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You-Are-Here Maps in Emergencies –

The Danger of Getting Lost

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Abstract. This article evaluates criteria for the design of so-called You-Are-Here (YAH) maps, i.e. maps that explicitly indicate the position of the map reader. Established design criteria (Levine, 1982, O'Neill, 1999) are rendered more precise and applied in an exemplary assessment of three YAH maps as they can be found in public buildings as part of a general emergency scheme. The clarification of the YAH map terminology is necessary to allow for assessing the quality of existing YAH maps and consolidates the basis of rule-based generation of location-aware information services. Possibilities for further empirical evaluation of YAH maps are discussed and the role of location-aware technology is considered for smart mobile systems and smart environments.

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INTRODUCTION

Information about one's location is essential for numerous daily tasks such as planning a route to take and finding a desired destination. For modern information systems it is necessary to provide information about ones location in a cognitive ergonomic format using cognitively relevant features of the environment rather than numerical coordinates. While humans are not aware of the complexity of cognitive processes involved in the task of locating oneself in familiar environments (Gärling et al., 1983, Baskaya et al., 2004, Golledge, 1999), the scrutinies of determining *where am I* reveal themselves in unfamiliar or partially familiar environments.

Therefore, in cases of emergencies, understanding of provided spatial information is crucial, for example for leaving a building if it is on fire; the means are manifold: green exit signs mark emergency exits, fire wardens are trained to guide people, and dwellers of public buildings undergo instructions to the safety regulations relevant for their workplace. Most of the signage and the safety instructions are designated by official authorities.

In addition to the signs and the training, maps—mostly annotated floor plans—are placed at various locations in public buildings. Sometimes these maps are equipped with so-called You-Are-Here (YAH) symbols that should help the user to locate and orient herself. These maps are therefore referred to as YAH maps. They allow a user to update, for example, her knowledge about exit possibilities and existing fire fighting equipment in preparation for a potential emergency, whenever she passes a YAH map. Yet, apparently no clear principles for the design of these maps and for their proper placement have been applied to take into account the results from pertinent research about the usefulness and usability of these maps. Basic and

well established principles of map design and spatial cognition (Levine, 1982, Levine et al., 1984, Liben and Downs, 1993) are continuously neglected in the design and placement of YAH maps, world-wide. This is not only a matter of theoretical interest but can be dangerous for people in buildings in case of an emergency.

A different explanation for the design mistakes in emergency YAH maps is that the responsible authorities are aware of the problems but proper plans are not implemented due to cost efficiency considerations. With current information technology and the omnipresence of map-like representation along with the inexpensive production of maps, the missing element is a formal specification of the design criteria for these YAH maps that allows for rule-based generation.

This article extends a perspective offered by early cognitive science research (e.g., Levine, 1982, Levine et al., 1984, O'Neill, 1999) by integrating new findings and establishing a consistent terminological framework for the evaluation and design of YAH maps. The results are applied to evaluate YAH maps and discussed with respect to technological developments and further empirical evaluation.

PRINCIPLES OF GOOD MAP DESIGN AND DESIGN CRITERIA FOR YAH MAPS

Spatial cognition research provides manifold insights into the trilateral relationship of a user who tries to locate herself in an environment by means of a map with the aim to plan further actions by the information she reads off the map (e.g., Liben and Downs, 1993). We will briefly discuss main aspects that guide these interactions depicted schematically in Figure 1. The overall goal for YAH maps is to create a *sense of place* (Agarwal, 2005).

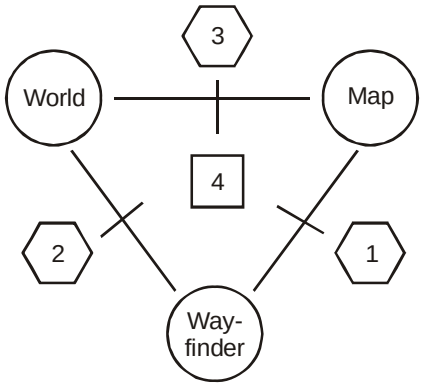

Figure 1. The trilateral relationship between wayfinder, world, and map.

A first step to establish a sense of place is to read off information from a map (relation 1 Figure 1). Literature on map design and visual graphic communication provides us with a rich knowledge base for formulating general and effective design criteria (e.g., Tufte, 1990, Tufte, 1997, Kosslyn, 1989, Keates, 1996, Lloyd, 2000). Interesting for the present study are those relevant for so called *task-specific maps* (e.g., Freksa, 1999, Muehrke and Muehrke, 1986, Tversky, 2000) as we focus on maps used in an emergency scheme. These criteria comprise:

- **Completeness:** All the information that is necessary to fulfil a given task, for example route information to leave a building, needs to be represented in the map. Different levels of the representation are pertinent: The representational characteristics of the graphic medium make the explicit representation of some information superfluous contributing to the advantageous use of map-like representations (cf., Larkin and Simon, 1987).

- **Perceptibility / syntactic clarity / visual clutter:** All the relevant graphic features for a given task—once they are represented in the map—need to be easily perceptible and identifiable (readable). The biggest threat to easy perception is *visual clutter* (e.g., Phillips and Noyes, 1982). The negative

effects have been known and behaviourally validated in early research (Dobson, 1980).

- **Semantic clarity:** All the symbols and map features need to be easily imbued with meaning. In the optimal case, this should be accomplished within the map itself, i.e. the symbols used should be self-explanatory. If this cannot be achieved, a proper legend is required. Three sub-aspects can be differentiated.
    - **Ambiguity:** The information for solving the tasks should be displayed in a non-ambiguous way.
    - **Consistency:** All objects of the same kind should be in the map, if one is depicted.
    - **Signage:** Iconic signs should be used to make a legend obsolete.
- **Pragmatics:** We consider two aspects:
    - **Convenience:** A good design should take into account how, when, and where the information is used.
    - **Contact and date information.** A map should provide information on its creation date and its creator.

For the special case of YAH maps—indicating a user's current position within an environment—the literature provides additional design criteria. Levine (1982) identified design and positioning guidelines for YAH maps to enhance their suitability for aiding wayfinding processes. These criteria have been extended and experimentally evaluated by several authors (e.g., O'Neill, 1999, Warren and Scott, 1993, Warren et al., 1992, Lloyd, 2000, Levine et al., 1982, Montello, 2005). YAH

map design principles (relation 2-4 Figure 1)—additionally to the general map design aspects—can be summarized as follows:

- **General (global) placement:** The evaluation of environmental characteristics based on their complexity and their structural characteristics has gained considerable attention in recent years (Hillier and Iida, 2005, O'Neill, 1999, O'Neill, 1991b, Levine et al., 1984, Bafna, 2003). Together with agent simulations (Raubal, 2001, Frank, 2000) the identification of critical points for finding one's way and for reorientation in an environment is a task that is close to being automated. A distinction has to be made between indoor and outdoor environments (e.g., Gartner et al., 2004). While placement evaluations for two dimensional outdoor environments have progressed well (e.g., Richter and Klippel, 2002), the intricacies of the third dimension in indoor environments require further studies (Hölscher et al., in prep, Moeser, 1988, Fontaine and Denis, 1999).

- **Local placement:** Once the general placement for a YAH map has been chosen, attention has to be paid to the local placement, for example, where at an intersection or in a building the YAH map should be installed (Levine et al., 1984, Best, 1970). One important aspect of the local placement of YAH maps is the use of asymmetries to facilitate locating 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 (see below) shown on the map provides many cues for its location. Therefore, the location of the map in the environment becomes non-ambiguous.

- **Correspondence:** YAH maps should allow for easily establishing a correspondence between the represented information and the information that is immediately perceptible (see Figure 1). Self-localization, i.e. the understanding of where one is, is a prerequisite to use the map for planning where to go and which route to take (Liben and Downs, 1993). While locating oneself should be guided by a YAH symbol (see below), several aspects contribute to whether or not the orientation within an environment can be accomplished easily. We discuss here *alignment*, *architectural cues*, and the *YAH symbol*.

    - **Alignment:** The YAH map and the environment should be aligned. If a map is aligned with the environment the top of the map corresponds to the relation 'in front of' of the user viewing the map. Hence, the different reference systems involved can be easily matched: the absolute reference system of the map, the relative reference system of the user, and the intrinsic reference system of the YAH symbol representing the intrinsic characteristics of the user (eg., Levine, 1982, Levinson, 2003). The relations LEFT and RIGHT are the same in the looked at map and in the viewed environment fostering the establishment of a correspondence (e.g., Shepard and Hurwitz, 1984, Warren and Scott, 1993). Apart from the YAH symbol, alignment is the most important criterion for the design of good YAH maps: People usually expect YAH maps to be aligned and they use them accordingly (Shepard and Hurwitz, 1984). Thus, non-aligned YAH maps significantly complicate the wayfinding process.

- **Architectural cues:** YAH maps should be designed such that architectural cues and natural landmarks are included and that the shape of the route drawn in the YAH map relates to the actual shape of the route the user has to take in the environment, i.e. the behavioural pattern depicted corresponds to the behavioural pattern to be carried out (Klippel, 2003, Montello, 2005). As these are important cues in people's wayfinding behaviour (Golledge, 1999, Golledge and Stimson, 1997) this eases map use and reinforces learning and remembering the environment's layout. In the case of emergency YAH maps, the shape of the environment is mostly provided with high precision and is rectangular in most cases as these maps are mostly architectural floor plans. There are, however, exceptions in the regularity, which should be pointed out if available.

- **YAH symbol:** The YAH symbol fulfils two tasks: First, it locates the user within an environment; second, it should indicate the user's orientation with respect to her immediate surroundings. If a YAH symbol complies with both tasks it is referred to as a *complex YAH symbol* (Levine, 1982). The double function can be achieved by combining a dot with an arrow or by a triangular shaped symbol designs. Complex YAH symbols significantly ease orientation at current locations and allow determining the route to the destination as, again, relating map features to features in the environment is facilitated; alignment of the map and the orientation of the complex YAH symbol should correspond to each other.

- **Alignment of text in the map:** The text in a map should be generally readable without requiring to turn one's head.

- **Redundancy:** Redundancy is a concept that is quantitatively not well defined and can have positive as well as negative impacts. Combining the principles mentioned above may allow for easier self-localization, orientation and determination of the route to the destination, i.e. to exit the building (see also Hirtle, 2000). On the other hand, increasing redundancy may lead to worse performance if, for example, the visual or cognitive complexity inhibits the extraction of information from a map (O'Neill, 1991a).

ASSESSING YAH MAPS

Given the criteria for the design of good maps and the specific criteria of YAH maps defined in the previous section, we evaluate exemplarily three YAH-Maps found at the University of Melbourne. The maps were chosen to exhibit how different environmental characteristics interact with the representational characteristics of maps, especially when these maps are of the same type, i.e. annotated floor plans. This choice allows us to work out the importance of location-aware information on the basis of maps of the same type. How these results can be applied to a wider range of YAH maps is discussed in Section 5.

Additionally to the criteria of good map design and those established for YAH-Maps we discuss important aspects for YAH maps in emergencies: emergency exits behind secured doors, ambiguous information at decision points, and temporarily unstable information.

Building 723 Swanston Street, Ground Floor

The first example is taken from the ground floor of a building at 723 Swanston Street, Melbourne, Australia. The YAH map is installed on a lift alcove between two elevator doors (see Figure 2 and Figure 3).

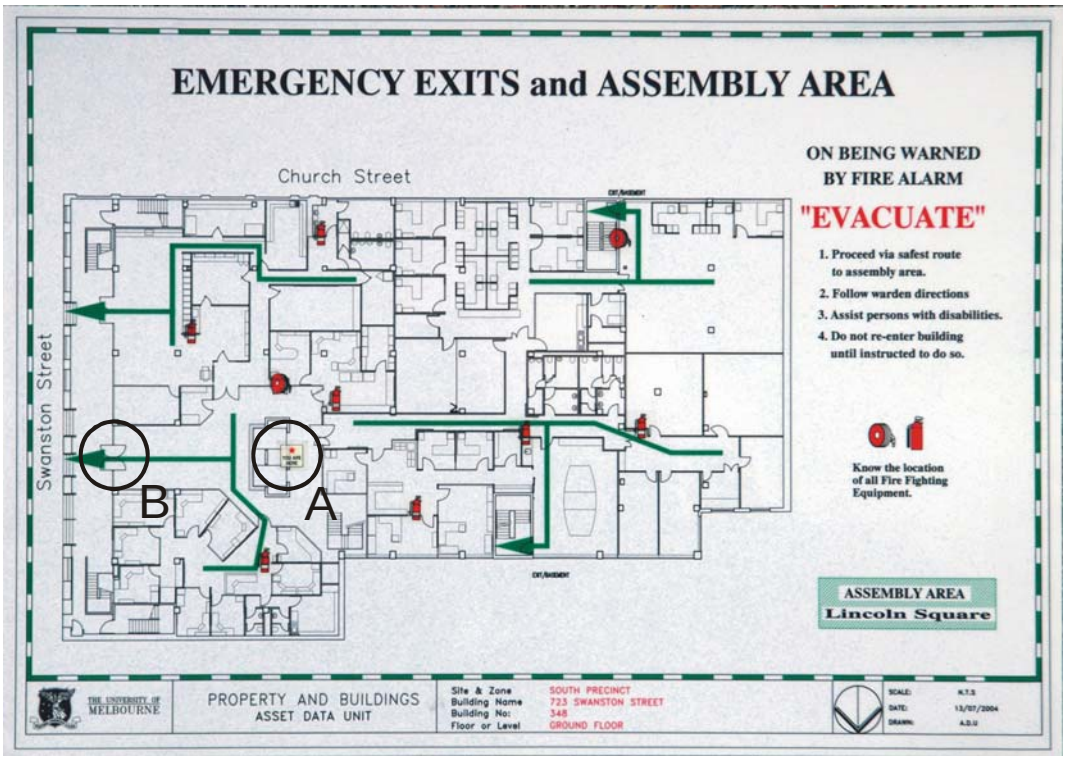

Figure 2. YAH map 1 at lift alcove 723 Swanston Street, ground floor.

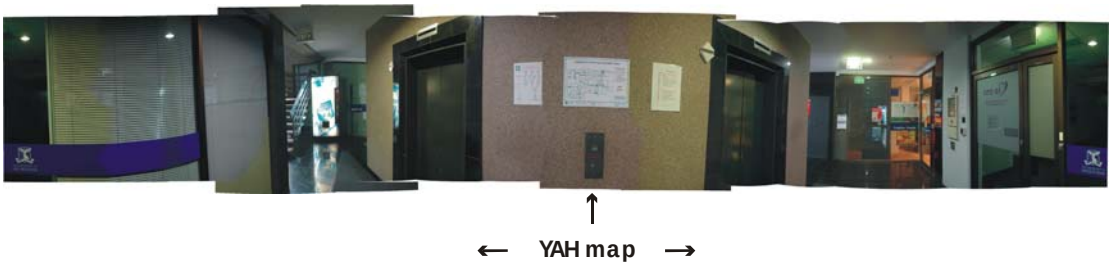

Figure 3. 360˚ view YAH map 1.

General Criteria

Completeness: In general it is possible to extract the required information from this map. The current location is indicated by a YAH Symbol (Figure 2, circle A) and a textual annotation "You are here" ensures that the YAH symbol can be interpreted

correctly; the main entrance/exit door to Swanston Street (Figure 2, circle B) is contained in the map although not explicitly marked. The route, or better several routes are indicated but not marked from the current position.

Perceptibility / syntactic clarity / visual clutter: The relevant features are the current location and the next exit. The exit to take is not explicitly marked, i.e., the user has to figure out the closest exit herself. The YAH symbol is barely visible (Figure 2, circle A). The map is a floor plan annotated for the case of emergencies. Accordingly, the amount of visual clutter is high. Several objects are superfluous, for example, movable objects, like under desk containers; several of these objects have changed position or are no longer existing. Other information, like exit possibilities behind closed doors in other parts of the building, is not important for someone who is using the map at this position. Hence, some of the clutter could be avoided by omission and/or using iconic symbols.

Semantic clarity: The YAH symbol is annotated with text. The green lines can be recognised as possible escape routes, although that is not made explicit. There are, however, many signs/features in the map that are not readily recognisable by lay persons and are architectural specifications. For instance, the location of the restrooms could be used as a valuable landmark but instead has to be inferred from the toilet-shaped symbols instead of using a standardized sign.

Ambiguity: The exit routes from the current position are marked very prominently in the map, whereas the main exit to Swanston Street (Figure 2, circle B) is not marked explicitly—other than by the general green arrows. The inexperienced lay user of this map might infer that all exit routes are suited equally well. Most of the

exits, however, are secured by hierarchical entrance rights which bear the possibilities to seriously trap users.

Consistency: The green exit signs are prominent markers within the building. Around the YAH map location several of them are installed. Their display in the map, however, is missing. That no exit signs are displayed on the exit Swanston Street is regarded critical and inconsistent.

YAH Map Criteria

General placement: The placement is close to an important, highly frequented location, i.e. the elevator. Additionally the map is opposite the entrance/exit of one of the bigger units on this floor.

Local placement / asymmetry: The asymmetry in this case is the symmetry, i.e. the location between two elevator doors. As this map is not intended as a map for visitors to find their destination but for people who want to leave the building or fight a fire, a placement opposite the elevator doors as suggested by Levine (1982) does not seem appropriate here.

Correspondence: As the green exit signs are prominent landmarks in the building environment, they could be used in the map to enhance the mapping, i.e. to establish the trilateral relationship between user-map-environment (see Figure 1).

Alignment: The map is misaligned with respect to the user's perspective. To be correctly aligned the map needs to be rotated 90 degrees clockwise. The alignment would ease orientation and would reduce the necessity for mental or head rotation.

Architectural cues: It could be better stressed that the map location is directly between the two elevator doors. Instead, the YAH symbol (i.e. the red star in Figure 2, circle A) is slightly misplaced.

YAH symbol: The YAH symbol is just a star providing position information but no orientation.

Redundancy: Not used.

General Evaluation

This map reveals several general issues that are neglected in the design of maps and YAH maps: Starting with the problem of visual clutter, the reuse of a map that is designed for a different purpose, and neglecting specific design criteria for the establishment of a sense of place. This map bears little usefulness in cases of emergencies.

Basement 723 Swanston Street

The second example is taken from the basement in the same building (Figure 3 and Figure 4). While the design scheme of the map is the same as in YAH map example 1, the environment is quite different.

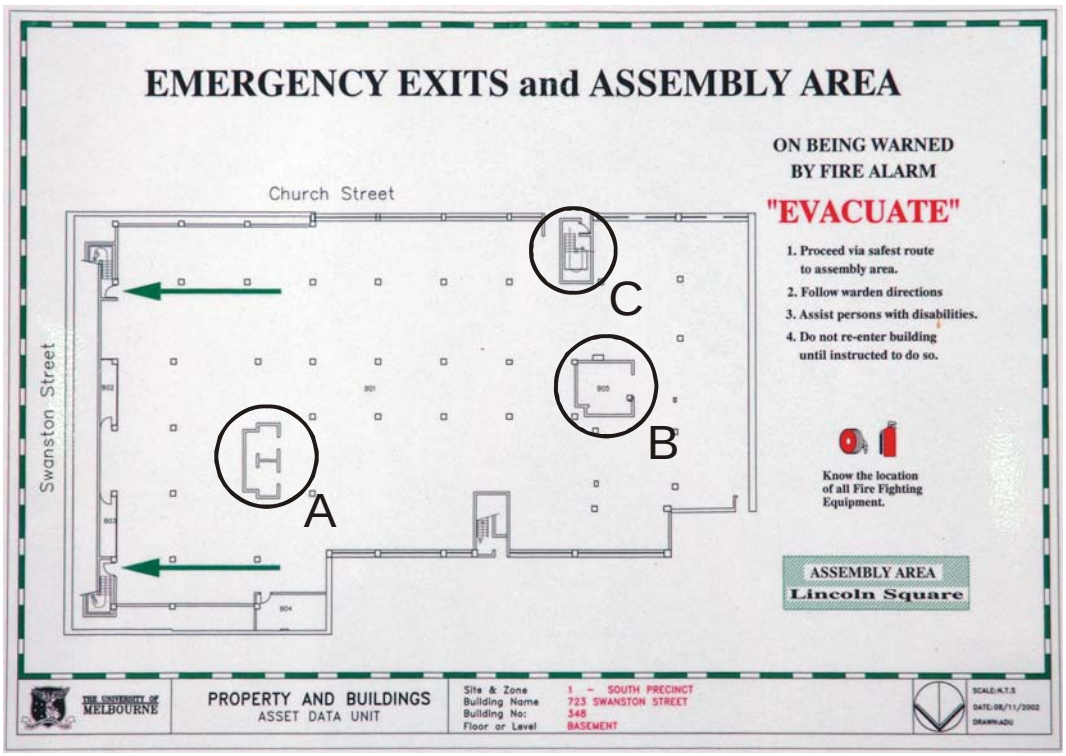

Figure 4. YAH map 2, basement (parking lot) 723 Swanston Street.

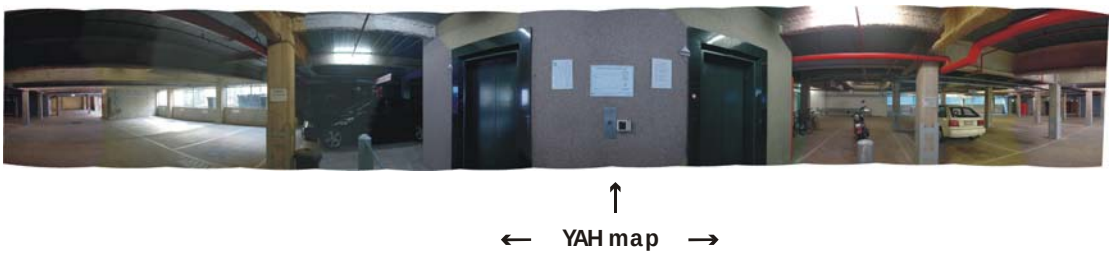

Figure 5. 360˚ view YAH map 2.

General Criteria

Completeness: In this map two exit routes are indicated. A third exit (Figure 4, circle C) that would lead directly out of the building is not marked. It is highly questionable, if this information can be inferred from the map. It would be crucial to add this information as the third exit is in the back of the user when she is facing the map.

Perceptibility / syntactic clarity / visual clutter: Due to the fact that there are only a few structural elements in the basement, all map objects are easy to perceive.

Semantic clarity: The legend explains items that are not indicated in the map. While floor plans often are self explanatory with respect to the geometric features of the building as such in an 'empty' environment the interpretation of the represented elements proves to be difficult. The distinction of the elevator (Figure 4, circle A) from the second main pillar (Figure 4, circle B) can only be achieved in interaction with the environment. The meaning of the dots all over the map is unclear (but may be inferred after a while as the support pillars).

Ambiguity: Besides the ambiguity between the lift alcove and the main pilar, the map does not contain much more information that could be displayed ambiguously. The map as such, however, is location-ambiguous due to the missing YAH symbol (see next Section).

Consistency: Green exit signs that are in the environment are omitted in the map. The fire-fighting equipment seems to be not present on the basement but is, nevertheless, indicated in the map margin.

YAH Map Criteria

General placement: The general placement, similar to YAH map 1, is at a highly frequented location within the environment.

Local placement / asymmetry: Just like in the example of YAH map 1, the identification of the current location is (or better could be) achieved by symmetry, i.e. indicating the location of the map *between* two elevator doors, rather than by asymmetry.

Correspondence: As there is little structure in the basement the use of the exit signs would help to establish a correspondence (as well as the correct alignment).

There are no identical labels that can be found in the map as well as in the environment.

Alignment: The map is misaligned. To be correctly aligned the map needs to be rotated 90 degrees clockwise.

Architectural cues: There are some architectural cues in the environment that could potentially help establish a correspondence, for example, a fence right of the lift alcove. These elements are not depicted.

YAH symbol: The YAH symbol has been omitted. Especially in an environment as unstructured and information empty, i.e. no knowledge is in the environment (Raubal and Worboys, 1999), establishing a correspondence is thereby inhibited.

Redundancy: Not used.

General Evaluation

This map is a good example of how the violation of correspondence requirements—misalignment, missing YAH symbol, missing architectural clues—in environments that do not naturally provide structure leads to an increased cognitive effort to establish the trilateral user-map-environment relationship. This failure makes the map barely usable, although the global location is suitable.

Geomatics Building 2nd Floor

YAH map 3 was found on the second floor of the Geomatics building.

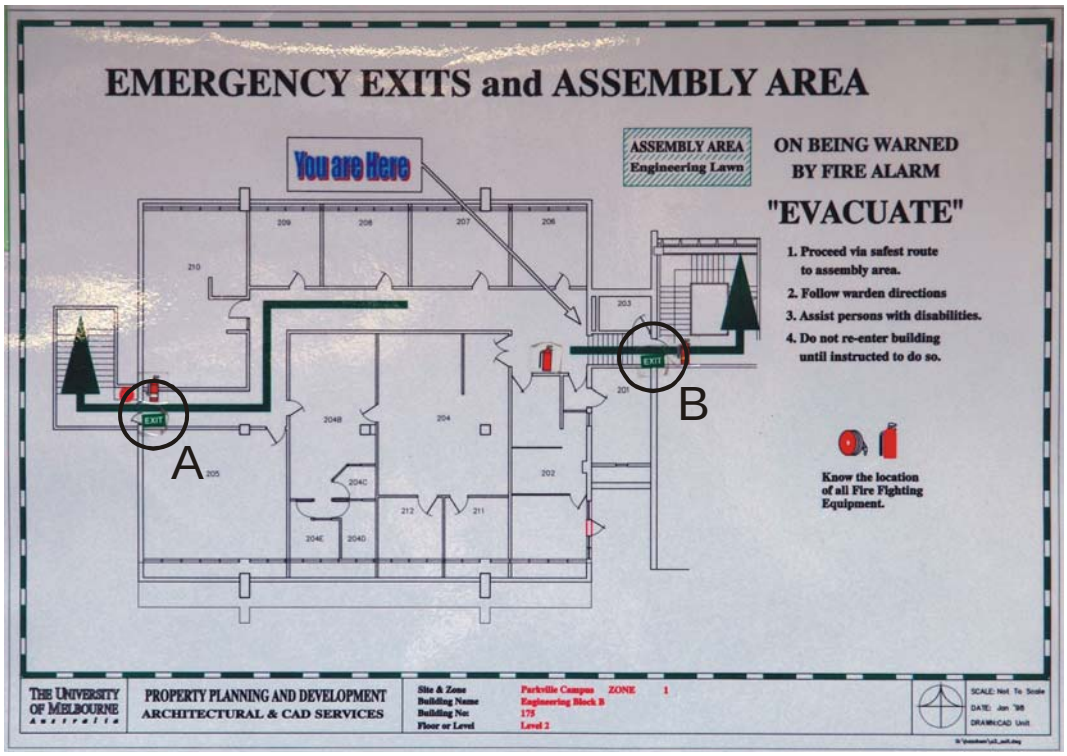

Figure 6. YAH map 3, Geomatics building 2nd Floor.

Figure 7. 360˚ view YAH map 2.

General Criteria

Completeness: The current position and exit routes are drawn in the map making it in general possible to infer the required information. The routes, however, do not start at the indicated (the map's and user's) position.

Perceptibility / syntactic clarity / visual clutter: Although the YAH indicator is not drawn directly in the map the current position and the routes are well perceivable. Due to the simple environment the amount of visual clutter is reasonable but could be reduced by omitting offices not passed by the exit routes.

Semantic Clarity: The YAH indicator is textual; the semantics of arrows should be clear. The green lines with arrow ends denote the exit routes. The symbols for the fire fighting equipment and the exit signs have been added subsequently. The symbols differ in the map but no legend is provided that would explain these differences, i.e. indicating the existence of different fire fighting equipment for different kinds of fires.

Ambiguity: The green exit signs (Figure 6, circle A and B) are arbitrarily placed in the map as an in-map legend for the green lines. Their position does not correspond to the green exit signs found in the environment.

Consistency: While room 203 is labelled with a number in the map, the actual door sign shows the function (women's restroom). There is also an additional fire extinguisher at the exit indicated by circle A in Figure 6.

YAH Map Criteria

General placement: The map is located at a wall that basically everyone who is leaving this part of the building regularly has to pass.

Local placement / asymmetry: The asymmetry of this place (stairs on the very left side) could be used to establish further correspondence if the map would have been aligned correctly.

Alignment: The map is misaligned and needs to be rotated 90 counter clockwise to fit the reference system of user-map-environment.

Correspondence: The green exit signs could be used as extra features to help establishing a correspondence.

Architectural cues: The stairs right to the YAH map provide a good feature of asymmetry.

YAH symbol: It is rather a YAH indicator lacking the inherent user reference systems that a complex YAH symbol could supply.

Redundancy: Not given.

General Remarks

The mentioning of the assembly area is at a different position than in the other maps. The symbols for the fire fighting equipment differ in the map but no legend is provided to explain the different types. The date on the map is 1998 which might explain why the symbols are added subsequently and why the indication of additional fire fighting equipment is missing.

A strange mismatch is induced in that the arrow indicating the exit route conveys the correct movement pattern but only as it incorporates one further decision point that is located in the staircase. This, again, indicates the influence of the proper depiction not only of the environment but also of the actions that have to be performed therein.

RESULTS AND DISCUSSION

The analysis of the map examples shows that the design and placement of YAH maps has not been guided by established principles of YAH map design and their placement (see Section 0). While we chose three map examples of the same design style to highlight how different environments effect the legibility of maps, the problems identified are omnipresent. Without having a systematic survey but many

other examples at hand, this situation is symptomatic for most YAH maps (e.g., search in Google's images for "emergency map"). One of the biggest problems identified is the difficulty of establishing a correspondence between the user, the map, and the environment (see Figure 1), i.e. the trilateral user-map-environment relationship necessary for updating one's cognitive map (Golledge, 1999). For a successful orientation and the planning of appropriate next steps in an emergency, accounting for this relationship is a necessity. The best researched—and probably most pertinent—criterion for YAH maps, their *alignment* with the environment, is violated in all discussed examples. All maps require the user to perform a mental rotation of 90 degrees clockwise to establish a correct forward-up relationship. While this might be feasible for locating oneself, the cognitive load increases if routes have to be planned on this basis. The discussed examples make it obvious that the success of the rotation task is strongly dependent on the structural cues provided in the immediate surroundings of the map placement. Additionally, none of the maps provides a complex YAH symbol that indicates the user's current orientation. Supplementary features in the environment that could be used to establish the correspondence more easily are often neglected. In our example, the prominent green exit signs would allow to relate information represented in the map to information present in the environment.

For the analysed cases, the global placement at highly frequented locations was a sensible choice. The criteria for placing YAH maps can be evaluated using approaches from different disciplines. For outdoor environments several factors can be combined to identify critical decision points for wayfinding in a closed environment (Richter and Klippel, 2002). To our knowledge, for indoor environments no such assessment has been done for the placement of YAH maps.

The asymmetry criterion for the placement of YAH maps introduced by Levine (Levine, 1982) can be extended by a symmetry criterion. Given the correct application of other YAH map design criteria, a symmetrical placement within an environment can be used to quickly identify one's position as well as the original asymmetry criterion.

If maps are drawn in a precise way like the floor plans in our example, i.e. they are spatially veridical, users expect them to be correct and complete (Habel, 2003). Missing features, like the fence in the basement in YAH map example 3, make these maps confusing, as they are not sketch maps, which might allow for the depiction of partial spatial knowledge.

These results reveal the necessity to advise proper and clear guidelines for those who are responsible for providing map-based orientation beyond the ones that can be already found in the literature (O'Neill, 1999, Levine, 1982). The examples in this paper show that the maps provided need improvement to fulfil the criteria of good map design and the special requirements for YAH Maps (in emergencies). A common terminology as proposed in this paper that guides the evaluation and the design is a first step.

IDENTIFICATION OF FUTURE RESEARCH DIRECTIONS

Requirements and Implementations of a (Semi) Automatic Interactive Systems for YAH Map Design and Placement

A system that semiautomatically creates location-aware YAH maps requires the specification of several design factors. For solidly installed YAH maps the first step is the identification of a suitable location within an environment. This location is

influenced by global and afterwards local properties of an environment. Several approaches for specifying these placement criteria and for outdoor environments evaluations have taken place (O'Neill, 1991b, Richter and Klippel, 2002). For the case of emergency YAH maps local criteria are more crucial (as it is better to have an additional map than being one short) that allow for creating a *sense of place* usable in emergency situations. The *legibility* of an environment has been characterised in environmental cognition and architectural literature (Weisman, 1987, Lynch, 1960). Yet, as it is a sensible approach to guide architectural design decision at least partially by aspects of spatial cognition, the problem remains pertinent for existing buildings; suitable YAH maps have to be advised for existing structures. A deeper understanding of aspects of spatial cognition is therefore desirable, especially in complex indoor structures (O'Neill, 1992, Hölscher et al., in prep).

Dynamically created emergency YAH maps pose additional challenges. It is useful to distinguish here between different visualization technologies of dynamically created emergency maps. Using immersive visualization technologies (Cartwright et al., 1999) emergency maps would be designed for a specific location, while their content changes according to the actual emergency situation. For example, if the next emergency exit is blocked by a fire, a dynamically created map could show the route to the next free exit (Graf and Winter, 2003, Pu and Zlatanova, 2005). Dynamically created maps for presentation on mobile devices have to deal additionally with the variable (and changing) position and orientation of the map reader. In this case, map design needs knowledge about the spatial environment, the emergency situation, the individual user, and her position, orientation and speed (Kealy et al., submitted). Another constraint is the small screen of current mobile devices. However, the map will be not only adaptive to the situation, but also to the user. For example, two

mobile users coming along the same place in an evacuation situation can get different advice according to their individual abilities and mobility. In both cases, the content will be drastically reduced, since the situation requires quick action. Sense of direction will be more relevant then sense of place.

The design of such maps can follow an approach taken in the project *Spatial Structures in Aspect Maps* (Berendt et al., 1998). Based on the distinction of knowledge into different aspects, precedence relations have to be established on which criteria are ranked higher than others. This holds for the objects represented in the map as well as for the specific criteria for YAH maps. Instead of using existing maps we suggest to pursue an approach known from sketch maps where the representation are constructed based on conceptual units (Klippel et al., 2005). To this end, we aim to fulfil communicative maxims (Grice, 1989) and especially avoid visual clutter.

The combination of two-dimensional and three-dimensional information, i.e. maps that are annotated with three-dimensional models of salient objects does show a lot of promise in increasing the efficiency of maps for orientation (Rakkalainen and Vainio, 2001). The technical capabilities of extracting, for example, map icons have advanced (DeCarlo et al., 2003) and in combination with availability of three-dimensional city models, the seamless integration of different information sources with exploiting the information best suited to a given task will be feasible.

Possibilities for Evaluation

We rendered the terminology associated with YAH maps more precise to allow for an easy evaluation of existing maps (Section 0). A further assessment should be based on established methodologies from cognitive science and related fields of research. Possibilities that we are currently exploring comprise the following:

Eye movement studies: Eye movement studies are becoming more and more popular as the technical (and economic) aspects of these systems are well advanced (Hayhoe and Ballard, 2005). Several studies in visual communication and related fields have shown the value of this methodology.

Virtual environments: Virtual environments allow for the manipulation of specific environmental characteristics. This procedure is necessary to establish a base line of human behaviour and human response to different environmental settings (Vinson, 1999).

Agent simulations: Great progress has been made in agent simulations within the last couple of years (Raubal, 2001, Frank, 2000). As agent models become more and more sophisticated these simulations can save valuable time and money for the assessment of necessary security provisions.

Behavioural studies: The analysis of wayfinding behaviour in complex building with several parts and several levels is part of current research programs (Hölscher et al., in prep). Interestingly, these studies show that maps seem to have no or a negative effect on the performance of wayfinders. In our opinion this is not because of the general inapplicability of maps as they have proven beneficial influence on spatial

problem solving, but is a further indicator of still to many maps that need improvement.

CONCLUSIONS

In this article we have shown how different approaches of spatial sciences can benefit from each other: On the one hand, the general aspect of mapping and data provision, on the other hand, spatial cognition research. Spatial cognition research offers many insights into processes how humans perceive, store, transform, and employ spatial information. Although there exist many accounts on how cartographic and cognitive research can be fruitfully combined from a more cartographic perspective (e.g., MacEachren, 1995), a closer relationship shows beneficial promises, and close collaborations are necessary to conduct research in so called *research cycles* in which behavioural findings are iteratively integrated in information systems.

Users should get an enhanced (integrated) sense of the one place that they are at (rather than several ways of seeing a place that burden their mental capacities). This can only be achieved if perceptual and cognitive aspects of the processing of spatial information are combined. The developed terminology is a synthesis from the literature and our own work in spatial cognition. It allows to improve YAH maps in two ways: First, it is a means to evaluate existing YAH maps; second, it is an extended guideline for designing and placing YAH maps. Additionally, the identified categories are the basis for a system that will autonomously create maps for specific locations. With the shift from solidly installed YAH maps to mobile systems or automatically updated ones and the development of smart environments additional possibilities for providing route information emerge.

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REFERENCES

Agarwal, P. (2005) In *Spatial Information Theory. International Conference, COSIT 2005, Ellicottville, NY, USA, September 14-18, 2005, Proceedings*(Eds, Cohn, A. G. and Mark, D. M.) Springer, Berlin.

Bafna, S. (2003) *Environment and Behavior,* **35,** 17-29.

Baskaya, A., Wilson, C. and Özcan, Y. (2004) *Environment and Behavior,* **36,** 839-867.

Berendt, B., Barkowsky, T., Freksa, C. and Kelter, S. (1998) In *Spatial Cognition. An interdisciplinary approach to representing and processing spatial knowledge*(Eds, Freksa, C., Habel, C. and Wender, K. F.) Springer, Berlin, pp. 313-336.

Best, G. A. (1970) In *Architectural Psychology*(Ed, Canter, D.) RIBA, London, pp. 72-91.

Cartwright, W., Peterson, M. P. and Gartner, G. (Eds.) (1999) *Multimedia Cartography,* Springer, New York.

DeCarlo, D., Finkelstein, A., Rusinkiewicz, S. and Santella, A. (2003) In *SIGGRAPH 2003*, pp. 848-855.

Dobson, M. W. (1980) *The Cartographic Journal*, **17,** 26-32.

Fontaine, S. and Denis, M. (1999) In *Spatial information theory. Cognitive and computational foundations of geographic information science*(Eds, Freksa, C. and Mark, D. M.) Springer, Berlin, pp. 83-94.

Frank, A. U. (2000) In *Spatial cognition II: Integrating abstract theories, empirical studies, formal methods, and practical applications*(Eds, Freksa, C., Brauer, W., Habel, C. and Wender, K. F.) Springer, Berlin.

Freksa, C. (1999) In *Visual and Spatial Reasoning in Design.*(Eds, Gero, J. S. and Tversky, B.) Key Centre of Design Computing and Cognition, University of Sydney, pp. 15-32.

Gärling, T., Lindberg, E. and Mäntylä, G. (1983) *Journal of Applied Psychology*, **68,** 177-186.

Gartner, G., Frank, A. U. and Retscher, G. (2004) In *Location based services & telecartography. Proceedings of the Symposium 2004*(Ed, Gartner, G.) Vienna University of Technology, Vienna, pp. 161-167.

Golledge, R. G. (Ed.) (1999) *Wayfinding behavior. Cognitive mapping and other spatial processes*, Johns Hopkins University Press, Baltimore.

Golledge, R. G. and Stimson, R. J. (1997) *Spatial Behavior. A Geographic Perspective.*, The Guilford Press, New York.

Graf, M. and Winter, S. (2003) *Österreichische Zeitschrift für Vermessung und Geoinformation*, **91,** 166-174.

Grice, H. P. (1989) *Studies in the way of words*, Harvard University Press, Cambridge, MA.

Habel, C. (2003) In *Roundations of Geographic Information Science*(Eds, Duckham, M., Goodchild, M. F. and Worboys, M.) Taylor & Francis, London, pp. 69-93.

Hayhoe, M. and Ballard, D. (2005) *Trends in Cognitive Sciences*, **9**.

Hillier, B. and Iida, S. (2005) In *Spatial Information Theory. International Conference, COSIT 2005, Ellicottville, NY, USA, September 14-18, 2005, Proceedings*(Eds, Cohn, A. G. and Mark, D. M.) Springer, Berlin, pp. 475-490.

Hirtle, S. C. (2000) In *Spatial cognition II -- Integrating abstract theories, empirical studies, formal methods, and practical applications*(Eds, Freksa, C., Brauer, W., Habel, C. and Wender, K. F.) Springer, Berlin, pp. 31-40.

Hölscher, C., Meilinger, T., Vrachliotis, G. and Brösamle, M. (in prep).

Kealy, A., Retscher, G. and Winter, S. (submitted) *Mobile Information Systems*.

Keates, J. S. (1996) *Understanding Maps*, Longman, Edinburgh.

Klippel, A. (2003) *Wayfinding Choremes. Conceptualizing Wayfinding and Route Direction Elements.*, Universität Bremen, Bremen.

Klippel, A., Lee, P. U., Fabrikant, S. I., Montello, D. R. and Bateman, J. (2005) In *Reasoning with Mental and External Diagrams: Computational Modeling and Spatial Assistance. Papers from the AAAI 2005 Spring Symposium. March 21-23, Stanford, California.*AAAI Press, Menlo Park, CA, pp. 90-95.

Kosslyn, S. M. (1989) *Applied Cognitive Psychology*, **3,** 185-225.

Larkin, J. H. and Simon, H. A. (1987) *Cognitive Science*, **82,** 207-225.

Levine, M. (1982) *Environment and Behavior*, **14,** 221-237.

Levine, M., Jankovic, I. N. and Palij, M. (1982) *Journal of Experimental Psychology: General,* **111,** 157-175.

Levine, M., Marchon, I. and Hanley, G. (1984) *Environment and Behavior,* **16,** 139-157.

Levinson, S. C. (2003) *Space in Language and Cognition,* Cambridge University Press, Cambridge.

Liben, L. S. and Downs, R. M. (1993) *Developmental Psychology,* **29,** 739-752.

Lloyd, R. (2000) In *Cognitive Mapping: Past, present, and future*(Eds, Kitchin, R. and Freundschuh, S.) Routledge, London, pp. 84-107.

Lynch, K. (1960) *The image of the city.,* MIT Press, Cambridge, MA.

MacEachren, A. M. (1995) *How Maps Work. Representation, Visualization, and Design,* The Guilford Press, New York.

Moeser, S. D. (1988) *Environment and Behavior,* **20,** 21-49.

Montello, D. R. (2005) In *Cambridge Handbook of Visuospatial Thinking*(Eds, Miyake, A. and Shah, P.) Cambridge University Press, Cambridge, pp. 257-294.

Muehrke, P. C. and Muehrke, J. O. (1986) *Map use: reading, analysis, and interpretation,* JP Publications, Madison, WI.

O'Neill, M. J. (1991a) *Environment and Behavior,* **23,** 553-574.

O'Neill, M. J. (1991b) *Environment and Behavior,* **23,** 259-284.

O'Neill, M. J. (1992) *Journal of Environmental Psychology,* **12,** 319-327.

O'Neill, M. J. (1999) In *Visual information for everyday use - design and research perspectives*(Eds, Zwaga, J. G., Boersema, T. and Hoonhout, H. C. M.) Taylor & Francis, London.

Phillips, R. J. and Noyes, E. (1982) *Cartographic Journal,* **19,** 122-132.

Pu, S. and Zlatanova, S. (2005) In *Geo-information in Disaster Management*(Eds, van Oosterom, P., Zlatanova, S. and Fendel, E. M.) Springer, Heidelberg, pp. 1143-1161.

Rakkalainen, T. and Vainio, T. (2001) *Computers & Graphics,* **25,** 619-625.

Raubal, M. (2001) *International Journal of Geographical Information Science,* **15,** 653-665.

Raubal, M. and Worboys, M. (1999) In *Spatial information theory. Cognitive and computational foundations of geographic information science.*(Eds, Freksa, C. and Mark, D. M.) Springer, Berlin, pp. 381-399.

Richter, K.-F. and Klippel, A. (2002) In *GI-Technologien für Verkehr und Logistik. Beiträge zu den Münsteraner GI-Tagen 20./21. Juni 2002.*(Eds, Möltgen, J. and Wytzisk, A.) IfGIprints, 13: Muenster, pp. 357-364.

Shepard, R. N. and Hurwitz, S. (1984) *Cognition,* **18,** 161-193.

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

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

Tversky, B. (2000) *Developmental Science,* **3,** 281-282.

Vinson, N. G. (1999) In *CHI 99.*

Warren, D. H. and Scott, T. E. (1993) *Environment and Behavior,* **25,** 643-666.

Warren, D. H., Scott, T. E. and Medley, C. (1992) *Perception*, **21,** 671-689.

Weisman, G. D. (1987) In *Housing the aged: Design directives and policy considerations*(Eds, Regnier, V. and Pynoos, J.) Elsevier, New York.