Dagstuhl Seminar 05491

Spatial Cognition: Specialization and Integration

Executive Summary

Representing and processing spatial information about our environment is an essential requirement of everyday cognition. We can find our way in the environment and learn the layout of a building or a city. We can infer the location of objects from the location of other objects. We can reach out and manipulate objects in the environment. We can envisage spatial arrangements to find creative solutions for complex technical problems, for construction planning of buildings, and for the creation of pieces of art. Today there is a great body of evidence on how humans (and animals) reason about space, how they navigate through familiar and unknown environments without getting lost, how they act in spatial environments, how they interact in space, and how they communicate spatial information. One of the major challenges for current research is how these abilities can be accomplished by technical systems.

A variety of disciplines are involved in the spatial cognition enterprise: besides computer scientists / AI researchers who develop and analyze calculi for qualitative spatial (and temporal) reasoning there are cognitive psychologists and biologists who study human spatial navigation behavior and other spatial task performance and their neural correlates; cognitive geographers who study the use of spatial knowledge in large-scale spatial environments and appropriate representations of geographic knowledge; philosophers of the mind who study conceptions of spatial entities and their formal description; cognitive roboticians who employ spatial representations for autonomous robot navigation and develop systems that autonomously acquire knowledge about their spatial environments; computational linguists who study human spatial concepts through the analysis of natural language and formalize this knowledge to support human-robot communication; architects who design spatial environments for human use and must configure these spaces according to functional requirements and according to human conceptions of space; informaticians try to make use of all these insights to develop appropriate representation and reasoning tools and to build assistance systems that support and complement human capabilities.

This Dagstuhl Seminar brought together researchers working on different aspects of spatial cognition and from the perspectives of various disciplines to discuss the state of the art in spatial cognition. A focus of the discussions was the trade-off between specialized representations and general approaches and the integration of different approaches into a common representational framework.

Specialized representations are needed for efficient spatial reasoning; for example, incomplete knowledge about spatial situations must be represented in such a way that not all possible extensions of an under-specified situation need to be computed. Specialized representations are also found in the communication between human and artificial cognitive agents whose cognitive and perceptual capabilities differ critically. Communication serves here as an integration process between two different spatial representations. To be successful we must establish ways to

Dagstuhl Seminar Proceedings 05491
Spatial Cognition: Specialization and Integration
http://drops.dagstuhl.de/opus/volltexte/2007/982

transform between different ontologies and abstractions in such a way that we can switch the perspective on a given segment of spatial reality.

A goal of the workshop was to clarify the relation and integration of different specialized representations of a segment of a spatial environment under different perspectives. For example, depending on the class of tasks to be solved, we may need representations of (3-dimensional) objects, (2-dimensional) regions, (1-dimensional) routes, or (0-dimensional) landmarks. For certain spatial tasks, e.g. navigation, there may be substantial advantages to abstract from most of the possible perspectives in order to maintain a single consolidated view of the environment, for example in a route graph representation.

The discussion about issues of integrating spatial representations is expected to result in a better understanding of the relationships between spatial environments, cognitive agents and their actions in spatial environments, interactions among cognitive agents and between agents and their environments, and the representations and processes involved. The interdisciplinary character of the seminar opened up the possibility of discussing the various contributions offered by different research efforts and for evaluating to what extent they are alternative approaches towards the same goal or necessary complementary efforts to explain and understand spatial cognition in terms of a computational process model.

The contributions from different lines of research in spatial cognition were critically evaluated and discussed. To what extent are optimization criteria from informatics applicable to cognitive performance? Do we have to take additional dimensions into account? How useful are empirical studies of populations of cognitive agents for understanding their computational mechanisms? How much variation and variability can we expect in spatial cognitive functions and more generally: in cognitive abilities? What is the role of formal systems for spatial cognition and spatial cognition research? What is the relation between visual and linguistic forms of spatial representations? The roles of multiple conceptual and spatial reference systems, of low-level and high-level structures, of multiple spatial ontologies, and of the problem context may turn out to be of particular relevance in this discussion.

A valuable result of the Dagstuhl Seminar was the assessment of the relative importance of various virtues of spatial cognition systems – like completeness, uniformity, consistency, precision, crispness, tractability, formality, and others – and of the various methods employed for spatial cognition research – formal approaches, empirical studies, computational models, robot implementations, etc. Should we invest in efforts to integrate these different approaches in a more systematic fashion?