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A Model of Representing Extension and Shrinking for Spatial Relations

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ABSTRACT

Aiming at region connection calculus (RCC) can only roughly represent spatial topological relations, and have difficulty in representing the distance, direction and so on. Therefore, based on RCC theory, Region Extension and Shrinking Calculus are proposed, and then a formalized metrization method using region as a basic unit is introduced. Based on RESC theory, taking the advantage such as application simplicity and easy realization of gird area method. The experiment proves the spatial relations can be easily obtained by Grid-Region method, and it is an effective way to represent spatial relations.

Keywords: *RCC, Spatial Extension, Qualitative, Topological*

1. Introduction

SR [1] (Spatial Reasoning) is an important subfield of AI (Artificial Intelligence), usually using the technology and method of AI to model, describe and represent about the spatial objects. Research in SR is motivated by a wide variety of possible application areas including GIS (Geographic Information System), robotic navigation, and high level vision, spatial propositional semantics of natural languages, engineering design, and common-sense reasoning about physical systems.

The qualitative spatial relations mainly include topological, direction and distance relations. The topological relation is the most important basic relation of spatial relation. The model can be divided to region topology and point set topology. The direction relation describes the sequence relation among spatial relations, and its main describing methods are based on cone and projection. The distance relation is some metrization relation among spatial objects. Clementine divided the distance to different layers such as near, middle and far layers, and combing the cone direction model and distance relation, then introduced position calculus method.

Spatial reasoning usually needs to combine various spatial relations, but still so far no unified model can formally describes the topological, directional and the distance spatial relations based on the same theory.

Based on solving the above problems, a new model named ESFR for region extension and shrinking is proposed. The model takes advantage of the novel metrization method to define the topological, directional and the distance relation. And at the meantime, based on the properties of easily realization of the grid area method, it is used to verify the formal model of spatial relations based on spatial region extension and shrinking.

2. Region Extension and Shrinking

In order to unify the spatial topological, qualitative distance relation and qualitative direction relation, the spatial representing model is constructed. So the notion of extension and shrinking of region is defined.

The notion of Region extension and shrinking is based on sum of region (namely sum region). Now, there are a lot of forms of region [2,4]. Tiansi [5] introduced how to recognize a spatial environment when the spatial relations are changed. The literature [2] defined the sum of x and y:

$$sum(x,y) \triangleq \tau z\left[\forall w\left[C(w,z) \equiv C(w,x) \wedge C(w,y)\right]\right] \quad (1)$$

To generalize the definition, the region x and y are modified to the sum of some region satisfied with some condition, the definition of the modified sum region is defined as follows:

$$sum(\phi x) \triangleq \tau y\left[\forall w\left[C(w,y) \equiv \exists v\left[\phi v \wedge C(w,v)\right]\right]\right] \quad (2)$$

Especially, for the region A and E, if the predicate ϕ x equals $CG(x,E) \wedge C(A,x)$, in which $CG(x,E)$ represents x equals E, and then the region satisfied with the predicate ϕ is:

$$sum\left(CG(x,E) \wedge C(A,x)\right) \triangleq \tau y\left[\forall w\left[C(w,y) \equiv \exists v\left[CG(v,E) \wedge C(A,x) \wedge C(w,v)\right]\right]\right] \tag{3}$$

If the predicate ϕ x equals $P\left(EX(x,E), A\right)$, and P is the partial relations of RCC-8, then the sum region satisfied predicate ϕ is:

$$sum\left(P\left(EX(x,E),A\right)\right) \triangleq \tau y\left[\forall w\left[C(w,y) \equiv \exists v\left[P\left(EX(v,E),A\right) \wedge C(w,v)\right]\right]\right] \tag{4}$$

2.1. Region Extension

Given the region A and E, then the extending region from A to E is the sum region satisfied predicate $CG(x,E) \wedge C(A,x)$, namely, $EX(A,E)$, and $EX(A,E) \triangleq sum\left(CG(x,E) \wedge C(A,x)\right)$, in which A is the base region, E is the metrization region of A. A is extended by n from A, denoted by $EX(A,E)$, namely,

$$EX_n(A,E) \triangleq EX\left(EX\left(EX(A,E),E\right)\cdots,E\right) \tag{5}$$

$$EX_0(A,E) \triangleq A \tag{6}$$

2.2. Region Shrinking

Given the region A and E, then the shrinking region from A to E is the sum region satisfied the predicate $P\left(EX(x,E),A\right)$, namely, $SHR(A,E)$, namely, $SHR(A,E) \triangleq sum\left(P\left(EX(x,E),A\right)\right)$, A is the base region, E is the metrization region. A is shrinking from A for n times shrinking, namely $SHR_n(A,E)$.

$$SHR_n(A,E) \triangleq SHR\left(SHR\left(SHR(A,E),E\right)\cdots,E\right) \tag{7}$$

$$SHR_0(A,E) \triangleq A \tag{8}$$

When A and B are fixed, the max value of n in $SHR_n(A,E)$ can be denoted as $SHR\_Max_m(A,E)$, which is the center of A, or the centre region.

Using the region as the spatial primitive, C(x,y) and congruence relation CG(x,y) as the original spatial relation, and adding the metrization function of region extension, the spatial relations such as topology, distance, direction, position and move can be formalized.

3. Spatial Relation

3.1. Topology Relation

In the model of topology of RCC-8, DC(x, y) represents x is apart from y. In the application, the apart degree should be considered. Therefore, based on the region extension, DC can be separated to $DC_{n,E}$.

Definition 5 Apart degree. Given the region A and B, if there exits a region E and the positive integer n, A is not connected to B through E by n-1 times extension, but A is connected to B through E by n times extension, then the apart agree of A and B can be represented as $DC_{n,E}(A,B)$, namely, shown as the Equation (9):

$$\begin{aligned} &DC_{n,E}(A,B) \\ &\triangleq \exists n,E\left[DC\left(EX_{n-1}(A,E),B\right) \wedge C\left(EX_n(A,E),B\right)\right] \end{aligned} \tag{9}$$

The predicate $DC_{n,E}(A,B)$ is known as "The apart degree between A and B is n*E". The **Figure 1** can be represented the apart degree of A and B is n*E, the surround region of A represented by the n times extension using as n dashed circle. According the definition 2, the Equation (10) can be obtained:

$$DC_{n,E}(A,B) \equiv DC_{n,E}(B,A) \tag{10}$$

The predicate of $DC_{n,E}(A,B)$ represented the apart degree of A and B is measured by n and E, and the granularity of metrization is depended on E. When E is confirmed, the bigger is the variable of n, and the bigger is the apart degree.

3.2. Direction Relation

A and B is two regions, A. East, A. South, A. West and A. North is four borderlines of the region of region A.

$$East(A,B) \triangleq \exists n,S\left[S(S) \wedge \neg C\left(ETT_{n-1,S}(A.East,S),B\right) \wedge C\left(ETT_{n,S}(A.East,S),B\right)\right] \tag{11}$$

The other direction relations can be defined as West (A,B), South(A,B), North(A,B), etc.

$$\begin{aligned} &West(A,B) \triangleq \exists n,S\left[S(S) \wedge \neg C\left(ETT_{n-1,S}(A.West,S),B\right) \wedge C\left(ETT_{n,S}(A.West,S),B\right)\right] \\ &South(A,B) \triangleq \exists n,S\left[S(S) \wedge \neg C\left(ETT_{n-1,S}(A.South,S),B\right) \wedge C\left(ETT_{n,S}(A.South,S),B\right)\right] \\ &North(A,B) \triangleq \exists n,S\left[S(S) \wedge \neg C\left(ETT_{n-1,S}(A.North,S),B\right) \wedge C\left(ETT_{n,S}(A.North,S),B\right)\right] \end{aligned} \tag{12}$$

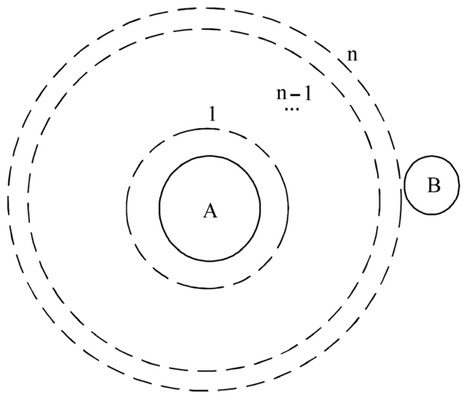

Figure 1. Apart degree.

For example, when the region calculus is got on the object B, and the extending region $ETT(B,S)$ from B is firstly intersection with A. East, so we say the object B is in the east of object A is shown as *East*(*B*,*A*), and the **Figure 2** is showed as follows:

4. Grid Region Method

Grid region method has the properties of easy application and realization. If some part of A accounts for some grid, then all the grids accounting the region can be represented as the predicate S(A). The grid region is extended based on the RESC theory, using the grid unit as the metrization region, and the metrization region can be extended as **Figure 3**.

The algorism for grid region extension is as follows:

1) Choose the region need to be extended

2) Read the region grid coordinate of the selective region

3) According to the mark of the read grid unit, justify whether the grid unit is the outer grid unit, if it is the outer grid unit, then executing (4). If it not the outer grid unit, then execute (5).

4) Extension according to the coordinate obtained from (3). Firstly, fetch three grid units such as the top left, top, top right corners, and justify whether the mark is the free grid unit. If it is the free grid unit, change the value of the mark (the counts of the extension). After that, fetch the right bottom corner, bottom and the left bottom corners to do the same justify. Finally, fetch the left and right grid unit to do the same justify. After the justification is finished, execute (3).

5) Go on read the grid coordinate of the next region, execute (3).

5. Application Instance

Based on the introduction of the above RESC, grid region method realizes qualitative spatial representing system.

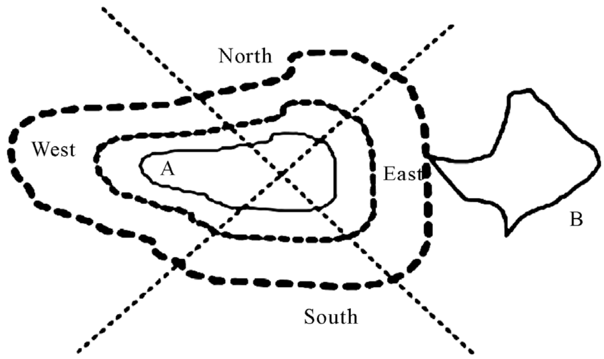

Figure 2. Direction representing.

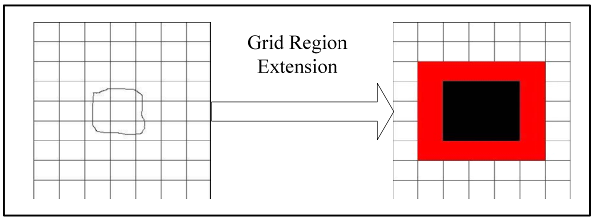

Figure 3. Grid region extension.

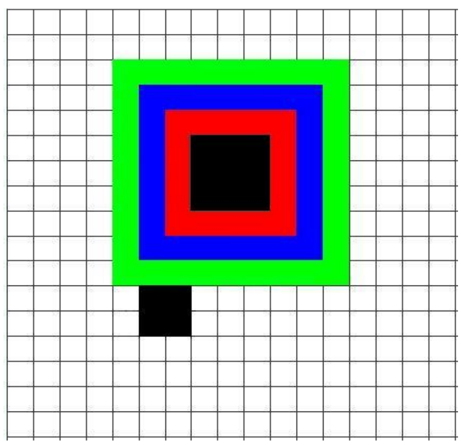

Figure 4. Application instance.

The system has three modules such as topology relation reasoning module, direction relation module, distance relation module. The space is firstly grid, then given the region 1 and 2, and the given region is grid, the grid unit is as the extending region to extend the region S(1), according RESC theory, the topology relation of S(1) and S(2) is shown as apart (DC), and the apart degree is 3 grid degree, direction relation is S(2) is in the north of S(1), the distance relation is the absolute distance between A and B is 3 grid unit distance, namely, the distance relation is $Dist_{3,S}(1,2)$,in which S is the grid unit, the distance between them is 3 grid unit, the direction relation is South(1,2),namely, the region 2 is in the south of the region 1, which is showed as **Figure 4**.

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