Human Spatial Cognition: Cognitive Science joins AI and Robotics

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Cognitive science at Freiburg has a long-standing tradition of cooperating with computer science in basic and applied research. In this project report we present current research in spatial cognition as part of the SFB/TR8 Spatial Cognition (Bremen and Freiburg) in our lab in Freiburg. Our research interests cover the analysis of wayfinding strategies, external and internal spatial representations, navigation behavior, and complexity in spatial reasoning.

1 Introduction

Spatial cognition is a field that boasts an incredibly wide spectrum of theoretical approaches and practical problems. The rise of GIS (geo-information systems) and GPS-based navigation significantly ignited public interest in spatial cognition. On the theoretical side, fierce debates over linguistic relativity focused on the conceptualization and verbalization of space, and thereby caused additional interest. And, last but not least: Spatial abilities have been known for a long time as one of the few fields in which reliable gender differences have been repeatedly found. The mechanisms involved in spatial cognition are manifold, ranging from dead reckoning (in animals and robots, as well as in people) to scene recognition (salient landmarks, especially) and to the use of navigational tools like signposts, maps, or GPS and Google Earth, not forgetting verbal directions for wayfinding. Even the sensory equipment can be vastly different across species (and even more so in technical systems). Some animals make use of the earth's magnetic field (e.g., migrant birds) or the polarization of sunlight (the famous desert ants). On the technical side, robots have quite different sensors, e.g., the laser scanners we use in conjunction with Radio Frequency Identification (RFID) in one project. Small wonder that in spatial cognition, a multitude of research methods have been employed, ranging from empirical approaches (behavioral experiments on wayfinding, exploration, or search in real or virtual environments, psychometric tests of spatial abilities, observational field studies, etc.) to formal accounts (like ontologies, spatial calculi for reasoning, or complexity measures). Since most people nowadays move around in a human-made environment, our research also takes the design perspective. In sum, spatial cognition is one of the most multifaceted, methodically intricate, but also wonderfully interesting fields of research. Most of our research reported here takes place within the SFB/TR-8, initiated by Christian Freksa of Bremen, although we also report some research funded by the Volkswagen-Stiftung. The SFB was founded in 2002, building on a former DFG Special Priority Program. Speaker of the SFB is Christian Freksa (vice speaker: Bernhard Nebel); Thomas Barkowsky acts as its scientific manager. The projects (more than 15, plus a Young Researcher's Group) are organized in the three subgroups of Reasoning, Action, and Interaction. Our project SpaceGuide (comprising ArchWay and ObjectSpace) is conducted in cooperation with the Freiburg robotics group, headed by last year's Leibniz laureate Wolfram Burgard. Project MapSpace is done in close cooperation with Bremen. A further cooperation is the VW "Tandem" project of Thora Tenbrink (Bremen) and Jan M. Wiener.

2 Wayfinding Strategies

Humans solve manifold navigation tasks on a daily basis, ranging from search and exploration in novel environments to the planning of complex routes in familiar environments. In order to solve such navigational problems efficiently, humans apply a wide range of strategies. While navigation and wayfinding behavior has been studied for decades, much research focused on the investigation of spatial memory. Only few studies addressed the strategies underlying navigation behavior – i.e. the question of how spatial information from different sources is processed and integrated to solve different navigational problems. Consequently, it is still difficult to predict behavior for everyday tasks such as search, exploration, or route planning. The goal of this project is to investigate the cognitive strategies underlying such tasks. In order to reach this objective we consider navigation behavior with respect to the specific task, properties of the environment, and participants' knowledge. We utilize different methodological approaches including behavioral navigation experiments in physical and virtual environments (VE). In addition, we record eye-movements to investigate visual attention during navigation.

Navigation Behavior. With respect to navigation, physical environments allow us to investigate people's behavior in realistic situations. Virtual environments, on the other hand, enable us to manipulate the environment. In a typical experiment, participants are asked to solve different tasks while we record their trajectories, time taken to solve the task, deviations from the optimal path, distance and direction judgments as well as verbal data. In a series of studies, we identified a number of different strategies that people apply during navigation. The selection of the specific strategy depends on internal and external factors. One internal factor is familiarity: people who were familiar with the environment tended to choose hierarchical strategies, i.e. they first navigated to

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