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Application of Spatial Reasoning in Predicting Rainfall Situation for Two Disjoint Areas

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Abstract. In this article, we extend the 9 - intersection matrix to 27 - intersection matrix on the basis of RCC8 relations, propose 27 - intersection model between two disjoint regions and a simple region. Giving the algorithm, 31 kinds of topological relations between two disjoint regions and a simple region by specific procedure, and give schematic diagrams of the 31 kinds of topological relations, verifying 31 kinds of topological relations are achievable. In order to further research the topological relations between two disjoint regions and a simple region, in this article we have completed the reasoning for topological relations between two disjoint regions and a simple region, and given the conceptual neighborhood graph. By comparison of related work, we can draw a conclusion that the 27 - intersection model is superior to the expressive power of the 8-intersection model. Through the representation model of topological relations established in this article, we can predict the rainfall situation on two areas, and give the probability of rainfall in different regions.

Keywords: topological relations, RCC8, simple region, intersection matrix, rainfall

1 Introduction

China is one of the most affected countries by tropical cyclones. In China, typhoon happens each year on an average of seven to eight, and China is a country that has most typhoons coming and most disasters with typhoon [1]. In the research of tropical cyclone, although some results have been made in prediction of tropical cyclone path, the predictions are still unsatisfactory for most exceptional path. At the same time, the edge of the region is not certain, all of these problems increase the difficulty in forecasting typhoon rainfall.

To establish a model that can adapt to the uncertainty of the typhoon area and improve the accuracy of typhoon rainfall warning, this article gave a new idea that forecasting typhoon rainfall is on the basis of spatial reasoning.

Spatial reasoning [2- 4] is an important branch of artificial intelligence. It has become an interdisciplinary research topic involving disciplines, for example logic, algebra, topology and graph theory. Over the past three decades, the research on spatial

reasoning has been extremely active, which is one of the fundamental aspects in the fields of geographic information system[5], image databases [6,7] and CAD/CAM systems [8].

In this article, we specifically proposed a representation model between two disjoint regions and a simple region, this model is applied to predict the disaster-affected for two designated areas. This helps to improve the rainfall early warning and disaster assessment mechanism, has a guiding significance in the establishment of disaster prevention and early warning mechanisms to reduce disaster losses and casualties.

2 The Representations Model between Two Disjoint Regions and a Simple Region

2.1 9- intersection model

In 1991, Egenhofer et al. [8] constructed 4-intersection model, as follows gave 4 - intersection matrix, here A^0 denotes the in-house of A and ∂A denotes the out-house of A . Then we can obtain 16 topological relations (contain the case that cannot exist in the real world):

$$\begin{pmatrix} A^0 \text{ I } B^0 & A^0 \text{ I } \partial B \\ \partial A \text{ I } B^0 & \partial A \text{ I } \partial B \end{pmatrix}$$

Based on the 4-intersection model, the complement A^- of region A is regarded as the exterior of region A , we extended the 4- intersection matrix to 9- intersection matrix[9], as follows:

$$\begin{pmatrix} A^0 \text{ I } B^0 & A^0 \text{ I } \partial B & A^0 \text{ I } B^- \\ \partial A \text{ I } B^0 & \partial A \text{ I } \partial B & \partial A \text{ I } B^- \\ A^- \text{ I } B^0 & A^- \text{ I } \partial B & A^- \text{ I } B^- \end{pmatrix}$$

When considering region in the real world, we obtain 8 kinds of relations corresponding to RCC8 relations[10]. RCC8 relations are disjoint; meet; overlap; coveredby; inside; equal; covers; contains, as shown in Fig. 1:

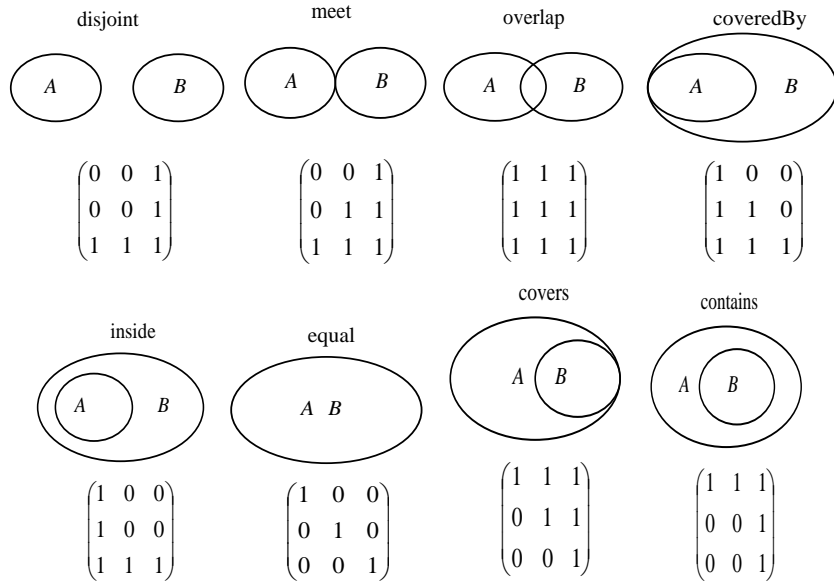


Fig. 1 9-intersection model and 8 kinds of topological relations

2.2 The 27- intersection model between two disjoint regions and a simple region

Based on the definition of 9 - intersection model, we extend the 9 - intersection model, and get the 27- intersection model that can express the topological relations between two disjoint regions and a simple region .

2.2.1 The 27- intersection matrix between two disjoint regions and a simple region

Based on 9-intersection model, space region is divided into nine sections, as shown in Fig. 2:

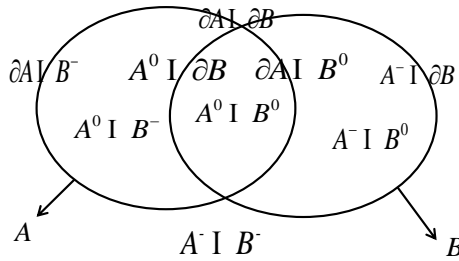


Fig. 2 9 parts of the space is divided

Similarly, three regions of A, B, C can divide the space into 27 parts, in other word, we can get 27- intersection matrix, as follows:

$$\begin{pmatrix} A^0 \cap B^0 \cap C^0 & A^0 \cap B^0 \cap \partial C & A^0 \cap B^0 \cap C^- \\ A^0 \cap \partial B \cap C^0 & A^0 \cap \partial B \cap \partial C & A^0 \cap \partial B \cap C^- \\ A^0 \cap B^- \cap C^0 & A^0 \cap B^- \cap \partial C & A^0 \cap B^- \cap C^- \\ \partial A \cap B^0 \cap C^0 & \partial A \cap B^0 \cap \partial C & \partial A \cap B^0 \cap C^- \\ \partial A \cap \partial B \cap C^0 & \partial A \cap \partial B \cap \partial C & \partial A \cap \partial B \cap C^- \\ \partial A \cap B^- \cap C^0 & \partial A \cap B^- \cap \partial C & \partial A \cap B^- \cap C^- \\ A^- \cap B^0 \cap C^0 & A^- \cap B^0 \cap \partial C & A^- \cap B^0 \cap C^- \\ A^- \cap \partial B \cap C^0 & A^- \cap \partial B \cap \partial C & A^- \cap \partial B \cap C^- \\ A^- \cap B^- \cap C^0 & A^- \cap B^- \cap \partial C & A^- \cap B^- \cap C^- \end{pmatrix}$$

Denote $A_0 = A^0, A_1 = \partial A, A_2 = A^-$, Order $M_{ijk} = A_i \cap B_j \cap C_k, i, j, k = 0, 1 \text{ or } 2$.

Then above 27- intersection matrix can be regarded as M .

$$M = \begin{pmatrix} M_{000} & M_{001} & M_{002} \\ M_{010} & M_{011} & M_{012} \\ M_{020} & M_{021} & M_{022} \\ M_{100} & M_{101} & M_{102} \\ M_{110} & M_{111} & M_{112} \\ M_{120} & M_{121} & M_{122} \\ M_{200} & M_{201} & M_{202} \\ M_{210} & M_{211} & M_{212} \\ M_{220} & M_{221} & M_{222} \end{pmatrix}$$

Definition 1 For a simple region A , define $\varepsilon(A) = \begin{cases} 1 & A \text{ is not empty} \\ 0 & A \text{ is empty} \end{cases}$. Then M is regarded as M_ε .

$$M_\varepsilon = \begin{pmatrix} \varepsilon(M_{000}) & \varepsilon(M_{001}) & \varepsilon(M_{002}) \\ \varepsilon(M_{010}) & \varepsilon(M_{011}) & \varepsilon(M_{012}) \\ \varepsilon(M_{020}) & \varepsilon(M_{021}) & \varepsilon(M_{022}) \\ \varepsilon(M_{100}) & \varepsilon(M_{101}) & \varepsilon(M_{102}) \\ \varepsilon(M_{110}) & \varepsilon(M_{111}) & \varepsilon(M_{112}) \\ \varepsilon(M_{120}) & \varepsilon(M_{121}) & \varepsilon(M_{122}) \\ \varepsilon(M_{200}) & \varepsilon(M_{201}) & \varepsilon(M_{202}) \\ \varepsilon(M_{210}) & \varepsilon(M_{211}) & \varepsilon(M_{212}) \\ \varepsilon(M_{220}) & \varepsilon(M_{221}) & \varepsilon(M_{222}) \end{pmatrix}$$

So we can represent the topological relations between two disjoint regions and a simple region with a 0-1 matrix.

2.2.2 Properties of 27-intersection model between two disjoint regions and a simple region

Definition 2 We define an operation “ \vee ” on the set $\{0, 1\}$, as shown in Table 1:

Table 1. The operation on “ \vee ”

\vee	0	1
0	0	1
1	1	1

Definition 3 For any $m \times n$ 0-1 matrices $A = (a_{ij})_{m \times n}$ and $B = (b_{ij})_{m \times n}$, we define $A \vee B = (a_{ij} \vee b_{ij})_{m \times n}$.

According to the above definition, we can get $\varepsilon(AYB) = \varepsilon(A) \vee \varepsilon(B)$. Order RCC8 to Ω , among

$$\Omega = \left(\begin{pmatrix} 0 & 0 & 1 \\ 0 & 0 & 1 \\ 1 & 1 & 1 \end{pmatrix}, \begin{pmatrix} 0 & 0 & 1 \\ 0 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix}, \begin{pmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{pmatrix}, \begin{pmatrix} 1 & 0 & 0 \\ 1 & 1 & 0 \\ 1 & 1 & 1 \end{pmatrix}, \right.$$

$$\left. \begin{pmatrix} 1 & 0 & 0 \\ 1 & 0 & 0 \\ 1 & 1 & 1 \end{pmatrix}, \begin{pmatrix} 1 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 1 \end{pmatrix}, \begin{pmatrix} 1 & 1 & 1 \\ 0 & 1 & 1 \\ 0 & 0 & 1 \end{pmatrix}, \begin{pmatrix} 1 & 1 & 1 \\ 0 & 0 & 1 \\ 0 & 0 & 1 \end{pmatrix} \right)$$

For any two ordinary regions X and Y, the corresponding matrix of their topological relations must belong to the set Ω , so we can get Theorem 1:

Theorem 1 Two disjoint regions A , B and a simple region C corresponding topological relation between any two matrixes must satisfy the following three formulas:

$$\left(\begin{matrix} \bigvee_{s=0}^2 \varepsilon(M_{00s}) & \bigvee_{s=0}^2 \varepsilon(M_{01s}) & \bigvee_{s=0}^2 \varepsilon(M_{02s}) \\ \bigvee_{s=0}^2 \varepsilon(M_{10s}) & \bigvee_{s=0}^2 \varepsilon(M_{11s}) & \bigvee_{s=0}^2 \varepsilon(M_{12s}) \\ \bigvee_{s=0}^2 \varepsilon(M_{20s}) & \bigvee_{s=0}^2 \varepsilon(M_{21s}) & \bigvee_{s=0}^2 \varepsilon(M_{22s}) \end{matrix} \right) = \begin{pmatrix} A^0 I B^0 & A^0 I \partial B & A^0 I B^- \\ \partial A I B^0 & \partial A I \partial B & \partial A I B^- \\ A^- I B^0 & A^- I \partial B & A^- I B^- \end{pmatrix} \in \Omega, \quad (1)$$

Here $\bigvee_{s=0}^2 \varepsilon(M_{00s}) = \varepsilon(M_{000}) \vee \varepsilon(M_{001}) \vee \varepsilon(M_{002})$

$$\left(\begin{matrix} \bigvee_{s=0}^2 \varepsilon(M_{0s0}) & \bigvee_{s=0}^2 \varepsilon(M_{0s1}) & \bigvee_{s=0}^2 \varepsilon(M_{0s2}) \\ \bigvee_{s=0}^2 \varepsilon(M_{1s0}) & \bigvee_{s=0}^2 \varepsilon(M_{1s1}) & \bigvee_{s=0}^2 \varepsilon(M_{1s2}) \\ \bigvee_{s=0}^2 \varepsilon(M_{2s0}) & \bigvee_{s=0}^2 \varepsilon(M_{2s1}) & \bigvee_{s=0}^2 \varepsilon(M_{2s2}) \end{matrix} \right) = \begin{pmatrix} A^0 I C^0 & A^0 I \partial C & A^0 I C^- \\ \partial A I C^0 & \partial A I \partial C & \partial A I C^- \\ A^- I C^0 & A^- I \partial C & A^- I C^- \end{pmatrix} \in \Omega \quad (2)$$

$$\begin{pmatrix} \bigvee_{s=0}^2 \varepsilon(M_{s00}) & \bigvee_{s=0}^2 \varepsilon(M_{s01}) & \bigvee_{s=0}^2 \varepsilon(M_{s02}) \\ \bigvee_{s=0}^2 \varepsilon(M_{s10}) & \bigvee_{s=0}^2 \varepsilon(M_{s11}) & \bigvee_{s=0}^2 \varepsilon(M_{s12}) \\ \bigvee_{s=0}^2 \varepsilon(M_{s20}) & \bigvee_{s=0}^2 \varepsilon(M_{s21}) & \bigvee_{s=0}^2 \varepsilon(M_{s22}) \end{pmatrix} = \begin{pmatrix} B^0 \mid C^0 & B^0 \mid \partial C & B^0 \mid C^- \\ \partial B \mid C^0 & \partial B \mid \partial C & \partial B \mid C^- \\ B^- \mid C^0 & B^- \mid \partial C & B^- \mid C^- \end{pmatrix} \in \Omega \quad (3)$$

Since the intersection of two sets is empty or not, we obtain the following Theorem 2.

Theorem 2 The topological relation between two disjoint regions and a simple region given by 27-intersections model are exclusive and complete.

2.2.3 Constraints of 27-intersection model between two disjoint regions and a simple region

Theorem 1 gave a indispensable condition for a 0-1 matrix corresponding to a topological relation. Therefore, not every 0-1 matrix can be represented in a topological relation, some 0-1 matrix cannot be achieved. To get achievable topological relations, we will add three constraints.

Restricted condition 1 A 0-1 matrix corresponding to an achievable topological relation must satisfy the following three formulas.

$$\begin{pmatrix} \bigvee_{s=0}^2 \varepsilon(M_{00s}) & \bigvee_{s=0}^2 \varepsilon(M_{01s}) & \bigvee_{s=0}^2 \varepsilon(M_{02s}) \\ \bigvee_{s=0}^2 \varepsilon(M_{10s}) & \bigvee_{s=0}^2 \varepsilon(M_{11s}) & \bigvee_{s=0}^2 \varepsilon(M_{12s}) \\ \bigvee_{s=0}^2 \varepsilon(M_{20s}) & \bigvee_{s=0}^2 \varepsilon(M_{21s}) & \bigvee_{s=0}^2 \varepsilon(M_{22s}) \end{pmatrix} = \begin{pmatrix} A^0 \mid B^0 & A^0 \mid \partial B & A^0 \mid B^- \\ \partial A \mid B^0 & \partial A \mid \partial B & \partial A \mid B^- \\ A^- \mid B^0 & A^- \mid \partial B & A^- \mid B^- \end{pmatrix} \in \Omega \quad (4)$$

$$\begin{pmatrix} \bigvee_{s=0}^2 \varepsilon(M_{0s0}) & \bigvee_{s=0}^2 \varepsilon(M_{0s1}) & \bigvee_{s=0}^2 \varepsilon(M_{0s2}) \\ \bigvee_{s=0}^2 \varepsilon(M_{1s0}) & \bigvee_{s=0}^2 \varepsilon(M_{1s1}) & \bigvee_{s=0}^2 \varepsilon(M_{1s2}) \\ \bigvee_{s=0}^2 \varepsilon(M_{2s0}) & \bigvee_{s=0}^2 \varepsilon(M_{2s1}) & \bigvee_{s=0}^2 \varepsilon(M_{2s2}) \end{pmatrix} = \begin{pmatrix} A^0 \mid C^0 & A^0 \mid \partial C & A^0 \mid C^- \\ \partial A \mid C^0 & \partial A \mid \partial C & \partial A \mid C^- \\ A^- \mid C^0 & A^- \mid \partial C & A^- \mid C^- \end{pmatrix} \in \Omega \quad (5)$$

$$\begin{pmatrix} \bigvee_{s=0}^2 \varepsilon(M_{s00}) & \bigvee_{s=0}^2 \varepsilon(M_{s01}) & \bigvee_{s=0}^2 \varepsilon(M_{s02}) \\ \bigvee_{s=0}^2 \varepsilon(M_{s10}) & \bigvee_{s=0}^2 \varepsilon(M_{s11}) & \bigvee_{s=0}^2 \varepsilon(M_{s12}) \\ \bigvee_{s=0}^2 \varepsilon(M_{s20}) & \bigvee_{s=0}^2 \varepsilon(M_{s21}) & \bigvee_{s=0}^2 \varepsilon(M_{s22}) \end{pmatrix} = \begin{pmatrix} B^0 \mid C^0 & B^0 \mid \partial C & B^0 \mid C^- \\ \partial B \mid C^0 & \partial B \mid \partial C & \partial B \mid C^- \\ B^- \mid C^0 & B^- \mid \partial C & B^- \mid C^- \end{pmatrix} \in \Omega \quad (6)$$

Restricted condition 2 For simple bounded regions, $A^- \mid B^- \mid C^-$ must be nonempty, namely $M_{222} = 1$.

Restricted condition 3 The regions A and B are disjoint, so we can get the following formula:

$$\begin{pmatrix} \bigvee_{s=0}^2 \varepsilon(M_{00s}) & \bigvee_{s=0}^2 \varepsilon(M_{01s}) & \bigvee_{s=0}^2 \varepsilon(M_{02s}) \\ \bigvee_{s=0}^2 \varepsilon(M_{10s}) & \bigvee_{s=0}^2 \varepsilon(M_{11s}) & \bigvee_{s=0}^2 \varepsilon(M_{12s}) \\ \bigvee_{s=0}^2 \varepsilon(M_{20s}) & \bigvee_{s=0}^2 \varepsilon(M_{21s}) & \bigvee_{s=0}^2 \varepsilon(M_{22s}) \end{pmatrix} = \begin{pmatrix} A^0 I B^0 & A^0 I \partial B & A^0 I B^- \\ \partial A I B^0 & \partial A I \partial B & \partial A I B^- \\ A^- I B^0 & A^- I \partial B & A^- I B^- \end{pmatrix} = \begin{pmatrix} 0 & 0 & 1 \\ 0 & 0 & 1 \\ 1 & 1 & 1 \end{pmatrix} \in \Omega \quad (7)$$

According to the above three constraints, we can give specific algorithm, and then get the topology diagram.

2.2.4 Schematic diagram of topological relations between two disjoint regions and a simple region

According to the restricted condition, we can give the main idea of algorithm, as shown in Table 2:

Table 2. The main idea of program

topologicalRelationGen(null; TR)	// Input: null
Output: topological Relations that satisfy all the constraints	
$TR \leftarrow 2^{27}$	basic topological relations //
All basic topological relations	
$TR \leftarrow \text{null}$	// TR blank
for each t in TR	2^{27}
if t satisfy restricted condition 1	
// Inspection t satisfy restricted condition 1	
if t satisfy restricted condition 2	
// Inspection t satisfy restricted condition 2	
if t satisfy restricted condition 3	
// Inspection t satisfy restricted condition 3	
$TR \leftarrow \{TR, t\}$	// Put topological Relation into TR
end if	
end if	
end for	
return TR	// Return results

31 kinds of 0-1 matrices were gotten through the program, and then according to the 31 kinds of topological relations matrix, we specifically draw this 31 schematic diagrams of topological relations, as shown in Fig. 3(Specifically, we give the corresponding topological relations and the corresponding matrix), and verified that 31 kinds of 0-1 matrices can uniquely correspond to the topological relations between two disjoint regions and a simple region.

we know a topological relation, we will simply reasoning unknown topological relations.

Table 3. Reasoning table

$R(A,B)$	$R(A,C)$	$R(B,C)$
disjoint	disjoint	disjoint meet overlap coveredby inside equal covers contains
	meet	disjoint meet overlap coveredby inside
	overlap	disjoint meet overlap coveredby inside
	coveredby	disjoint meet overlap coveredby inside
	inside	disjoint meet overlap coveredby inside
	equal	disjoint
	covers	disjoint
	contains	disjoint

4 The Conceptual Neighbourhood Graph between Two Disjoint Regions and a Simple Region

The conceptual neighbourhood graph of 31 topological relations between two disjoint regions and a simple region is given, as shown in Fig. 4. We use the straight line connected two circle to represent the corresponding two kinds of topological relations between one step to another. The digital serial number corresponding to the circle is a schematic diagram of topological relations in Fig. 4.

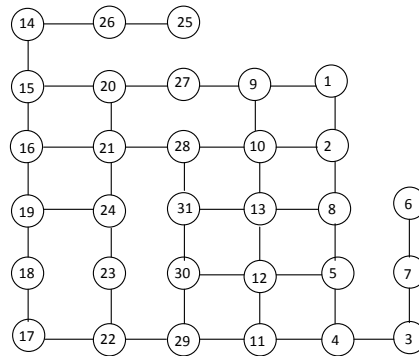


Fig. 4 the conceptual neighbourhood graph of 27-intersection model

5 Applications

5.1 Two disjoint areas and rainfall area are abstractly considered as two disjoint regions and a simple region

The studied region in this article as shown in Fig. 5, shows the possible rainfall situation in Taizhou and Ningbo. Taizhou is regarded as the region A , Ningbo is regarded as the region B , and rainfall region is regarded as region C . Therefore, the problem of predicting the possible rainfall situation in Taizhou and Ningbo is converted to the study of the topological relations between the two disjoint regions A , B and a simple region C .



Fig. 5 the regional map

5.2 Affected probability of the target region

We understand that the topological relations between rainfall region, two specified disjoint target regions and 31 kinds of topological relations are a one-to-one correspondence. It is important to note that in order to adapt to the uncertainty of abnormal typhoon landing, we stipulated that the rainfall situation associated with typhoons is completely natural and random, so we think that the probability of occurrence for 31 kinds of topological relations between two disjoint areas and rainfall area is equal, that is the probability of each situation is $1/31$.

For example, in region B , we studied the situation where region B is influenced by the rainfall, region A and region B is similar. By the study of schematic diagram of the topological relations, we had found that when the topological relations of region B and region C is disjoint, meet, region B is not affected by the rainfall. There are 13 kinds of situations corresponding to both cases according to Table 2, respectively,

which correspond to the number 1, 2, 9, 10, 14, 15, 16, 20, 21, 25, 26, 27, 28 of the Fig. 3, and then the probability is 41.93%.

When the topological relation of region B and region C is contains, covers, overlap, region B is partly affected by the rainfall. There are 7 kinds of situations corresponding to three cases according to Table 2, respectively, which correspond to the number 6, 7, 8, 13, 19, 24, 31 of the Fig. 3, and then the probability is 22.58%.

When the topological relation of region B and region C is inside, coveredby, equal, region B is perfectly affected by the rainfall. There are 11 kinds of situations corresponding to three cases according to Table 2, respectively, which correspond to the number 3, 4, 5, 11, 12, 17, 18, 22, 23, 29, 30 of the Fig. 3, and then the probability is 35.48%.

According to the reasoning table of the topological relations, we can predict the possible rainfall situation. When we know the possible rainfall situation of an area, then we can study the possible rainfall situation of another area. For example, when we know $R(A,B)=$ disjoint and $R(A,C)=$ overlap, then $R(B,C)$ can be obtained, they are disjoint, meet, overlap, coveredby, inside.

We can further study the rainfall situation according to the conceptual neighbourhood graph, namely when we know the rainfall situation of an area, we can further study the next rainfall situation. For instance, when we know that the situation corresponding to the number 25 of Fig.3 happens, namely contains(A,B), disjoint(A,C), then the next possible rainfall situation corresponds to the number 26 of Fig.3, namely covers(A,B), disjoint(A,C).

5 The Comparison of Related Work

LI Jian et al. constructed the 8-intersection model[11] that can represent the topological relations between two disjoint regions and a simple region. We can get 17 kinds of topological relations by the 8-intersection model, as shown in Fig. 6.

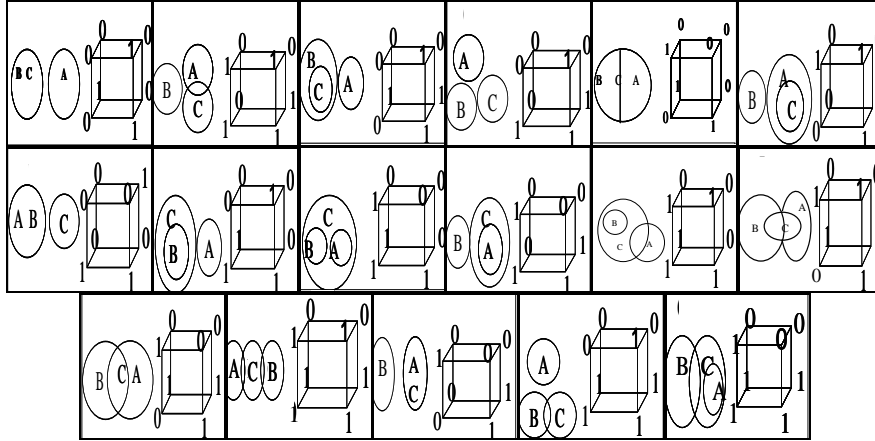


Fig. 6 Schematic diagrams of the 17 kinds of topological relations based on 8-intersection model

In this article, we can get 31 kinds of topological relations by the study of the 27 - intersection model. However, we can only get 17 kinds of topological relations by 8- intersection model. Thus, expressive power of the 27 - intersection model is superior to expressive power of the 8 - intersection model. The reason while the expressive power of the 8 - intersection model is weaker is as follows: 8 - intersection model cannot differentiate between some cases (as shown in Fig. 7: two different situations) It is worth noting that when the specified target region is not affected by rainfall area, does not mean that the residents of the specified target region cannot take protective measures. It is different that the topological relations of region B , C are disjoint and the topological relations of region B , C are met. As shown in Fig. 7, (a) Figure corresponds to the schematic diagram of number 1 of Fig. 3, (b) Figure corresponds to the schematic diagram of number 2 of Fig. 3. Although two schematic diagrams of topological relations all represent that the specified target region is not affected by rainfall, they are very different in essence. When the situation which corresponds to (a) Figure happens, the residents of the designated target region cannot take protective measures. We can find that (a) Figure can be transformed to (b) Figure according to the conceptual neighbourhood graph, and target region still is not affected by rainfall. However, while the situation which corresponds to (b) Figure happens, the residents of the designated target region must take protective measures to reduce property damage.

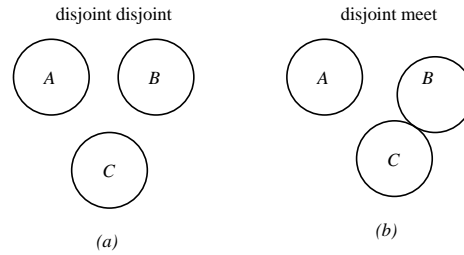


Fig.7 Two different situations

7 Conclusions

In this article, we established a representation model between two disjoint regions and a simple region, we also got schematic diagrams of the 31 kinds of topological relations between two disjoint regions and a simple region, and then specially gave the reasoning table of the topological relations and the conceptual neighbourhood graph between two disjoint regions and a simple region. This specific theory can be applied to predict the rainfall of two disjoint areas, and we got the chance of rain for a specific area, then we can predict the rainfall situation by reasoning table and conceptual neighborhood graph of topological relations, which is of great significance for residents to take the next step of preventive measures to reduce disaster losses.

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