From Perception to Decision Making by Means of Qualitative Abstraction

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Abstract

Spatial Cognition is an interdisciplinary research area that - among other things - serves as a testbed for numerous approaches to knowledge representation and for results from artificial intelligence, cognitive psychology, soft computing, geography, biological cybernetics, and robotics. Spatial and temporal granularity are of particular relevance in spatial cognition for at least two different reasons: (1) the granulation of information determines the ease or difficulty of matching representational descriptions with real world situations, and (2) the ability to transform representations between different spatial and temporal granularity levels determines the usability (flexibility and adaptivity) of representations for identification, reasoning, and communication purposes. The contribution presents current knowledge representation research carried out in the framework of the German Spatial Cognition Priority Program. Cognitive agents (in particular people and robots) must represent certain knowledge about their spatial environment to identify objects and to find their way. We distinguish general world knowledge (in particular about general structures of space and time) and specific situation knowledge. The two types of knowledge have rather different properties that necessitate different representational structures: while the general world knowledge enables certain inferences that always hold in spatio-temporal environments, the specific situation knowledge is incomplete, imprecise, fuzzy, and possibly conflicting. This requires special forms of representation and inference. Cognitive agents interact with their environment and with other agents by means of their perceptual and communication abilities. Motivated by results from artificial intelligence and cognitive psychology, we explore *qualitative* spatial representations for perception and communication, their potential, and their limits. Different reference systems and levels of representation for spatial knowledge will be discussed in the context of the type of task to be performed. Different types of contexts, specifically *linguistic context*, *situation context*, and *task context* that necessitate granularity adaptation are introduced. Particular attention is given to the distinction between core meaning and boundary meaning of spatial and temporal conceptual granules and how they affect the selection of granularity levels. We discuss ways of conveying the appropriate level of granularity in the communication of spatio-temporal representations. Relationships between fuzzy set representations and fuzzy reasoning on one hand and qualitative representations and qualitative reasoning on the other hand are drawn. Qualitative representations are treated as abstractions of fuzzy quantitative representations. Correspondences between the relations between fuzzy sets and the relations between qualitative representations are established. The notion of Conceptual Neighborhood (CN) of relations and its use for concept matching and granularity transformation is discussed. Unlike in arbitrary abstract domains, knowledge in concrete physical domains is naturally structured into CNs through the organization of our perception systems. This allows for natural hierarchical organization and conceptualization of different knowledge levels and the use of abstraction to efficiently communicate incomplete, imprecise, conflicting, and fuzzy knowledge. Also, computational complexity in neighborhood-based perceptual reasoning is reduced as compared to general abstract reasoning. CNs in conjunction with incomplete knowledge give rise to fuzzy knowledge. It is proposed that conceptual fuzzy knowledge may be induced - to a large extent - by incomplete specification of (spatial, temporal or other) ordering relations in conjunction with general spatial world knowledge. This could account for the mental existence of fuzzy concepts without the need for numerical fuzzy membership functions. Examples from spatial reasoning and linguistic descriptions will be presented.

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References

Freksa, C. 1991. Conceptual neighborhood and its role in temporal and spatial reasoning. In Singh, M., Travé-Massuyès, L., eds., *Decision Support Systems and Qualitative Reasoning*, 181–187, North-Holland.

Freksa, C. 1992. Temporal reasoning based on semi-intervals. *Artificial Intelligence*, 54:199–227.

Freksa, C. 1994. Fuzzy systems in AI. In Kruse, R., Gebhardt, J., Palm, R., eds., *Fuzzy systems in computer science*, Series: Artificial Intelligence, Braunschweig/Wiesbaden: Vieweg 1994.

Freksa, C. 1994. Fuzzy logic: an interface between logic and human reasoning. *IEEE Expert*, 9(4):20–21.

Freksa, C., Barkowsky, T. 1996. On the relation between spatial concepts and geographic objects. In Burrough, P., Frank, A. eds, *Geographic objects with indeterminate boundaries*, 109–121, Taylor and Francis, London.

Freksa, C. 1999. Spatial aspects of task-specific wayfinding maps. In Gero, J.S., Tversky, B., eds, *Visual and Spatial Reasoning in Design: A representation-theoretic perspective*, 15–32, Key Centre of Design Computing and Cognition, University of Sydney.

Zadeh, L.A. 1979. Fuzzy sets and information granularity. In M. Gupta, R. Ragade and R. Yager, eds., *Advances in Fuzzy Set Theory and Applications*, 3–18, North-Holland.

Zadeh, L.A. 1997. Toward a Theory of Fuzzy Information Granulation and its Centrality in Human Reasoning and Fuzzy Logic.

Zadeh, L.A. 1999. From Computing with Numbers to Computing with Words – From Manipulation of Measurements to Manipulation of Perceptions. *IEEE Transactions on Circuits and Systems*, 45:105–119.