Casimir: Comprehensive Computational Modeling of Mental Spatial Knowledge Processing

Holger Schultheis, Sven Bertel, Thomas Barkowsky, Christian Freksa, Inessa Seifert
SFB/TR 8 Spatial Cognition, Universität Bremen, Germany
{schulth, bertel, barkowsky, freksa, seifert}@sfbtr8.uni-bremen.de

The ability to reason about space and spatial relations is crucial for a wide range of human activities. Due to this importance, spatial reasoning has been the subject of much psychological research over the last decades. One main finding is that spatial cognition processes employ special types of mental representations, namely *spatial mental models* and *mental images*. These representations are built from knowledge in long-term memory as well as from information that is available from the environment via perception. Furthermore, mental models/images have been found to possess an array of analogical properties, i.e., certain relations in the representing mental world are analogous to relations in the represented external world.

A comprehensive computational model of mental spatial knowledge processing that employs analogical representations as observed in humans does not yet exist. To close this gap, we currently develop *Casimir* in the framework of project R1-[ImageSpace] of the SFB/TR 8 Spatial Cognition. Casimir comprises various modules, for instance, regarding long-term and working memories, or externalization. It is intended to serve psychological studies and the study of artificial cognitive systems equally well. The modules realize distinct cognitive systems involved in spatial reasoning; they communicate via a common blackboard architecture, and consistent spatial cognition emerges from their interplay.

In long-term memory, the persistent (spatial) knowledge of the model is stored as a graph similar to a semantic network. Every node in the graph represents some information which is linked to associated nodes (i.e., information). Knowledge retrieval is realized by spreading activation as every node has some activation which declines over time, partly spreads to nodes linked to it, and determines whether this node is retrieved. Nodes with activation above a certain threshold enter working memory. A retrieval process results in some subgraph, termed *spatial knowledge fragment.* In working memory, this fragment is transformed into an analogical format, such as a spatial mental model or mental image. The actual type of representation depends on the spatial task to be solved. In accord with basic psychological research we assume that the construction of mental images is cognitively more costly than the construction of mental models. Consequently, mental images are only created if the current task demands additional visual detail (e.g., form information) that only mental images but not mental models can provide. Whereas mental models and knowledge fragments reside in working memory proper (i.e., are held in non-specific representation formats), mental images due to their similarity to visual perception are held in a dedicated spatio-analogical substructure of working memory.

Due to the limited capacity of human working memory, humans frequently externalize spatial information into diagrams to reduce memory load. The externalization module realizes this aspect by mapping analogical working memory representations onto diagrams and vice versa.