# Spatial Reasoning and Agents: Exploring Possibilities

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## 1 Where are we standing?

The fields of spatial reasoning and agent research have been gaining momentum in recent years. One reason behind this development has surely been the widespread adoption of mobile devices such as mobile phones, car navigation systems, PDAs, etc. Furthermore, the ever increasing power of computers in general has enabled new forms of interaction, e. g., verbal interfaces, presentation agents, or virtual reality. The rapid growth of the internet and of the information within it has sparked the demand for new technologies and interaction metaphors.

In this context, both spatial reasoning, and the agent based approach have been providing useful techniques to handle the inherent complexity of the corresponding applications and to allow for an easy access by an untrained user: natural language speech in- and output for navigation assistants, advanced search engines, or geographic information systems are just a few examples, where spatial reasoning and/or agent technology have been successfully applied. However, only limited attention has been payed to the possibilities that lay in combining ideas from both fields. But before exploring the promises and pitfalls of this combination, a more detailed examination of the two (heterogenous) disciplines is required.

The agent paradigm has been used in several very different ways [4]. On one hand, it has been promoted as the successor to object oriented programming approach in the software development and engineering field. On the other hand, it has served as an approach to simulating 'real' societies in social sciences. Furthermore, interface agents have been proposed, that act as mediators between a human user and an application (in the classical sense). Additionally, there are agents that act on behalf of a human user, and negotiate with other agents. The common denominator of this broad spectrum of applications covering technical, social, and conceptual is the abstract idea of an agent, which Wooldrige defines as a *a computer system that is situated in some environment, and that is capable of autonomous action in this environment in order to meet its design objectives* [5].

The field of spatial reasoning is very diverse as well (cf. [3]). There is research led by the goal to develop a mathematical sound foundation of space and reasoning about it, while others are aiming at addressing very practical issues in real world applications. A large body of calculi exists that encompasses approaches using very different AI techniques ranging from neural networks and fuzzy logic to topology. Models are designed that are inspired by psychology and try to mimic human reasoning, but there are also those used in engineering (e. g. robotics) and those that try to address philosophical and mathematical questions. The link between all these is the drive to understand the very fundamental concept of space and to develop appropriate reasoning mechanisms.

## 2 Where can we go?

Considering the diversity of research in spatial reasoning and agents, it stands to expect several points, where an interaction is possible. The first scenario that comes to mind is probably that of *mobile agents:* software entities that roam a network in order to fulfill a specific job, probably interacting with other agents (or software systems) in the process. The major factor of their situatedness is the location, where they reside at certain point of time. Many relevant factors are determined by this, e. g. cost and availability of process-

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ing power, bandwidth, or services. Consequently, reasoning about space (and time) is a prerequisite if an agent is to make informed decisions and to act autonomously.

Because of the general importance of spatial information in this context, it might be a good idea to investigate how to integrate location awareness and basic spatial reasoning abilities into the underlying infrastructure. Several alternatives exist for this task such as creating centralized 'servers' for spatial reasoning and location detection, embedding those abilities in every agent, or introducing a new meta level. Additionally, individual agents should be able to communicate about spatial issues, which calls for the development of an appropriate language.

But agents do not only talk about and move in 'real' (physical) space: they do so also in their 'own' space, i. e. the space defined by the computers and networks they are living on. An investigation of the intrinsic characteristics and possible reasoning frameworks of this space might yield valuable results not only for the reasoning abilities of agents but also in a more general way as the examination of a very different space might open new possibilities in the realm of physical space. Furthermore, the relation between those two spaces as well as the transition between them seems well worth a closer investigation (e. g. as more and more people are moving – *surfing* – through this space.)

An additional application domain for both agent and spatial reasoning techniques may be in the field of interface agents [1]: These agents have to interact with human users (employing various media and modi such as pointing, natural language, etc.) in an easily accessible way, which may very well include spatial topics (e. g. 'What's that button next to the picture?'). On a broader scale, they have to integrate and reason about issues from two different spaces (e. g. screen space and 'real' space) as well. Furthermore, the use of interface agents may be beneficial in the context of empirical evaluation, for example experiments, where the comprehensibility of navigational instructions is investigated.

Finally, using a multi-agent system to realize a spatial reasoning system can be beneficial in several ways [2]. On one hand, basic processes – such as selecting a frame of reference or a reference object – can be mapped directly onto agents, whereby the interaction between those processes can be made explicit. On the other hand, the multi-agent approach facilitates the modification and extension of a spatial reasoning system by encapsulating functionality and explicit interaction. This applies particularly to real-world applications, where many (non-spatial) factors such as user models, computational resources, etc. need to be taken into account.

# 3 The bottom line

This paper tried a short overview over possible connections between the fields of agent research and spatial reasoning. The examples provided on this topic were by no means complete but illustrate that there are indeed interesting starting points for further research. While it seems that (mobile) agents to indeed require some sort of spatial reasoning in order behave adaptively in a given situation, the spatial reasoning field can also gain from applying agent-based techniques.

# References


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