gaining survey knowledge—especially, if it is combined with solidly installed maps at the entrances to an environment. Additionally, as visitors do not solely depend on their electronic guide anymore, acceptance of this form of wayfinding support may increase.

6. OUTLOOK

So far the model takes into account spatial aspects of the paths' geometry. Refining the applied criteria and integrating additional ones like the handling of open places and further chunking mechanisms can improve the two-dimensional geometrical modeling.

Sometimes plane geometrical aspects are not sufficient to guarantee an efficient placement of YAH maps as, for example, the line of sight to important landmarks may be obstructed. Hence, three-dimensional criteria have to be found and rules have to be implemented that organize the interaction of two- and three-dimensional aspects. As we restricted ourselves to criteria derivable from a map's geometry additional information available in recent databases like the number of pedestrians or varying importance of routes has to be integrated.

Our research also has revealed open question regarding the interaction between map, user, and environment. Some of these questions can be answered by theoretical considerations whereas others require conducting psychological experiments. As we performed already some experiments on the importance of landmarks in route directions and on chunking of route segments further studies are planned to shed some light on questions like which level of abstraction ideally supports wayfinding processes.

Even though the focus of this paper is the computational model for placing YAH maps we also reviewed research on the design of YAH maps as such.

The overall goal then is to combine the two fields of research resulting in a model that calculates the best placement for YAH maps and designs the maps corresponding to their actual placement. Besides the criteria found for YAH maps regarding their alignment and their interaction with the represented environment, design guidelines for efficient visual information processing (Tufte, 1990, 1997) have to be applied.

ACKNOWLEDGEMENTS

This paper stems from research in the *Aspect maps* project (FR 806-8) funded by the Deutsche Forschungsgemeinschaft (DFG). For comments on the design and theoretical considerations we thank Christian Freksa and Thomas Barkowsky.

REFERENCES

Arthur, P. and Passini, R. (1992). *Wayfinding – People, signs, and architecture*. New York: McGraw-Hill.

Barkowsky, T., Latecki, L.J., and Richter, K.-F. (2000). Schematizing maps: Simplification of geographic shape by discrete curve evolution. In C. Freksa, W. Brauer, C. Habel, and K.F. Wender (eds.). *Spatial cognition II — Integrating abstract theories, empirical studies, formal methods and practical applications* (pp. 41–53). Berlin: Springer.

Baus, J., Ding, Y., Kray, C., and Walther, U. (2001). Towards adaptive location-aware mobile assistants. In *Workshop Notes of the IJCAI 2001 Workshop on Artificial Intelligence in Mobile Systems*.

Baus, J., Breihof, C., Butz, A., Lohse, M. and Krüger, A (2000). Some Aspects of Scouting Smart Environments. In *Proceedings of the AAAI Spring Symposium on Smart Graphics*.

Berendt, B., Barkowsky, T., Freksa, C., and Kelter, S. (1998). Spatial representation with aspect maps. In C. Freksa, C. Habel, and K. F. Wender (eds.). *Spatial cognition: An interdisciplinary approach to representing and processing spatial knowledge* (pp. 157–175). Berlin: Springer.

Daniel, M.-P. and Denis, M. (1998). Spatial descriptions as navigational aids: A cognitive analysis of route directions. *Kognitionswissenschaft*, 7, 45–52.

Denis, M. (1997). The description of routes: A cognitive approach to the production of spatial discourse. *Cahiers de Psychologie Cognitive*, 16. 409–458.

Dijsktra, E.W. (1959). A note on two problems in connexion with graphs. *Numerische Mathematik*, 1, 269–271.

Downs, R. M. and Stea, D. (1977). *Maps in minds: Reflections on cognitive mapping*. New York: Harper & Row.

Freksa, C. (1999). Spatial aspects of task-specific wayfinding maps – A representation-theoretic perspective. In J.S. Gero and B. Tverksy (eds). *Visual and spatial reasoning in design* (pp. 15–32). University of Sidney, Key Centre of Design Computing and Cognition.

Freundschuh, S.M. (1991). The effect of the pattern of the environment on spatial knowledge acquisition. In D.M. Mark and A.U. Frank (eds.). *Cognitive and linguistic aspects of geographic space* (pp. 167-183). Dodrecht: Kluwer.

Golledge, R. (ed.) (1999). *Wayfinding behavior. Cognitive mapping and other spatial processes*. John Hopkins: Baltimore.

Hirtle, S.C. (2000). The use of maps, images and "gestures" for navigation. In C. Freksa, W. Brauer, C. Habel, and K.F. Wender (eds.). *Spatial cognition II — Integrating abstract theories, empirical studies, formal methods, and practical applications* (pp. 31–40). Berlin: Springer.

Hirtle, S.C. and Heidorn, P.B. (1993). The structure of cognitive maps: Representations and processes. In T. Gärling and R.G. Golledge (eds.). *Behaviour and environment: Psychological and geographical approaches* (pp. 170–192). Amsterdam: Elsevier Science.

Klippel, A., Tappe, H., and Habel, C. (2002). Pictorial representations of routes: Chunking route segments during comprehension. In C. Freksa, W. Brauer, C. Habel & K. Wender (eds.), *Spatial cognition III*. Berlin: Springer. [to be published 2002]

Krüger, A., Baus, J., and Butz, A. (2000). Smart graphics in adaptive way descriptions. In *Proceedings of Advanced Visual Interfaces*, AVI2000, Italy.

Lee, P.U., Tappe, H., and Klippel, A. (2002). Acquisition of landmark knowledge from static and dynamic presentation of route maps. In *Proceedings of the Cognitive Science Conference*, Fairfax, Virginia. [to be published 2002]

Levine, M. (1982). You-Are-Here maps. Psychological considerations. *Environment and Behavior*, 14, 221–237.

Levine, M., Marchon, I., and Hanley, G. (1984). The placement and misplacement of You-Are-Here-Maps. *Environment and Behavior* 16(2), 139–157.

MacEachren, A.M. (1986). A linear view of the world: Strip maps as a unique form of cartographic representation. *The American Cartographer*, 13(1), 7–25.

Malaka, R. and Zipf, A. (2000). DEEP MAP—Challenging IT research in the framework of a tourist information system. In D. Fesenmaier, S. Klein, and D. Buhalis (eds.). *Information and Communication Technologies in Tourism 2000*, *7th International Congress on Tourism and Communications Technologies in Tourism (ENTER 2000)* (pp. 15–27). Barcelona: Springer.

McNamara, T.P. (1991). Memory's view of space. *The Psychology of Learning and Motivation*, 27, 147–186.

Miller, G.A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review*, 63, 81–97.

O'Neill, M.J. (1999). Theory and research in design of 'You-Are-Here' maps. In J.G. Zwaga, T. Boersema, and H.C.M. Hoonhout (eds.). *Visual information for everyday use – design and research perspectives* (pp. 225–238). London: Taylor & Francis.

O'Neill, M.J. (1991a). Effects of signage and floor plan configuration on wayfinding accuracy. *Environment and Behaviour*, 23(5), 553–574.

O'Neill, M.J. (1991b). Evaluation of a conceptual model for architectural legibility. *Environment and Behaviour*, 23(3), 259–284.

Richter, K.-F. (2001). *Ein Verfahren zur Bestimmung geeigneter Standorte für You-Are-Here-Karten in Außengeländen*. Diplomarbeit (master thesis), Universität Hamburg.

Shepard, R.N. and Hurwitz, S. (1984). Upward direction, mental rotation, and discrimination of left and right turns in maps. *Cognition*, 18, 161–193.

Sorrows, M.E. and Hirtle, S.C. (1999). The nature of landmarks for real and electronic spaces. In C. Freksa and D.M. Mark (eds.). *Spatial information theory: Cognitive and computational foundations of geographic information science* (pp. 37–50). Berlin: Springer.

Tufte, E. (1990). *Envisioning information*. Conneticut: Graphics Press.

Tufte, E. (1997). *Visual explanations: Images and quantities, evidence and narratives*. Conneticut: Graphics Press.

Warren, D.H. and Scott, T.E. (1993). Map alignment in traveling multisegment routes. *Environment and Behavior*, 25, 643–666.