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Consistencies of fuzzy spatiotemporal data in XML documents

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Abstract

Researches on spatiotemporal data based on XML has received increasing attention due to that XML has a lot of advantages such as extensibility and flexibility. Although XML has been employed to model and handle spatiotemporal data, relatively little work has been carried out to further investigate the consistencies of spatiotemporal data, especially fuzzy spatiotemporal data in XML documents. In this paper, we first propose a fuzzy spatiotemporal data model, and then present the structure of fuzzy spatiotemporal data in XML document. After studying consistency conditions for fuzzy spatiotemporal data in XML documents, we demonstrate how updating operations, inserting operations, and deleting operations effect on consistencies of fuzzy spatiotemporal data in XML documents. Furthermore, we propose algorithms for fixing these inconsistencies. After investigating several characteristics of the three primitive changing operations on the fuzzy spatiotemporal data model, the performances of inconsistency fixing time are evaluated.

Keywords: Fuzzy spatiotemporal data; XML document; Consistency

1. Introduction

Spatiotemporal data has received much attention since (intelligent) applications [39] increased situations such as land management [14] and environment management [34] have shown urgent requirements on the management of spatiotemporal information. In the meantime, fuzziness is an inherent feature of most spatiotemporal applications, which are required to deal with both spatiotemporal and fuzzy phenomena. Due to its significance to spatiotemporal data, researches on combination of fuzziness and spatiotemporal data have been extensively proposed [40,44,45,47]. On the other hand, since XML has been the de-facto standard of information representation and exchange over the Web [25,26], it is playing an increasingly important role as a medium for integrating and exchanging data from different sources. Furthermore, XML has great extensibility explained by adding time dimension [42] and coupling with

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fuzziness by defining new tags [30]. To this end, the advent of XML seems to provide an opportunity for dealing with fuzzy spatiotemporal data. Unfortunately, although XML has been employed to model and handle spatiotemporal data [14,18,21,23,27,41], relatively little work has been carried out to further investigate the consistencies of spatiotemporal data in XML documents, especially consistencies of fuzzy spatiotemporal data in XML documents.

Researches on fuzzy spatiotemporal data in XML documents experience six stages: spatiotemporal data in traditional database, spatial data in XML documents, temporal data in XML documents, fuzzy temporal data in XML documents, spatiotemporal data in XML documents, and fuzzy data in XML documents. For the first stage, modeling and managing spatiotemporal data [10,38], in particular fuzzy spatiotemporal data [40,46], is a topic of great importance in traditional database. For the second stage, current efforts have mainly focused on the problems of representing and managing spatial data in XML documents associated with XML elements and attributes [32,36,48]. However, relatively little work has been focused on extending spatial data in XML documents to fuzzy spatial data in XML documents. For the third stage, approaches to represent and capture histories of XML documents have received attention [1,3,19]. What's more, the implementing approach [37] and the indexing approach [35] are also current studies. For the fourth stage, which is based on the prior one, temporal data in XML documents have been extended to the fuzzy field [24,55]. For the fifth stage, there are efforts to combine spatial and temporal properties into one framework, and analyze spatiotemporal data in XML documents [18,23,27]. For the last stage, in order to manage and handle fuzzy data in XML, a new fuzzy database [43] and a formal syntax for important fuzzy data types used to store fuzzy information [53,54] are proposed. To sum up, the above researches of the six stages do not cover modeling fuzzy spatiotemporal data in XML documents and further studies of consistencies of fuzzy spatiotemporal data in XML documents. Nevertheless, their efforts play a fundamental role in investigating consistencies of fuzzy spatiotemporal data in XML documents, and studies on it can be carried out on the basis of their efforts.

Concerning on verifying consistencies and finding conflicting nodes in XML documents, a considerable amount of studies have been proposed [17,51,52,59], since XML documents are subject to continuous changing operations so that it may violate their integrity constraints and cause inconsistencies. In [17], Fan et al. proposed a simple and expressive model (UCM) of integrity constraints for XML, and studied the problem of consistency of constraints. The work of Wu et al. [59] proposed a verifier for XML documents, which scans the original XML documents once and can deal with different types of constraints. Tan et al. studied the inconsistency problem in the field of XML and provided a repair framework for XML documents with three basic update operations in [51]. Furthermore, they considered how to get the consistent data from an inconsistent XML document, and provided a repair framework for inconsistent XML documents with three basic update operations in [52]. In addition to studies on consistencies in XML documents, there are also spatiotemporal efforts (spatial actually) on consistencies [15,16,49]. In [16], Duckham et al. explored the development and the use of a qualitative reasoning system for describing consistency between different geographic data sets. The work of Suter [49] focused on the structure and spatial consistency of network-based space layouts. Approaches for evaluating structural and topological consistency among multiple representations of complex regions with broad boundaries based on map generalization operators were presented in [15]. Unfortunately, although consistencies of data in XML documents and consistencies of spatial data have been extensively proposed, relatively little work has been carried out in extending it to consistencies of fuzzy spatiotemporal data in XML documents. However, their efforts provide basic methods of investigating consistencies of fuzzy spatiotemporal data in XML documents for references.

To the best of our knowledge, there are no reports on consistencies of fuzzy spatiotemporal data in XML documents. In this paper, we study consistencies of fuzzy spatiotemporal data in XML documents and propose algorithms for fixing inconsistencies of fuzzy spatiotemporal data in XML documents caused by changing operations. The paper makes the following main contributions:

- A fuzzy spatiotemporal data model is proposed according to dimensions of geographic entities introduced in [47]. Furthermore, the structure of fuzzy spatiotemporal data in XML documents is presented. Then, consistency conditions for fuzzy spatiotemporal data in XML documents are studied so that future consistency studies can be continued.
- On the basis of the proposed fuzzy spatiotemporal data model and its structure in XML documents, consistency conditions for fuzzy spatiotemporal XML documents are studied.
- Furthermore, we demonstrate how the three primitive changing operations [52], namely *update*, *insert*, and *delete*, effect on consistencies in fuzzy spatiotemporal XML documents. What's more, algorithms for fixing inconsisten-

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