Qualitative Semantic Representations

of Spatial Knowledge in Dialogue Systems

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This paper reports on our work in the Transregional Collaborative Research Center *Spatial Cognition* (SFB/TR8). The aim of this research is to achieve a natural and effective dialogic interaction between a human and an intelligent robot on spatial navigation tasks. Therefore, we have introduced a conceptual level representation of human spatial knowledge on top of the robot's quantitative representation. Specifically, we have developed a kind of graph, i.e., the Conceptual Route Graph, which combines the concepts of route graphs and qualitative spatial orientation calculi. After integrating the Conceptual Route Graph into a dialogue system, it shows several advantages. First, the Conceptual Route Graph can serve as the semantic framework for communication between the different components of a dialogue system. Second, spatial reasoning can be used to detect orientation mismatches in human route instructions, thus clarification subdialogues can be generated automatically. Moreover, the Conceptual Route Graph provides a formal interface to a robot for carrying out spatial navigation tasks.

1 Introduction

In the last 30 years a number of spoken dialogue systems have been developed to allow humans to interact with technical systems using natural language. Typically, they have been used in information query systems, in planning systems, or in intelligent robotic systems, where specialised components are used to supply domain specific information and knowledge. Since almost all dialogue systems use certain domain knowledge to interact with users, the representation of such knowledge thus decides not only the content, but the way the system interacts with users as well. Thus, the naturalness and the efficiency of a dialogue system depends largely on the representation of domain knowledge.

Our application focuses on dialogic communication between a user and an intelligent service robot (e.g., an intelligent wheelchair or an assistant robot) on navigation tasks. For robot navigation tasks there exist a number of representations of spatial information, varied from quantitative to qualitative. Although most robots use quantitative information for their nagivation, qualitative representations are more appropriate for representing human knowledge and for reasoning with and about it. One concrete application scenario of our project is the dialogic interaction between a user and the intelligent wheelchair *Rolland* [7], in which the user sits in the wheelchair and instructs Rolland to move around in a university building. According to our empirical studies (e.g., [10]) route descriptions of users are generally schematized and consist of critical elements like landmarks, e.g., "room", "door" and "window", and routes, e.g., "follow the corridor until the next junction". Furthermore, reorientations such as "turn left" and orientation relations such as "pass the lifts on the right" are widely used.

On the other hand, if person A describes a route to person B, subdialogues are often initiated by either A or B to clarify questions or uncertain aspects, because their spatial knowledge may not always match with each other. Similarly, knowledge mismatches can occur between a human user and a robot. Typical situations are, for instance, when the user refers to some spatial objects that are unknown to the robot for communication, or when a route description is so coarse that the robot does not know how to carry it out. To enable a natural and efficient dialogic interaction between a user and Rolland, we have developed a specific qualitative spatial representation, i.e., the *Conceptual Route Graph*, which serves as the interface for communication with users, supports spatial reasoning to detect mismatches in users' route descriptions, and can be mapped to the robot's quantitative spatial representation for carrying out nagivation tasks.

2 A Semantic Model for Dialogic Interaction

Route Graphs have been introduced as a general concept for navigation by various agents in a variety of scenarios [13]. They are a special class of graphs. A *node* of a Route Graph, called a *place*, has a particular position and has its own "reference system". An *edge* of a Route Graph, or *route segment*, directed from a source place to a target place, has three additional attributes: an *entry*, a *course* and an *exit*. An entry/exit at the cognitive level may contain qualitative orientation information (e.g., to the left/right), the course is then the path between two reorientations. Finally, a *route* is a concatenation of a sequence of connected route segments from one place to another.

Freksa puts forward the *Double-Cross Calculus* for qualitative spatial representation and reasoning using orientation information [4]. In this calculus, the concept *orientation grid* is introduced to represent qualitative orientation information. The grid is aligned to the orientation determined by two points in 2-dimensional space, the start point and the end