The Research of Fuzzy Segment Query under the Spatial Database

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***Abstract*—Recently years, the nearest neighbor (N-N) query in the spatial database contracts much public attentions and is studied widely. Because of the kinds of the query objects, there are generally three types, point to point (p-p), point to segment (p-s) and segment to segment (s-s). Most of them are precise data, and related documents are rich. However, the research about querying fuzzy objects with influential region is seldom and the related documents are few.**

In this paper, we mainly study the N-N query with the fuzzy segment in spatial database. Four located relations based on fuzzy segments are come up with, and we list the N-N algorithm. The experimental result shows high query efficiency.

***Index Terms*—N-N query, spatial database, fuzzy segment, R-tree**

I. Introduction

In the real life, some objects that can't be studied as points are always comfortable as segments, such as high-tension lines besides the road, rivers and forests. Considering the actual impact from them to the surrounding, we propose an influential region around the fuzzy objects, which may be affected with varying degrees. So it has something to do with the reality to query the fuzzy segments involved the influential regions. Through studying on it, we can deal with many incidents that are sudden and non-human around our living surroundings. If the degree that the influential region reflects is known, then efficient method will be proposed to solve the difficulties and reduce the risk maximally.

For many years, database technology and related estate based on certain data has become the mainstay of information industry, and people has positive attitude to the future trend of certain data. Recently years, with the quick development of economic and technology, uncertain data jumped into the view of public. Also it has got widespread concerning because of important applications [1] in many fields. How to deal with uncertain data and make contribution to our country become many scholars' researching objects and future trend. So the challenges [2] should be meet.

According to the type of uncertainty [3][4], the categories are fuzzy uncertainty and random uncertainty[5]. Spatial relation is a very important and basic research field. Although making significant progress, it should have further development in studying content and scope. Spatial relation studies on the constraint relations of spatial objects, so the uncertainty of data is bound to lead to the uncertainty of spatial relation.

Burrough[6] proposed that, generally, uncertainty is a degree that measured object lacks knowledges and it behaviors ambiguity and randomness. Goodchild[7] considered that uncertainty means the difference between real object and its performance in the GIS. When the true value of the phenomenon can be defined, the accuracy and the terms error were used to describe the uncertainty, but the true value may be not defined in many situations. So the methods to deal with uncertainty should be special, no using the precise method. Because it would result in loss of large amounts of information when processing uncertain data.

In connection with the uncertainty of spatial relation, the current research methods are the following: qualitative method [8], fuzzy method, rough method [9] and probabilistic method [10]. Among them, fuzzy method is used to describe the topological relations between fuzzy regions. In spatial relations, topological is the key and plays an important role. Measurement information (size, shape, distance and direction) plays the role of refining. In reference [11], the graphic of concept neighborhood based on Line/Line topological relations is defined.

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Reference [12] separately gave fuzzy similarity measure functions of topological relation, direction relation and distance relation. Xinming Tang [13] used nine-intersection model and 4*4-intersection model to distinguish 44 and 152 kinds of the topological relations between fuzzy regions. Indexing and querying the plane segment with uncertain border is also the focus to the research. Reference [14] proposed the "NNU" algorithm for uncertain spatial nearest query point. The limited probability neighbor query is proposed in reference [15], which is with a probability threshold. In reference [16], the probability neighbor query algorithm of multi-dimensional data is described. The literatures about spatial relations of plane segments with uncertain border have not been found.

Next, we mainly use the fuzzy method to study two fuzzy segments' topological relations and the nearest neighbor algorithm.

II. BASIC KNOWLEDGE

A. Improved R-tree Indexing Structure

The R-tree [17] is a tree-like data structure, similar to the B-tree. The main goal of R-tree is to organize the spatial data in such a way that a search will visit as few spatial objects as possible before returning the result. The decision on what nodes to visit is made based on the evaluation of spatial predicates, so the tree must be able to hold some sort of spatial data on all nodes.

To retrieval segments in static environment, the R-tree's structure should be adjusted as follow:

Leaf nodes contain index record entries of form

(Index, Obj_ID, coordinate_1, coordinate_2)

The coordinate*_1* and *coordinate_2* are two endpoints' coordinates of the segment. This makes accurately find the location of the segment. Non-leaf nodes contain index records of the form

(Index, Child_Pointer)

The *Child_Pointer* points to his sub nodes.

B. Line-Object Fuzzy Partition

Topological relations between spatial objects are described as TRFF (Topological relations between fuzzy objects), TRFC (Topological relations between fuzzy objects and crisp objects) and TRCC (Topological relations between crisp objects).

In the real world, uncertainty results from two factors, randomness and ambiguity [6]. To the existing GIS-software, a precise method is used to model the ambiguity. The ambiguity of TRFF comes from ambiguity of two objects as well as fuzzy partition to the fuzzy topological spaces. The fuzzy partition to segment M is shown in Fig 1. The inside and border of M are no longer a curve or points, but a surface with a membership degree. The points in Line-Space have the memberships belong to internal, external and borders. From Fig 1, the border is the track which is passed by the fuzzy circles whose centers are the points on M with a certain radius.

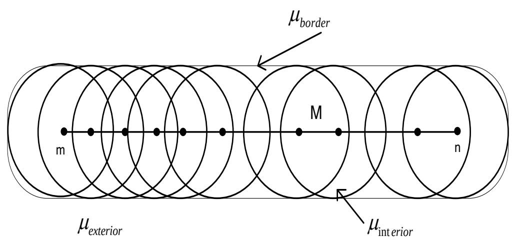

Figure1. Fuzzy partition of segment M

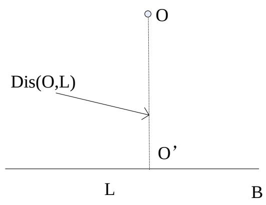

Figure 2. O' is on L

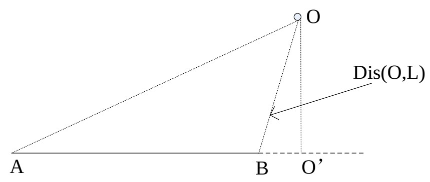

Figure 3. O' is out of L

The centers have the minimum membership (0.0), and the points outside the circle have the maximum membership (1.0). The internal membership is reduced gradually from the border to the center. The fuzzy border is composed of two circles whose centers are M's endpoints and whose radiuses are certain. From the center to the border, the membership is reduced gradually. M's fuzzy internal is the premium set of its fuzzy external, and the membership becomes gradually larger from the border to the center. In M's space, arbitrary segments are in the membership fields of M, including internal, border and external. Also, these segments have three membership degree resulted from M separately, not belonging a unique part. For example, if there is a segment that is greatly far from M, its internal membership degree on M is 0, its border membership degree on M is 0 and its external membership degree is 1.

It is assumed that r is the radius of the fuzzy circle (r>=0), so the membership degree functions [2] of fuzzy internal, fuzzy border and fuzzy external are:

$$\mu_{border}(x,y;r)=\begin{cases}0 & d_1(x,y)\ge r\\ \dfrac{r-d_1(x,y)}{r} & d_1(x,y)\le r\end{cases}$$

$$\mu_{interior}(x,y;r)=\begin{cases}0 & d(x,y)\ge r\\ \dfrac{r-d(x,y)}{r} & d(x,y)\le r\end{cases}$$

$$\mu_{exterior}(x,y;r)=\begin{cases}0 & d(x,y)\ge r\\ \dfrac{d(x,y)}{r} & d(x,y)\le r\end{cases}$$

Among them, *d(x,y)*is the minimum distance between the border and a point *(x, y)*, and $d_1(x, y)$ is the minimum distance between the endpoints and a point *(x, y)*.

C. The Distance Formulas of Segments[29]

Definition 1: Given point O and segment *L*, $l_i \in L$, $i \in [1, +\infty]$. The distance between O and L is denoted by dis(O,L)={dis(O,li)|dis(O,li)≤dis(O,lj),i,j∈[1,+∞]}.

If the projection of *O, O'* is contained by L, which is shown in Fig 2, then

dis(O,L)=dis(O,O')

If the situation is opposite, then it is shown in Fig 3, then

dis(O,L)=MIN(dis(O,A), dis(O,B)).

According to the definition above, the distance formula between the segments can be given.

Definition 2: Given two segments, M and N, with $m_i \in M(i \in [1, +\infty])$,$n_i \in N(i \in [1, +\infty])$, the distance between m_I and n_I is expressed as *dis* (m_i, n_i). It is assumed that:

*d*is(M,N)={dis(mi,ni) | dis(mi,ni) ≤ dis(mk,nk), i, k∈[1,+∞]}.

III. Distance Discussing Based On The L-L Uncertainty Model

There are two kinds of spatial objects discussed recently. Considering the topological relations between fuzzy objects, TRFF, it is necessary to think over the ambiguity of the objects. Therefore, the description of TRFF must deal with the fuzzy attribution and the fuzzy partition for topological space of objects.

A. The Screening Method Based MBR

When taking the *N-N* query based segments, it is necessary to retrieve the nodes of R-tree. Usually, the *MBR* of the node *A* should contain three fuzzy areas of the segment, $\tilde{A}^\circ$, $\partial\tilde{A}$, $\tilde{A}^-$. Firstly, the relations among the *MBRS* should be detected, so as to decide which *MBRS* are candidates. Secondly, the positions of fuzzy areas will be determined.

Finally, the relations between objects will be judged, and the *N-N* [18] of query object will be found.

Definition 1: It is given that segment *L* and segment *Q* with their *MBRS*. The nearest distance [19] between two *MBRS* is denoted by *MINDIS*.

Theorem 1. The shorter the distance between query MBR and queried MBR is, the bigger possibility it will become candidate. If *MINDIS>0*, then two segments must not be intersected.

Prove: Only to make the MINDIS smaller, the query segment is nearer to the queried segment. In N-N query, it will be more likely the candidate. In R-tree, the Non-leaf nodes' MBRS cover the whole region of the fuzzy segments. If MINDIS>0, there can be no intersection in

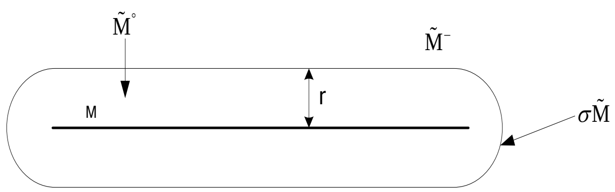

Figure 4. Line Object Topological Space fuzzily Partition

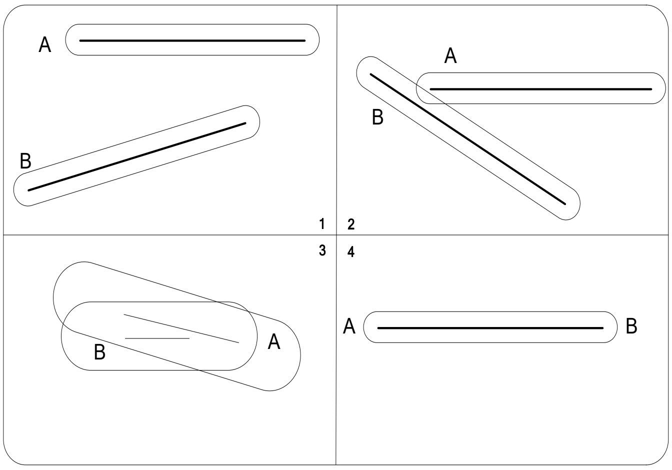

Figure 5. Fuzzy Membership of Topological Relations

the two MBRS. So that it is impossible that the two segments are intersected.

Theorem 2. It is assumed that there are two nodes, *M* and *N*, from R-tree. If the relation is: *MINDIS (M)* < *MINDIS (N)*, then the candidate must be not in the MBR of N and the node will be neglected. If there are no leaf nodes that heir *MINDIS* are smaller than the current *MINDIS*, then the algorithm ends.

Prove: If *MINDIS (M)* is smaller than *MINDIS (N)*, the MBR of M is closer to the query object. It meets the condition that becomes a candidate. Because of the uniqueness of result, so M is selected and N is neglected.

B Expended Nine-Intersection Model of the Locations between Segments

Definition 1: Given a line *M* with a degree of membership, the topological space [20] is divided fuzzily into internal, border, and external, following certain overlap. $\tilde{M}^{\circ}$ is the internal fuzzy sets of M, $\tilde{M}^{-}$ is the external fuzzy sets of M, and $\partial\tilde{M}$ is the border fuzzy sets of M. The "r" is the fuzzy radius, r≥0. An example is shown in Fig 4.

Segment *A* and segment *B* are given with six fuzzy sets [21] of M, $\tilde{A}^{\circ}, \partial\tilde{A}, \tilde{A}^{-}, \tilde{B}^{\circ}, \partial\tilde{B}, \tilde{B}^{-}$. It is assumed that U_{AB} is for the space set of A and B, then the expended nine-intersection model [22] of *A* and *B* is followed:

$$\tilde{T}(A,B)=\begin{bmatrix}\sigma(\tilde{A}^{\circ}\cap\tilde{B}^{\circ}) & \sigma(\tilde{A}^{\circ}\cap\partial\tilde{B}) & \sigma(\tilde{A}^{\circ}\cap\tilde{B}^{-})\\ \sigma(\partial\tilde{A}\cap\tilde{B}^{\circ}) & \sigma(\partial\tilde{A}\cap\partial\tilde{B}) & \sigma(\partial\tilde{A}\cap\tilde{B}^{-})\\ \sigma(\tilde{A}^{-}\cap\tilde{B}^{\circ}) & \sigma(\tilde{A}^{-}\cap\partial\tilde{B}) & \sigma(\tilde{A}^{-}\cap\tilde{B}^{-})\end{bmatrix}$$

The parameter σ is the largest membership degree of two fuzzy sets. For example:

$$\sigma(\tilde{A}^{\circ}\cap\tilde{B}^{\circ})=\max_{(x,y)\in U_{AB}}(\min(\mu_{A\mathrm{interior}}(x,y),\mu_{B\mathrm{interior}}(x,y)))$$

So the location relations between two fuzzy regions are determined by their expended nine-cross model [23] [4], then the specific relations between two segments are known and the distance between them is get lastly. There are four kinds of nine-intersection model below:

$$(1)\ \tilde{T}(A,B)=\begin{bmatrix}0.0 & 1.0 & 1.0\\ 1.0 & 0.0 & 1.0\\ 1.0 & 1.0 & 1.0\end{bmatrix},$$

So *distance (A,B)≥2r*. The fuzzy regions of A and B are disjoint. An example is shown in 1of Fig 5.

$$(2)\ \tilde{T}(A,B)=\begin{bmatrix}\mu_{11} & 0.0 & 1.0\\ 0.0 & 0.0 & 1.0\\ 1.0 & 1.0 & 1.0\end{bmatrix},$$

So *2r*>*distance(A,B)≥r*, $\mu_{11}=\dfrac{r-d(x,y)}{r}\in[0,1]$.The fuzzy regions of *A* and *B* are intersected described in 2 of Fig 5.

$$(3)\ \tilde{T}(A,B)=\begin{bmatrix}\dfrac{r-d(x,y)}{r} & \dfrac{r-d(x,y)}{r} & \dfrac{r-d(x,y)}{r}\\ \dfrac{r-d(x,y)}{r} & \dfrac{r-d_1(x,y)}{r} & \dfrac{d(x,y)}{r}\\ \dfrac{d(x,y)}{r} & \dfrac{d(x,y)}{r} & 1.0\end{bmatrix},$$

So *r*>*distance(A,B)≥0*. Other values are between 0 and 1. The fuzzy regions between A and B are contained, which is illustrated in 3 of Fig 5.

$$(4)\ \tilde{T}(A,B)=\begin{bmatrix}1.0 & 1.0 & 0.5\\ 1.0 & 1.0 & 1.0\\ 0.5 & 1.0 & 0.0\end{bmatrix}$$

So *distance (A,B)=0*. The fuzzy regions between A and B are coincidence, which is described in 4 of Fig 5.

C. The Precise Distance of Segments

The fuzzy relations between segment and segment contain fuzzy disjoint, fuzzy intersection, fuzzy contains and fuzzy coincidence. In the two-dimensional space, if the relation between two segments is intersection [24], then their nearest distance is zero. Based on the fuzzy relationships above, the actual locations between segments not intersected will be discussed as follow, and the nearest distance will be referred. A definition is introduced here:

Definition 1 ： Segment *L* and Segment *Q* are known with their endpoints *m*、*n* and *m'*、*n'*. The projection area of *Q* for L is expressed by *region (Q)*.

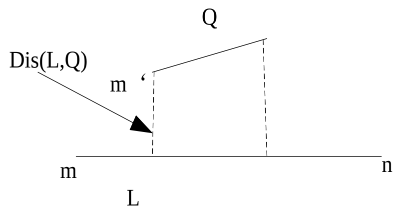

Figure 6. Situation A of L-L

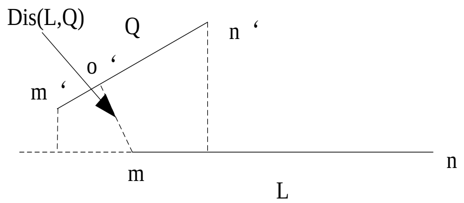

Figure 7. Situation B of L-L

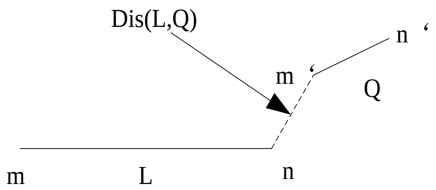

Figure 8 Situation C of L-L

Respectively, we will discuss the nearest distance of each relation based on fuzzy relations.

(1) Fuzzy Disjoint

① $region(Q) \subset L$. The nearest distance is like

$$dis\ (L,Q)=dis(L, m')(dis(L,n')),$$

which is shown in Fig 6.

② $L \cap region(Q) \neq \varnothing$. The nearest distance is:

$$dis\ (L,Q)=dis(m,o'),$$

which is illustrated in Fig 7.

③ $L \cap region(Q) = \varnothing$ .The nearest distance is:

$$dis\ (L,Q)=dis(m(n),m'(n')),$$

as is shown in Fig 8.

(2) Fuzzy Intersection

$L \cap region(Q) \neq \varnothing$, then the relations between *L* and the projection of *Q* have the same three situations above. So the method of calculation will not be repeated.

(3) Fuzzy Contained

L (Q) is in internal fuzzy region of *Q (L)*.

①If *L* is intersected with *Q*, so

$$dis(L,Q)=0.$$

②If *L* is not intersected with *Q*, then the distance belongs to ①, ② of fuzzy disjoint.

(4) Fuzzy Coincidence

If *L* and *Q* is coincidence, then

$$dis\ (L,Q)=0.$$

Ⅳ. THE NEAREST NEIGHBOR ALGORITHM[25]

A. The Description of Determining Projection Region Algorithm

Algorithm 1 *INT relation (region (Q),L)*

INPUT: Segment L and Region (Q);

OUTPUT: The sign value of L and Region (Q);

BEGIN

IF region (Q) is in L completely

RETURN 0

ELSE

IF region (Q) partly

RETURN 1;

ELSE

RETURN 2

END

B. The Description of Calculating the Distance of Segments Algorithm

Algorithm 2 *FLOOT Dis (L, Q)*

INPUT: Segment L and Segment Q;

OUTPUT: The Nearest Distance between them;

BEGIN

IF intersect (Q, L)

RETURN 0.0;

ELSE

VALUE: =Relation (region (Q), L);

CASE VALUE =0;

D_segment= dis_1 *(L, Q);*

CASE VALUE=1;

D_segment= dis_2 *(L, Q);*

CASE VALUE=2;

D_segment= dis$_3$ (L, Q);

RETURN D_segment;

END

C. The Traversal Algorithm in R-tree

Algorithm 3 *Search (Node R-tree_root, Line L)*

INPUT: R-tree_root, Segment L;

OUTPUT: The nearest segment of L;

BEGIN

Dis= +∞;

MBR_current:=R-tree_root;

WHILE R-tree traversal is completed DO

IF MBR_current intermediate node

THEN

IF MINDIS (MBR_current, MBR_L) ≥ Dis

THEN

IF R-tree traverse ends

THEN

RETURN K;

ELSE

MBR_current take his sub-node

ELSE

FOR (all MBR ∈ MBR_current)

Dis_MBR=MINDIS (MBR$_i$, MBR_L);

// Found the nearest MBR to MBR_L;

MBR_current:= MBR$_i$;

ELSE // the node is leaf-node

FOR (all MBR ∈ MBR_current)

Found the nearest MBR$_i$ to MBR_L

MBR_current:= MBRi

FOR (all segment ∈ MBR_current)

Xddis=Intersect (L, Segment$_i$);

IF min (Xddis) =0.0

THEN

VALUE (Q) =VALUE (Segment$_i$);

RETURN Q;

END;

ELSE

D_segment:=min (Xddis);

IF D_segment <dist

THEN

Dis=D_segment;

END;

RETURN Q;

END

V. EXPERIMENTAL RESULTS

A. Experimental Designation

Hardware environment: Pentium(R) 4 CPU, 3.00GHz, 512MB Memory, Window XP.

Software environment: VS2008, C#.

The dataset space used is 1000×1000.The selection of datasets uses the objects of Gaussian distribution. The experiment simulated static objects from 1k to 10k. The disk page size is set to 1k, and we use 400 objects to build R-tree.

In this section, we conduct a comparison in N-N query performance between precise data and imprecise data about I/O cost and correct percentage of query. If the quality querying the imprecise data is close to that of accurate data, then the experiment also has a practical significance.

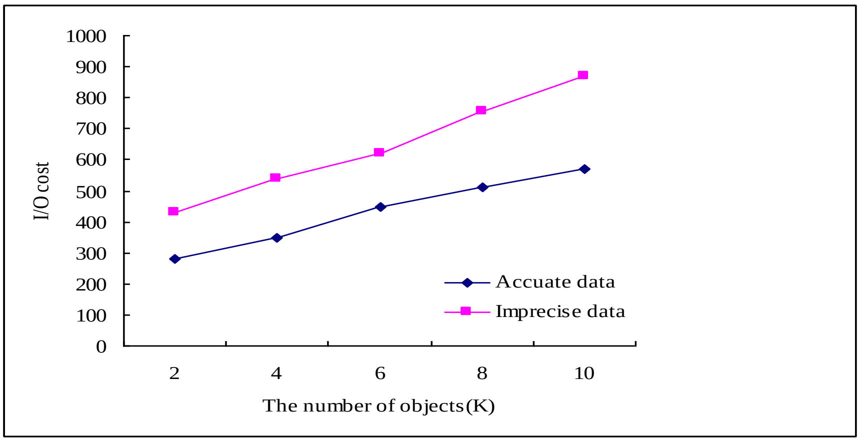

Figure 9 Comparison of I/O Access in N-N Query between accurate data and imprecise data

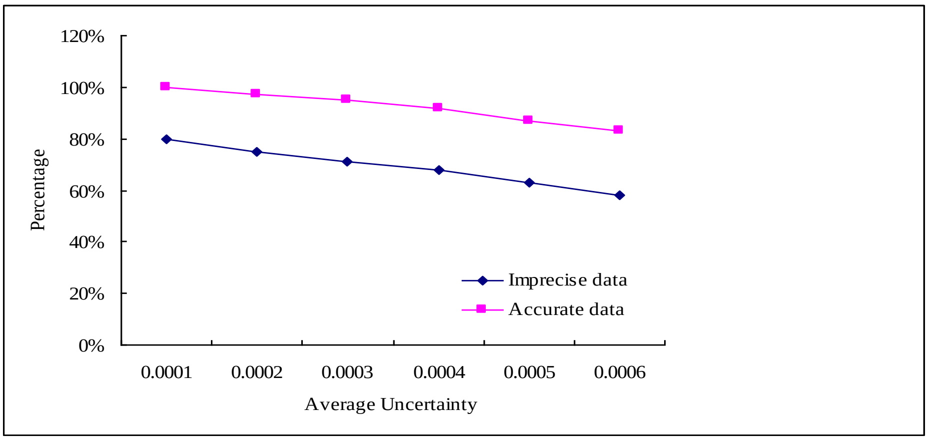

Figure 10 Effect of uncertainty on percentage of R between accurate data and imprecise data

B. Experimental Evaluations

From Fig 9, we can know that the I/O visit times based on imprecise data is three seconds of that of accurate data. From Fig 10, it can be understood that correct percentage based on imprecise data is five fourths of that of accurate data. Although its performance is worse than that in accurate data, there is a certain practical significance in the whole, and this theory is also available.

Ⅵ. Conclusion And Future work

In this paper, we studied the N-N query [26] problem of fuzzy segments based on spatial database. L-L uncertainty [6] model is proposed under the backdrop of real life. Through adding the coordinates of endpoints of segment to indexing of leaf nodes [27][28], we make sure the accurate location of segments. And the N-N query algorithm based on it is proposed. From the experimental results, it shows low I/O access and good performance. Because the polygon is composed of segments, so this makes our research work has the practical significance. This article is to work at the N-N query based on the segments on two-dimensional space. The future researching direction can be the N-N query based on the polygons of two-dimensional space.

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