Chapter 104
Integrated Ontologies for Spatial Scene Descriptions

Sotirios Batsakis
Technical University of Crete, Greece

Euripides G.M. Petrakis
Technical University of Crete, Greece

ABSTRACT

Scene descriptions are typically expressed in natural language texts and are integrated within Web pages, books, newspapers, and other means of content dissemination. The capabilities of such means can be enhanced to support automated content processing and communication between people or machines by allowing the scene contents to be extracted and expressed in ontologies, a formal syntax rich in semantics interpretable by both people and machines. Ontologies enable more effective querying, reasoning, and general use of content and allow for standardizing the quality and delivery of information across communicating information sources. Ontologies are defined using the well-established standards of the Semantic Web for expressing scene descriptions in application fields such as Geographic Information Systems, medicine, and the World Wide Web (WWW). Ontologies are not only suitable for describing static scenes with static objects (e.g., in photographs) but also enable representation of dynamic events with objects and properties changing in time (e.g., moving objects in a video). Representation of both static and dynamic scenes by ontologies, as well as querying and reasoning over static and dynamic ontologies are important issues for further research. These are exactly the problems this chapter is dealing with.

BACKGROUND

Formal spatial, temporal and spatio-temporal representations have been studied extensively in the Database (Gutting, 1994) and recently, in the Semantic Web literature (Arpinal, Sheth, Ramakrishnan, Usery, Azami, & Kwan, 2006). The related work is surveyed in the following sections focusing on work inspired by ontologies and the Semantic Web.

Spatial entities (e.g., objects, regions) in classic database systems are typically represented based upon a reference coordinate system using points,

lines (polygonal lines) or Minimum Bounding Rectangles (MBRs) enclosing objects or regions and their relationships (Petrakis, 2002). Relations among spatial entities can be topological, orientation or distance relations. In turn, spatial relations can be qualitative (i.e. described using lexical terms) or quantitative (i.e. described using numerical values).

Many spatial ontologies for the semantic Web are known to exist, the majority of them being defined based upon a reference coordinate system and qualitative topological and direction relations (e.g., RCC-8 relations). Reasoning rules for various relation sets have been proposed as well (Cohn & Hazarika, 2001; Renz & Nebel, 2007). Recent approaches use specialized representation languages such as GML or general-purpose Semantic Web languages such as OWL (Abdelmoty, Smart, Jones, Fu, & Finch, 2005). The SPIRIT spatial search system (Jones, Abdelmoty, Finch, Fu, & Vaid, 2004) combines an ontology with indexing mechanisms. In Katz and Grau (2005) RCC-8 topological relations are represented using OWL-DL. In the work by Hazarika (Hazarika & Roy, 2008), information retrieval is enhanced using RCC-5 topological relations among objects. Along the same lines, Grutter (Grutter & Bauer-Messmer, 2007) suggest extracting RCC-8 relations using a separate coordinate system which is not part of the ontology. SWETO-GS (Arpinal, Sheth, Ramakrishnan, Usery, Azami, & Kwan, 2006) is a geospatial ontology enhanced with Spatiotemporal Thematic Proximity (STTP) reasoning and interactive visualization capabilities. Liu and Hao (2005), combine topological and direction relations. A combination of RCC-5 with cardinal direction relations is proposed by Chen, Liu, Zhang, and Xie (2009). An almost orthogonal (to representation) issue is speed of search. Petrakis (2002a) and Dellis and Paliouras (2007) emphasize on the indexing of spatial information using R-trees for improving the speed of search of nearest-neighbor and range queries.

The representation of spatio-temporal knowledge has also motivated research within the Semantic Web community. Related work includes Chen, Perich, Finin, and Joshi (2004) where the temporal ontology is enhanced by Allen's temporal relations. In this work, the RCC-8 relations form the core of the spatial representation. Worboys and Hornby (2004) suggest a model for representing objects and events combining spatial and temporal information. Wang et al. (2004) introduce a spatiotemporal representation in OWL supporting logic-based reasoning by limiting spatial relations to inclusion relations. In the work by Sheth et al. (Sheth, Arpinar, Perry, & Hakimpour, 2009), the SPIRIT spatial query engine (Jones, Abdelmoty, Finch, Fu, & Vaid, 2004) is combined with temporal RDF (Gutierrez, Hurtado, & Vaisman, 2007) in an integrated spatiotemporal representation mechanism. Finally, the MOQL query language (Li, Ozsu, Szafron, & Oria, 1997) has been proposed for querying spatio-temporal information in databases.

INTEGRATED SCENE DESCRIPTION ONTOLOGIES

Issues relating to spatial and temporal aspects of scene descriptions are discussed next. Particular emphasis in given to ontology models integrating both kinds of knowledge.

Temporal Representation

Dealing with information that changes over time is a critical problem in Knowledge Representation (KR). Representation languages such as OWL (description logics), frame-based and object-oriented languages (F-logic) are all based on binary relations (e.g., being the employee of a company) without any temporal information. Adding the time dimension to this information would lead to ternary relations which are not supported by OWL (Hayes & Welty, 2006). However,

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