Chapter 10
Spatiotemporal Query Algebra Based on Native XML

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ABSTRACT

A formal algebra is essential for applying standard database-style query optimization to XML queries. We propose a spatiotemporal XML data model and develop such an algebra based on Native XML, for manipulating spatiotemporal XML data. After studying NXD spatiotemporal database and query framework, formal representation of spatiotemporal query algebra is investigated, containing logical structure of spatiotemporal database, data type system, and querying operations. It shows that the model and algebra lay a firm foundation for managing spatiotemporal XML data.

INTRODUCTION

Since a considerable amount of spatiotemporal data emerges in spatiotemporal applications (Benferhat, Ben-Naim, Papini, 2010; Mehrotra, Sharma, 2009), the requirement of managing spatiotemporal data has attracted much attention both from academia and industry (Abiteboul, Quass, McHugh, et al., 1997a; Koyuncu, Yazici, 2003; Sözer, Yazici, Oğuztüzün, et al., 2008). As the next generation language of the Internet, XML is playing an increasingly important role. In addition, XML is gradually gaining acceptance as medium for integrating and exchanging data from different sources. In that case, the advent of XML seems to provide an opportunity for managing spatiotemporal data (Senellart, Abiteboul, 2007). Unfortunately, current efforts have mainly focused on the problems of modeling general data in XML (Ma, Liu, Yan, 2010) and modeling spatiotemporal data in XML (Huang, Yi, and Chan, 2004), and relative little work has been carried out in representing spatiotemporal data in XML.

As evidenced by the successful relational technology (Prade, Testemale, 1984), a formal algebra is absolutely essential for applying standard database-style query optimization to XML queries. Due to its significance, researches on this issue have been extensively proposed (Beeri, Tzaban, 1999; Buratti,

Montesi, 2006; Jagadish, Laks, Lakshmanan, et al., 2001; Magnani, Montesi, 2005). Beeri and Tzaban (Beeri, Tzaban, 1999) propose an algebra that can handle multi-valued attributes, has support for detection and handling of run-time errors, and most of its operations preserve order. Buratti and Montesi (Buratti, Montesi, 2006) address the import issue of establishing a formal background for the management of semi-structured data. They define a data model and propose an algebra which is able to represent most of XQuery expressions. Jagadish et al. (Jagadish, Laks, Lakshmanan, et al., 2001) present TAX, a Tree Algebra for XML, which extends relational algebra by considering collections of ordered labeled trees instead of relations as the basic unit of manipulation. Magnani and Montesi (Magnani, Montesi, 2005) present a model for the management of relational, XML, and mixed data. Their query algebra can represent queries not expressible by other proposals and by the current implementation of TAX. Moreover, they show that relational-like logical query rewriting can be extended to their algebraic expressions. However, they do not provide a formal algebra that can support the spatiotemporal XML queries. As a result, we need a valid formal algebra for the XML queries that can serve as a well understood and order-sensitive intermediate representation.

Accordingly, the motivation of the chapter is trying to build a spatiotemporal XML model for algebraic operations. The rest of the chapter is organized as follows. In Section 2, we introduce basic knowledge. A spatiotemporal data model is proposed in Section 3. After studying NXD spatiotemporal database and query framework in Section 4, formal representation of spatiotemporal query algebra based on Native XML is investigated in Section 5. Section 6 presents the related work, and Section 7 concludes the chapter.

SEMANTICS OF SPATIOTEMPORAL DATA

Spatiotemporal data have a set of characteristics that make them distinctly different from the more familiar lists and tables of alphanumeric data used in traditional business applications. In the case of spatiotemporal data, we measure it by five dimensions according to characteristics of spatiotemporal data (Bai, Yan, Ma, 2013). The dimensions of spatiotemporal data contain OID, ATTR, P, M, and T.

OID: It provides a means to refer to different spatiotemporal data, and describes changing history of the spatiotemporal data relating both its ancestor and descendant. The ancestor indicates where the object comes from and how it comes into being, and the descendant shows what the object finally changes into and why the change occurs. Moreover, changing types of spatiotemporal data typically include four types: create, split, merge, and eliminate.

1. **ATTR:** It is used to describe static properties of spatiotemporal data (e.g., land owner's name, area, typhoon intensity, air pressure, etc.). There may be one or more attributes in a spatiotemporal data. This dimension heavily depends on the application domain.
2. **P:** It describes position of the spatiotemporal data, which contains point, line, and region. From P, we can obtain: (a) position of spatiotemporal data; (b) relationship between two spatiotemporal data (topological, direction, and distance relationship).
3. **M:** It describes motion, which contains direction of movement and value of movement. The direction of movement denotes where the spatiotemporal data moves. The value of movement denotes the velocity of a spatiotemporal data.

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