QUALITATIVE DETAILED DESCRIPTION FOR SPATIAL DIRECTION RELATIONS

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Commission II, WG II/2

KEY WORDS: Spatial Information Sciences, GIS, Analysis, Model, Reasoning, Spatial Direction Relations

ABSTRACT:

Direction relation is an important spatial relation. Descriptions and representations for direction relations have different levels of detail because of different dimensions of spatial objects and different scales of the embedding spaces. Based on direction-relation matrix, interior direction relations are used to perfect the representation of direction relations and the binary-encoding idea is brought creatively to construct interior detailed matrix to describe multiple interior direction relations by a uniform matrix. The model integrates topological information into the description model for direction relations which will lay the foundations of spatial compositive reasoning.

1. INTRODUCTION

Spatial direction relations, who describe the partial and total order of spatial objects, play an important role in spatial query and retrieval, similarity assessment for images and so on. At present, there are many models for describing spatial direction relations, in which the direction-relation matrix [1] and its improved model, deep direction-relation matrix [2], presented by Goyal are now the best models but they take so insufficient consideration for the shapes and sizes of objects that they cannot describe and differentiate more detailed direction relations when the Minimum Bounding Rectangles (MBRs) of the target object and the reference object intersect mutually. Towards this problem, Reference [3] used the method of topological optimization to perfect direction-relation matrix and Reference [4] presented detailed direction relations to describe direction relations in large scale. Because the methods use multiple matrixes to describe different detailed direction relations, the methods have complicated and difficult computing process that needs bigger space and longer time for computing, so the description models will influence the efficiency of spatial analysis and reasoning. Therefore, in the paper, our starting point is direction-relation matrix. A description model for direction relations, which is independent of geometrical types of objects, will be presented to describe direction relations across different levels of detail. And then, in the hierarchical frame of direction relations, the model will compose multiple-spatial information to enhance compositive description for spatial relations.

2. DETAILED DESCRIPTION FOR DIRECTION RELATIONS

Because of different dimensions of spatial objects and different levels of detail in different-scale spaces, the description and representation for direction relations should have different levels of detail. In the paper, two detailed models are integrated in the description frame for different detailed demands and deep direction-relation matrix is a basic model for the consistency of the description forms in the frame. In the frame, exterior direction relation regards the embedding space as the partitioned space and uses the neighbor code to describe precisely direction relations among objects owning different geometrical types. Interior direction relation regards the OC tile of the reference object as the partitioned space and uses the detailed code to construct interior detailed matrix which represents the inner, boundary and ring direction relations in a unified form. The former is used to describe direction relations in small-scale space and the latter is used in large-scale space.

2.1 Exterior Direction Relation

Because direction-relation matrix forms the center region (the OC tile) of the reference object, the geometrical type of the reference object has direct influence on the partition configuration of the embedding space (Fig.1) Different dimensions of the reference object a result in different configurations. Besides the intersections between the direction tiles and the target object, the intersections between the target object and 12 boundary lines or 4 boundary points forming direction tiles should be considered. To solve the above problem, deep direction-relation matrix will be the description model of exterior direction relation.

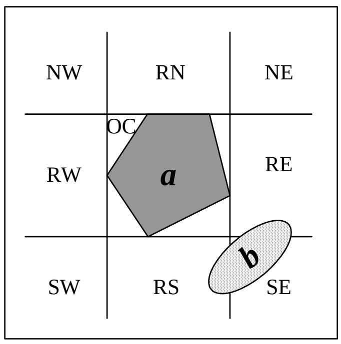

Figure 1. The Partition of exterior direction relation

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The neighbor code D is a 9-bit binary code which describes the intersections between the target object and the direction tiles or the boundary components. Bit 0 recodes the intersection between the target object and the relevant direction tile whose value is 0 or 1, and bits 1-8 record the intersections with the boundary components, whose values are 0 or 2i. The equation is:

$$D = \begin{cases} 1 & , \; x_0 = 1 \\ \sum_{i=1}^{8} 2^i x_i & , \; x_0 = 0 \end{cases} \qquad (1)$$

where x_0 is the bit 0 of the binary code.

Deep direction-relation matrix has the same partition rule and the same matrix configuration with direction-relation matrix, but it uses the neighbor codes D of the direction tiles as matrix elements (Equation 2).

$$dir_{dep}(a,b) = \begin{bmatrix} D_{\mathrm{NW}} & D_{\mathrm{RN}} & D_{\mathrm{NE}} \\ D_{\mathrm{RW}} & D_{\mathrm{OC}} & D_{\mathrm{RE}} \\ D_{\mathrm{SW}} & D_{\mathrm{RS}} & D_{\mathrm{SE}} \end{bmatrix} \qquad (2)$$

Deep direction-relation matrix can describe precisely direction relations among different objects which have different geometrical types because the neighbor code can be uniquely decomposed into its contributing bits. Therefore, deep direction-relation matrix has obvious superiority in describing direction relations across different levels of detail and composing different relations.

2.2 Interior Direction Relation

Direction-relation matrix cannot provide detailed description for direction relations when the MBR of the target object lies in the OC tile of the reference object. Therefore, in the detailed frame, interior direction relation regards the OC tile as the partitioned unit, and uses the encoding idea of the neighbor code to construct interior detailed matrix for describing detailed direction relations.

In interior detailed partition, the center of MBR of the reference object is the center of the partition and the extended lines of the boundary lines of the rectangle which uses λ_w and λ_h as the width and the height respectively are the axes of the partition. Therefore, the OC tile is divided into 9 sub-regions to define inner, boundary and ring direction relations. The interior regions of the reference object are divided into 9 regions to define the inner direction relations, which are denoted by RNP, RSP, REP, RWP, NEP, SEP, NWP, SWP and OCP respectively. The boundaries of the reference object are divided into 9 segments to define the boundary direction relations, which are denoted by RNL, RSL, REL, RWL, NEL, SEL, NWL, SWL and OCL respectively. The ring regions of the reference object are divided into 9 regions to define the ring direction relations, which are denoted by RNR, RSR, RER, RWR, NER, SER, NWR, SWR and OCR respectively (Figure 2).

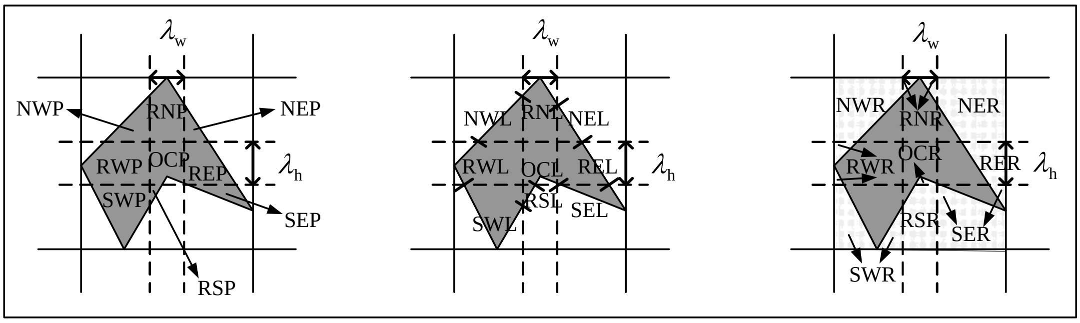

Figure 2. Interior direction relations

In Reference [5], three 3×3 matrixes are respectively used to describe the inner, boundary and ring direction relations when describing interior direction relations, so the method needs relatively larger space and longer time to record and computer. To solve the problem, the binary-encoding idea will be used in describing interior direction relations in the paper. The detailed code will be defined to construct interior detailed matrix which will represent three interior direction relations with the same matrix.

The detailed code C is a 3-bit binary code which describes the intersections between the target object and the inner, boundary or ring of the reference object. Bit 0 recodes inner direction relations whose value is 0 or 1, and bit 1 records boundary direction relations whose value is 0 or 21 and bit 2 records ring direction relations whose value is 0 or 22. The equation is:

$$\mathrm{C} = \sum_{\mathrm{i}=0}^{2} 2^{\mathrm{i}} \mathrm{x}_{\mathrm{i}} \qquad (3)$$

where x_i is the bit i of the binary code

Interior detailed matrix has the same partition rule and the same matrix configuration with direction-relation matrix, but it uses the detailed codes C of the interior direction tiles as matrix elements (Equation 4).

$$dir_{ind}(a,b) = \begin{bmatrix} C_{\mathrm{NW}} & C_{\mathrm{RN}} & C_{\mathrm{NE}} \\ C_{\mathrm{RW}} & C_{\mathrm{OC}} & C_{\mathrm{RE}} \\ C_{\mathrm{SW}} & C_{\mathrm{RS}} & C_{\mathrm{SE}} \end{bmatrix} \qquad (4)$$

As Figure 3 shows, interior detailed matrix can differentiate detailed direction relations effectively so as to obtain more precise results for query when exterior direction relations are the same relation. In Figure 8, the following relations can be inferred quickly according to the detailed codes: (a) the target object locates at the south and southeast of the reference object and disjoints with the latter; (b) the target object locates at the northeast of the reference object and touches with the latter; (c) the target object locates at the north and northwest of the reference object and overlaps with the latter; (d) the target object locates at the center, east, north and northeast of the reference object and is covered by the latter. Consequently, the definitions and descriptions for interior direction relations can enhance information integration between topological and direction relations in the OC tile.

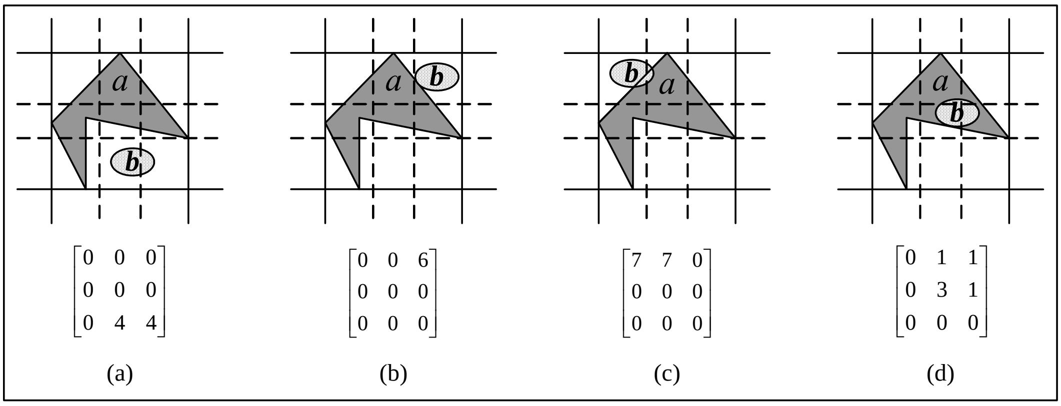

Figure 3. Interior detailed matrix can describe interior direction relations precisely

2.3 Detailed Description for Spatial Direction Relations

So far, spatial direction relations have been grouped orderly and detailed in the detailed frame of spatial direction relations. The model can meet different demands of spatial indexing and retrieval across different levels of detail. Moreover, the binary code is introduced to remedy the defect when direction-relation matrix represents spatial direction relations, which can describe spatial relations more precisely and effectively.

3. CONCLUSIONS

Direction relation is an important spatial relation. Descriptions and representations for direction relations have different levels of detail because of different dimensions of spatial objects and different scales of the embedding spaces. In the paper, based itself upon direction-relation matrix, the encoding idea of the neighbor code is brought creatively to construct interior detailed matrix which integrates topological information into the model for direction relations. Finally, the method realizes the detailed qualitative description for spatial direction relations across different levels of detail, which can not only overcome the drawbacks of the other models, but also lay the foundations of spatial compositive reasoning.

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