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Representation, reasoning and similar matching for detailed topological relations with DTString

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ABSTRACT

Most current topological relation models cannot capture the details of spatial relations; thus, complex spatial relations cannot be distinguished using these models. Under certain circumstances, only detailed topological relations can satisfy users' demand. To resolve this problem, this study proposes a new topological relation model named DTString that describes the full details of the topological relation between two regions by a boundary string. DTString is proved to be a JEPD (Jointly Exhaustive and Pairwise Disjoint) and atomic relation model. Thus, undividable topological relations can be captured with it, and this characterization makes it suitable for modeling complex topological relations. Furthermore, DTString-based reasoning algorithms are investigated; they are more efficient than algorithms based on geometric calculations because they use purely string-based calculations. Finally, methods for retrieving similar geometrical structures are investigated by combining topological relations with shape and distribution features. Experiment results show that DTString outperforms existing topological models. DTString and the proposed similarity measurements can be potentially applied to content-based image retrieval, spatial query and CAD, etc.

1. Introduction

Topological relations are pervasive and form an important part of the information process. Topological relationships have been widely studied by the geographic information systems (GIS) and spatial database communities for more than two decades, and topological predictions are widely applied in spatial query and spatial analysis. Topological relation of objects is regarded as a key element in image understanding and content-based image retrieval (CBIR) [4,6,17,21]. Tackling topological relations is also necessary for CAD, ontologies, Semantic Web, etc.

The current state-of-the-art topological relation models can be classified as either coarse-relation or detailed-relation models. Most of the existing topological relation models are coarse-relation models, including the classical topological model RCC-8 [18]. The number of basic relations in a coarse-relation model is very limited, and detailed topological information is lost. Little existing work is capable of capturing detailed (or refined) topological relations.

For example, the three patterns in Fig. 1 are PO (Partly Overlap) relations under the RCC-8 relation model [18], but not further distinguished. With a detailed topological relation model, their differences can be captured. An important concept

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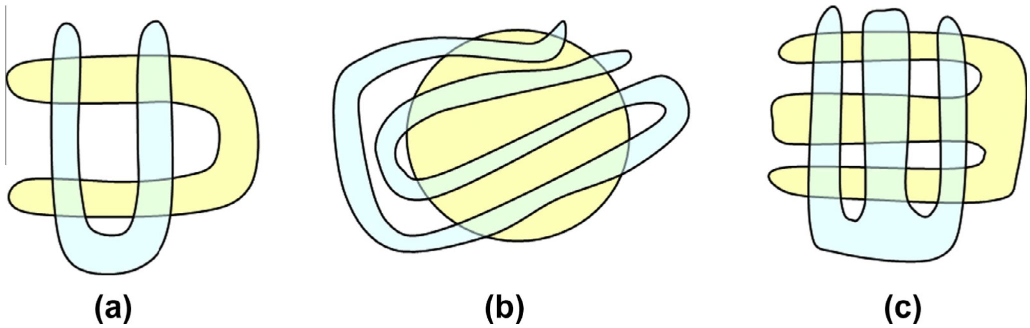

Fig. 1. Atomic topological relations.

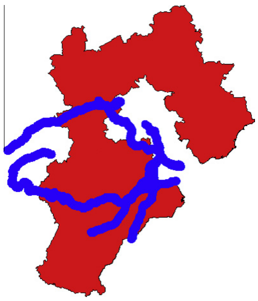

Fig. 2. Detailed topological relation in GIS.

introduced in detailed topological relation models is the atomic relation [13]. An intuitive explanation for the atomic relation is that any two patterns (each pattern includes two regions) in the same plane described by the same atomic relation can be continuously transformed into each other. A formal definition of *atomic relation* can be found in [13]. In Fig. 1, pattern (a) and pattern (b) can continuously transform into each other, while pattern (c) cannot continuously transform into (a) or (b). Since they are all under the same RCC-8 relation (PO), RCC-8 is not atomic. Atomic relations can be considered undividable relations from the topological viewpoint.

Under certain circumstances, only detailed topological relations will satisfy users' demand. Spatial analysis in GIS is one example. The red[1] region in Fig. 2 is Hebei Province in China, and the blue area is the buffer of major rivers crossing Hebei Province; the detailed topological relation between them is an important characterization in spatial analysis for agriculture, transportation, and other applications.

Medical image processing is another field requiring detailed topological relations, because even tiny details of topological relations in medical images should not be ignored. For instance, there are complex relations between parotid cancer tissues and facial nerves that must be inspected very carefully before tumor removal surgery to avoid damage to the facial nerves. There is also demand for detailed topological relations in CAD, spatial planning, context-based image retrieval, and other areas.

Research works dedicated to detailed topological relations are rare. Previous works can be improved in some aspects, such as object's domains, encoding schemas, reasoning abilities, and similarity matching algorithms. With these motivations, we propose a string-based detailed topological relation model, provide some related reasoning algorithms, and apply the model to geometrical structure retrieval.

This paper is organized as follows: In Section 2 we introduce some related works. In Section 3, the DTString representation is introduced. DTString is proved to be an atomic topological relation model in Section 4. Some reasoning algorithms for DTString are presented in Section 5. Relationships with other topological relation models are discussed in Section 6. Section 7 shows the application of DTString in similarity matching. Section 8 provides some experiments with simulation data and results. Finally, Section 9 draws a conclusion.

2. Related works

Studies of topological relations can be categorized into three major areas: representation, reasoning, and similarity matching. With regard to representation, the granularity of relations (coarse or detailed), the object domain (what kind of

[1] For interpretation of color in 'Figs. 2, 3 and 8', the reader is referred to the web version of this article.