Chapter 17
Cognitively Ergonomic Route Directions

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ABSTRACT

This contribution provides an overview of elements of cognitively ergonomic route directions. Cognitive ergonomics, in general, seeks to identify characteristics of cognitive information processing and to formalize these characteristics such that they can be used to improve information systems. For route directions, an increasing number of behavioral studies have, for example, pointed to the following characteristics: the use of landmarks, changing levels of granularity, the qualitative description of spatial relations. The authors detail these aspects and additionally introduce formal approaches that incorporate them to automatically provide route directions that adhere to principles of cognitive ergonomics.

COGNITIVE ASPECTS OF ROUTE DIRECTIONS

Route directions fascinate researchers in several fields. Since the 70s linguists and cognitive scientists have used verbal route directions as a window to cognition to learn about cognitive processes that reflect structuring principles of environmental knowledge (e.g., Klein, 1978). Over the last decade, the number of publications on various aspects of route directions has increased. Next to the general aspects of how to provide route directions and how to identify principles that allow us to define what makes route directions cognitively ergonomic, technical aspects of navigation support systems have become an additional focus. The question required from the latter perspective is part of a broader approach that aims to formally characterize the meaning (semantics) of spatial relations. In other words, if we want to bridge the gap between information systems and behavioral

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analysis we have to answer how we perform the transition from data to knowledge.

Several key elements can be identified based on psychological and linguistic literature on route directions that are pertinent for cognitively ergonomic route directions (Denis, 1997; Lovelace, Hegarty, & Montello, 1999; Tversky & Lee, 1999). These comprise the conceptualization of directions at decision points, the spatial chunking of route direction elements to obtain hierarchies and to change the level of granularity, the role of landmarks, the communication in different modalities, the traveling in different modes, and aspects of personalization (see Table 1). Most research on routes and route directions deals with navigation in urban structures such as street networks. The results discussed in this article focus on this domain.

APPROACHES TO REPRESENTING ROUTE KNOWLEDGE

Behavioral studies have substantiated key elements of cognitively ergonomic route directions. To implement these aspects in information systems detailed formal characterizations of route knowledge are required. The approaches discussed below are a representative vocabulary that allows for the characterization of mental conceptualization processes reflecting the results from behavioral studies (see Table 1). In this sense we can refer to them as *Ontologies of Route Knowledge* (Chandrasekaran, Josephson, & Benjamins, 1999; Gruber, 1993). In Guarino's terminology these approaches would most likely be called *domain ontologies* (Guarino, 1998).

Table 1. Cognitive ergonomics of route directions

• are qualitative, not quantitative,
• allow for different levels of granularity and organize spatial knowledge hierarchically,
• reflect cognitive conceptualizations of directions at decision points,
• chunk route direction elements into larger units to reduce cognitive load,
• use landmarks to:
° disambiguate spatial situations,
° anchor turning actions,
° and to confirm that the right actions have been taken,
• present information in multimodal communication systems allowing for an interplay of language and graphics, but respecting for the underlying conceptual structure,
• allow for an adaptation to the user's familiarity with an environment, as well as personal styles and different languages.

One of the earliest approaches is the *TOUR* model by Kuipers (Kuipers, 1978) that later developed into the *Spatial Semantic Hierarchy* (SSH) (Kuipers, 2000). Kuipers and his collaborators developed this approach to add the qualitativeness that can be found in the organization of a cognitive agent's spatial knowledge to approaches in robotics. The latter classically relied more on quantitative spatial descriptions. The SSH allows for modeling cognitive representations of space as well as for building a framework for robot navigation, i.e. qualitative and quantitative aspects are combined. The SSH especially reflects the aspect of hierarchical organization of spatial knowledge by providing different levels of information representation: the sensory, control, causal, topological, and metrical level. Ontological characterizations are developed for each level to match human cognitive processes.

The *Route Graph* model (Werner, Krieg-Brückner, & Herrmann, 2000) describes key elements for route based navigation. Similar to the SSH, it allows representing knowledge on different levels of granularity. However, it is much more abstract and does not provide any processes for acquiring this knowledge. It is intended to provide a formalism expressing key notions of route knowledge independent of a particular implementation, agent, or domain. Its focus is on a sound formal specification of basic elements and operations, like the transition from route knowledge to survey knowledge by merging routes into a graph-like structure.