EXTENDED ABSTRACT

ADAPTING ONE’S MENTAL MODEL: AN ESSENTIAL PROCESS FOR SUCCESSFUL NAVIGATION IN AN ENVIRONMENT

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BIOGRAPHY

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ABSTRACT

Navigating through an unknown environment is a common task which is often successfully completed even with incomplete maps. This paper proposes formalized strategies which describe how humans navigate through an unknown environment with the help of a partially incorrect map. The formalized strategies are based on the structure of an agent with state and assume that the human's mental representation of the environment dynamically adapts to the environment through perception of information from the real world. Recent research is aimed at describing errors in mental representations. This paper takes a different approach and gives a classification of differences between the real world and a map. It shows how the agent deals with these differences which are detected during the navigation process.

INTRODUCTION

A common task of humans is to navigate from one place to another, often in an unknown area. Typically street network maps are used. Most of the time successful navigation is possible, although the street network maps used are partially incorrect. The novel contribution of this paper is a proposed classification of errors in maps and the resulting errors in the agent's representation of the environment which is based on this map. The paper offers formalized navigation strategies that describe successful navigation in an unknown street network even with incomplete maps. It claims that decision errors in the navigating process with the help of a printed map are mainly based on topological errors of the paper map.

PREVIOUS WORK

Years ago geographers have claimed the need to understand the cognitive process of map readers while doing research on symbolization and design principles for cartography (Robinson and Petchenik 1976). Experimental studies were conducted to explore the interaction between the map and its reader. Sheppard and Adams (1971) found that up to 50 percent of persons use road maps for route finding in an unknown area. Gray and Russell (1962) found that 49 percent of the car drivers keep a map in their car, 16 percent of them use the maps 'often' and 21 percent 'sometimes'.

There is a common view that a mental representation of the environment is important for the navigation process.
Mental representations are often considered to be split into several parts (Lynch 1960, Appleyard 1970, Beck and Wood 1976, Kuipers 1978, Tversky 1993), which is not the case when the information is taken directly from a paper map. Much research aims at finding errors in mental representations of the environment. Systematic differences between people's knowledge of the world and the reality, such as hierarchical spatial reasoning (Stevens and Coupe 1978), perceptual organizing principles (Tversky 1981), or a varying perspective (Holoyak and Mah 1982) are found. Lynch (1960) points out that errors in cognitive maps are most frequently metrical, and rarely topological.

**HYPOTHESIS**

A situation is critical if a decision about which road to take cannot be made with certainty. Critical situations result from differences between the real world and the agent's mental representation of the environment. The decisions of the navigating agent are based on a paper map which is partially incorrect. An incomplete paper map either omits an element of the real world (omission) or represents an element that does not exist in reality (commission). The navigating agent decides which of these two cases is the reason for an error in the map. The hypothesis of the paper is that successful navigation is possible if the agent is able to make the correct decision between these two cases. (More complex analysis is necessary for cases where the destination is reached using backtracking).

**EXPLORING THE SITUATION**

The navigating human is viewed as an agent with state and performs actions such as perceiving information from the real world and moving through the environment. As a part of the agent's state he has a mental representation of the environment and expects to be at a certain position in the environment. Russell and Norvig (1995) call an environment dynamic if it can change when the agent performs a deliberate action on it. The environment is static if it cannot change through actions of the agent. The properties dynamic and static are mapped to the representation of an environment: If the agent's mental representation of an environment changes through movement or perception of the agent, it is called a dynamic mental model. In contrast to this, an environmental representation which is not influenced by the agent's behavior, is a static model, e.g., the information on a paper map of a street network.

The dynamic mental model represents the complete knowledge of the agent about the environment, may it be spatial or non-spatial. At the beginning of the navigation process, the agent gets his initial information from reading a partially incorrect street network map, which results in an incomplete mental model. As all of the agent's navigation decisions are based on the information in the dynamic mental model, decision errors can occur. Figure 1 and 2 show a street network in the real world, and its representation in a partially incorrect paper map. Differences between these two maps are marked with circles. The closed road results in a commission error, the other two street segments are a consequence of omission errors.

![Fig. 1: Street network in the real world](image1)

![Fig. 2: Street network represented on a paper map](image2)
From the dynamic mental model, the agent extracts a planned path from the start point to the end point. It is a sequence of street segments and crossings, somewhat similar to Kuipers’ TOUR model (Kuipers 1978). The planned path is not necessarily based on spatial relations.

Through his observations during the navigation process the agent can detect differences between the environment and the real world. Figure 3 shows the agent's state at node P1. As part of the agent's state, the actual planned path is marked as directed graph with arrows, whereas the rest of the dynamic mental model is visualized as undirected graph. The agent recognizes the new street segment from P1 to U1 as a result of an omission and adds it to his dynamic mental model. This change does not affect the planned path. At node P2 (figure 4) the agent recognizes a closed street segment between P2 and P3 as a comission error. The closed street segment is part of the actual planned path, hence the observations in P2 result in a change of the dynamic mental model and the planned path.

Reaching an intersection during the navigation process, the agent compares the directions of the observed street segments and the passed distance with the information of the paper map. As the agent is able to determine his position in nodes P1 and P2 from adjacent street segments, no critical decision situation occurs. I claim that in most decision cases the agent can realize whether omission or comission is the reason for differences between the real world and its mental representation, although the agent's assumption cannot be verified until he reaches the next known intersection or landmark. An example for a critical situation occurs at node PN (figure 1), where the agent cannot recognize, which of the offered street segments is part of the planned path as they share almost the same direction.

FORMALIZATION

The behavior of an agent with state is formalized using a functional programming language which is based on algebraic specifications. Algebraic specifications include formalized strategies about how the agents deals with errors in maps, and describe the ontology of the agent's mental representation of the street network. They are used to formally prove the correctness of the implementation of the presented model. Example behavior of agents can be simulated.

CONCLUSION

We proposed in this paper formalized strategies which describe how navigation through an unknown environment is possible, despite the use of a partially incorrect map. The paper offered a classification of differences between the real world and a representation on a map. The novel approach is to describe how agents deal with errors in incomplete maps during the navigation process. Of particular importance is the ability of the agent to adapt his mental representation of the environment through perception of information from the real world. As the formalized strategies are widely independent from the type of environment, future work will aim at
mapping the found strategies to the agent's mental behavior during the navigation process through the web space.

REFERENCES


