Study on Fuzzy Spatial Location Model and Spatial Query

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Abstract

The spatial relationships plays an important role in GIS spatial data modeling, spatial query and spatial analysis etc. From the cognitive view, we represent and apply the information of relationships between spatial objects in the real world in computer system, study the fuzzy extension about description of spatial relationships at the base. Guided the spatial query the paper makes the model on the base of regular indefinite spatial inferring, puts fuzzy theory and spatial relationships theory into the spatial query practice. The paper found indefinite spatial inferring model based on the regular rules and embed it in space decision support system as the fuzzy spatial inference machine. It involves various spatial problems such as topology, orientation, base direction, naming distance, comparison distance, scale, shape and so on. Every aspect has made some progress, solves the fuzzy location and query problems in applying GIS and get better result in the experimental test.
Keyword: spatial query, fuzzy inference, fuzzy location, inference machine, GIS.

I. Introduction

Since the complexity and fuzziness of the real world, the limitation of the people's cognitive and expression capacity, the spatial objects and itself has the intrinsic instability. To study the spatial relationships with the instability is becoming one of the hot spot and difficulty in studying the spatial relationships. At the same time it becomes one of the basic theory of the fuzzy spatial query analysis and the natural language query facing to the intelligent GIS [1][2].

We can use fuzzy reasoning to solve the fuzzy location problem in applying GIS. The user should represent the right position of the query point when we want to inquiry data from the spatial database, then we can get the specific mutuality data of the point from the spatial database. The information represented by the user is just language description, for example, "east to X meters at certain point, at another point west to Y meters, ……". But all of the description is unlikely sufficiently definite such as "fairly affirmative, basic affirmative, not certain." The system will proceed on the description of the position and the evaluation of asserting degree to infer and assert the nicety position.

Here, we solve the problem under the regular indefinite spatial inferring. For the speciality of solving problem, the definition of the fact, the rule and the inference machine algorithm are different from the traditional model. But it is effective to solve this sort of problem, since the model cannot improve the inference on the base of rule.

II. Objects and Operating Definition

A. *Definition of Facts*

We define two facts. One is the description to location(Loc), the other is the aim point of location(Aim).

location description can be expressed below:

Loc (Ref_obj, Ori, Dis)

Ref_obj：referent objects; Referent objects are represented by other geographic codes

Ori(Ox, Oy)：Orientation for example (0,0): represent orientation is not available ; east :(1,0)； south:(0,-1)。

Dis： distance； measured by meter

Location description is a formalized expression for user to describe location with language

for example ：Location(the People's square,(1,0),500) means that the location point is 500 meters east to the People's square.

Aim point can be expressed below:

Aim point is the location determined by system.

Aim(pos)

pos： position ；including the coordinate information of location：Pos. X, Pos. Y

B. *Definition of Following Action*

Generally speaking, the following action of inference machines is to insert new facts. Following it is various due to the specificity of the problems. Four sorts of the following actions are defined as follows:

Add fact [c]: Add facts, degree of belief is c

Del fact [c]: Delete facts

Update fact [c1]: update facts, degree of belief is c1

Show Message: Show warning message to users

During the operation of ADD and UPDATE, the degree of belief is not deter-mined by the algorithm of inference machine but the rules. This is also the difference between conventional inference machine and current one.

C. *Definition of Fuzzy Types*

Depict the distance between two aim points.

Format：DISTANCE (aim1 , aim2)

Aim2 and aim 2 are two aim points, the fuzzy item DISTANCE shows the degree of the distance between them.

Define fuzzy operators as follows:

Degree of distance operator：near, mid, far

Tone operator：mos_(most), hig_(highly), ver_(very), rel_(relatively), som_(some), lit_(little)

Fuzzy operator: app_ (approximately),pro_ (probably), abo_(about)

The membership functions are showed as follows:

Membership Function of Degree of Distance Operator near, mid, far are:

$$\text{near(x)} = \begin{cases} 1, & x < 0.2y \\ 2 - x/2y, & 0.2y \le x < 0.4y \\ 0 & 0.4y \le x \le y \end{cases} \quad (1)$$

$$\text{mid(x)} = \begin{cases} 0, & x < 0.2y \\ x/2y - 1, & 0.2y \le x \le 0.4y \\ 1 & 0.4y \le x < 0.6y \\ 3 - x/2y & 0.6y \le x < 0.8y \\ 0 & 0.8y \le x \le y \end{cases} \quad (2)$$

$$\text{far(x)} = \begin{cases} 1, & x < 0.2y \\ x/2y - 3, & 0.2y \le x < 0.4y \\ 0 & 0.4y \le x \end{cases} \quad (3)$$

suppose H_λ is tone operator, $(\text{H}_\lambda \underset{\sim}{A})(x) = [\underset{\sim}{A}(x)]^\lambda$ .when > 1, H_λ is called centralized operator. When < 1, H_λ is called diffused operator. Generally H_4 represents most, H_2 stands for highly, $\text{H}_{1.25}$ represents very, $\text{H}_{0.75}$ stands for relatively, $\text{H}_{0.5}$ is some, $\text{H}_{0.25}$ is little. For example, relevant near can be expressed by functions below:

$$\text{rel\_near(x)} = \begin{cases} 1, & x < 0.2y \\ (2 - x/2y)^{0.75}, & 0.2y \le x < 0.4y \\ 0 & 0.4y \le x \le y \end{cases} \quad (4)$$

$\lambda / 4$ is degree of belief of rules.

Membership Function of Fuzzy Operator app_ (approximately), pro_ (probably), abo_(about) can be expressed below:

A common form of fuzzy operator

$$F(\underset{\sim}{A})(x) = (\underset{\sim}{E} \bullet \underset{\sim}{A})(x) = \bigvee_{y \in U} [\underset{\sim}{E}\ x, y) \wedge \underset{\sim}{A}(y)] \quad (5)$$

$\underset{\sim}{E}$ is the similar relationship of U ,when , generally we suppose:

$$\underset{\sim}{\text{E}}(x, y) = \begin{cases} e^{-(x-y)^2}, & |x - y| < \delta \\ 0, & |x - y| \ge \delta \quad \delta > 0 \end{cases} \quad (6)$$

We have different δ values due to the variety of fuzzy degree. Generally we get δ of app_ (approximately) 0.9, δ of pro_ (probably) 0.75, δ of abo_(about) 0.5. Fuzzy item can be constituted by aspiration and conjunction of operators above.

D. Definition of Function

Functions below are applied in the rules:

Calculate Position (ro,o,d)

Return value： position coordinate Position(x,y) types

Function： return the reference object of distance R_o(xro,yro) the orientation of geometric center O(Ox, Oy)，aim point coordinates with distance d.

Condition： d ≥ 0

$$x = x_{ro} + O_x \times d \Big/ \sqrt{o_x^2 + o_y^2} \quad (7)$$

$$y = y_{ro} + O_y \times d \Big/ \sqrt{o_x^2 + o_y^2} \quad (8)$$

Dis(pos1,pos2)

Return value： numerical type

Function： return the geometric distance between pos1 and pos2 .

$$d = \sqrt{(pos1x - pos2x)^2 + (pos1y - pos2y)^2} \quad (9)$$

III. Definition of Rule Sets

Rules are statements that represents the relationship between priori statements and posteriori statements. There is a fuzzy or non-fuzzy deterministic factor which marks the degree of belief of rules for each rule[5][6]. The previous matter has one or several proposition which connected with AND or OR. The following matter has only one proposition.

```
{
   RULE name of rule
   IF (previous matter)  THEN following matter
}
CERTAINTY is determined factor
```

Weight and threshold also can be added into rules in addition to fuzzy comparison. Rules together with weight value represent the degree of importance of proposition. Weight value may be a fuzzy value; users can add a language variable in a weight value bracketed with parentheses. Threshold (system threshold) can be de-fined in determining whether rules should be triggered or not. If the determinacy of previous matters is greater than the threshold, rules will be triggered. If we hope that a certain rule has its own threshold, we can add it in previous matters marked with {}. Deterministic factors can also be added into rules to represent the determinacy of rules, in addition to weight value and threshold.

Rules Summary can be expressed below:

(I) Rule no.1 to no.5 is the preprocessing to location description, which avoid obvious contradiction in it.

(II) Rule no.6 to no.7 is to form aim points with location description.

(III) Rule 8 to 11 is to adjust degree of belief of aim points.

For example:

Rule no.3
IF Location1(ro1, o1, d1)[c1] and Location2(ro1, o2, d2) [c2] and o1<>o2 and c1-c2 <= 0.4
THEN Delete Location1, Delete Location2,
Show Message “location1 collides with location2”

Explanation: Reference objects described by location1 and location2 are the same but different in orientation, and have closed degree of belief. It shows that there is a contradiction between the description of location1 and location2 and both should be both deleted. Then system shows a warning message.

Rule no.6:
IF Location1(ro1,o1,d1)[c1] and o1>0
THEN Add Aim(Calculate Position(ro1,o1,d1)) [c1]

Explanation: poisoning with a single point, form an aim point.

Rule no.8:
IF Location(0,o1,d1) [c1] and Aim(pos) [c2] and LT(|dis(ro1,pos)-d1|,100,20)
THEN Update Aim [1-(1-c1)*(1-c2)]

Explanation: Aim point corresponds with location description of unknown orientation, aim point can be updated, and enhance the degree of belief.

Rule no.11:
IF Aim1(pos1) [c1] and Aim2(pos2) [c2]and DISTANCE (aim1,aim2) IS FAR and c1-c2>0.3
THEN Delete Aim2

Explanation: two aim points have far distance, degree of belief differ greatly from each other, delete the aim point with lower degree of belief.

IV. Inference Machine

At the beginning the inference facts are completely facts of location. A normal result after inference is to produce a Aim facts with higher degree of belief, while others are quite low. Otherwise inference is failed and can not be positioned. We need input facts again. Algorithm of inference machine can be described as follows:
(1) apply rule no.1 to no.5 into all location facts until no suitable rules are available.
(2) apply rule no.6 and no.7 into all location rules until no suitable rules are avail-able.
(3) apply rule no.8 to no.11 into all facts until no suitable rule are available.
(4) sequencing degree of belief of all Aim facts in descending and forming a array Aims.
If the degree of belief of Aims [0] is greater than 0.8 and that of Aims [1] is smaller than 0.5, algorithm will be succeed and quit and output position information Aims [0]. Otherwise algorithm fails and returns, and asks users to input facts again. The determination of degree of belief of rules for previous matters can be sorted into two cases. One is that it is actually a pattern matching with regard to factors such as Location (ro1, o1, d1) [c1] or Aim (pos) [c2]. If there are facts which can be matched, than degree of belief is 1, otherwise 0. That is to say we only concern the two-value logic whether the fact exists but not the fuzzy situation or degree of belief of the fact itself. Another one is that degree of belief is that of membership deter-mined by fuzzy set in case of “DISTANCE(aim1,aim2) is near”. Conjunction of previous matters are “and” and “or”. “And” is the fuzzy and operation, which equals to obtain the minimum of degree of belief of the two expressions; “or” is the fuzzy or operation, it means to obtain the maximum of degree of belief of the two expressions. Rules do not concern uncertainty, that is, the intensities of all rules are 1. The trigger of

rules is controlled by triggering threshold. If the degree of belief of previous matters is greater than that of the following matters, following matters will be executed. Different from conventional inference machine, degree of belief of following facts are determined by rules but not the degree of belief of previous matters or intensities of rules[7][8].

V. Data Calculation

we can get the location coordinates inquired by users via the spatial inference algorithm above, but the real aim of system is to obtain relevant data of certain facilities inquired by users. It is impossible for certain facilities to cover all the area of the whole district, so the probability of finding the right location of right facility is low. Possible case is that the facility lie somewhere near the location found. System determines the right location according to the distance between each position point and the facility and the relationship between their positions. System will list facilities, which are quite near the position point, and ask for users' choices. If the choices are more than 3, only the foremost three of them will be list.

VI. Realization

In order to realize the model above, we need to apply diverse technologies such as expert system, GIS, database management, and so on. Actually, it can also be regarded as a small space decision support system[9], so it contains the common features of spatial decision support system. Basic construction is as fig. 1.

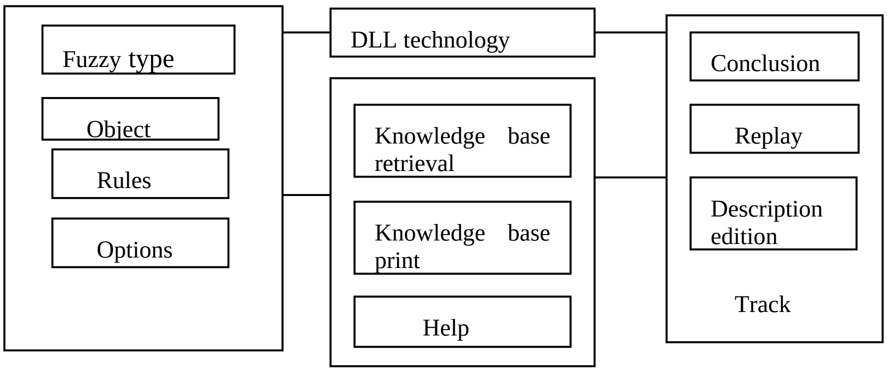

Fig. 1. One Spatial Decision Support System SDSS

Same as most expert system tools, the kernel of SDSS is also constituted by facts base, rule base and inference machine[10][11]. And it utilizes production rule as the basic knowledge express mode. Knowledge base stores all the knowledge from the field experts. Knowledge can be represented as rules, semantic net, frame or objects. Inference machine collects knowledge from knowledge base to make inference. For production system, inference machine determine which rules can be triggered according to the facts in global data base. These rules are sequenced ac-cording to priority. Rules with highest priority will be triggered first. Expert systems now can provide functions by arming tools which gain knowledge. Constructing SDSS with expert system shell involve utilizing external communication mechanism to enlarge applied environment. So it is necessary to connect with database, GIS and mathematical calculation programs. SDSS shown in the figure above can meet the satisfaction, and it can deal with uncertainty. The whole system also needs the sup-port from these pieces. It needs expert system shell to handle rules set and facts, GIS and relation database to search data, mathematical model and module to process function such as "Calculate Position" widely used in rules.

During the work of this module, man-machine interacting interface will collect information submitted by users first, space inference and management module will put users' information into expert system shell after explanation and boot inference machine to make inference. Inference machine use rules set and facts to make inference, mathematical model processing module will be called during the execution of rules to process some functions. Result will be returned to inquiring module after inference and transformed into concrete precise inquiring statements to call corresponding data and displayed to users through man-machine interacting interface. If results can not be figured out due to fail description or description collision, space inference and management module will ask users to input information again through man-machine interacting interface and reboot inference machine.

mixed programming with Visual C++ 6.0 and Visual Basic 6.0. It can connect well with other parts as a subsystem.

When users input fuzzy query statements, system begins keywords match first. These keywords include location, distance, orientation and fuzzy operator. And then, system makes explanation and inference calculation through spatial decision support system to figure out users' query demands. And system calls corresponding fuzzy operator to make calculation and transform them into precise query demands and put them into data query module to visit spatial data and pick up corresponding position data which meet demands. System returns result set finally.

VII. Conclusion

Fuzzy spatial inference is a quite hot topic. Nowadays, fuzzy spatial inference involves various spatial problems such as topology, orientation, base direction, naming distance, comparison distance, scale, shape and so on. And every aspect has made some progress. Fuzzy spatial position inference discussed in this paper is only one application. The model has been applied into GIS-based optical fiber network resource management and get better result in the experimental test.

References

[1] David A.B, A Framework for the Integration of Geographical Information Systems and Model Base Management [J]. Geographical Information Science, 2001, 15(4).

[2] Chun Liu, Dajie Liu. On the spot Study of GIS and its Application[J]. Modern Map-ping. 2003, Vol.3 (6)

[3] (American)Shashi Shekhar, SanjayChawla，Kunqing Xie，Xiujun Ma，Dongqing Yang, etc translation Spatial database[M]. Beijing: Engineering Industry Publishing Company，2004 (1).

[4] The Open GISTM Abstract Specification ,Version 4[J] ,Open GIS Consortium ,1999

[5] Dubo is D, Prade H.Fuzzy. Sets in Approximate Reasoning. Fuzzy Sets and Systems, 1991, 40 (1)

[6] Watkins F A. False Controversy: Fuzzy and non Fuzzy Faux pas. IEEE Expert, 1995, 10 (4)

[7] KangLin Xie, JinYou Fu Nerve Fuzzy Logical Control System Membership Function and Inferring Rule Assertion[J].Shanghai Traffic University Transaction, 1997, Vol. 8(31).

[8] FangShe Li,BaoShu Wang Fuzzy Nerve Net Inference Machine Structure on the Base of Fuzzy Logic[J]. XiAn Electronic Science and Technology University Transaction, 1998, Vol. 6 (25).

[9] Qiao Wang,JiTao Wu Research the Standardization Problem in Spatial Decision Support System [J]. Mapping Transaction, 1999, Vol. (2).

[10] Cohn AG, Hazarika SM. Qualitative Spatial Representation and Reasoning: An overview. Fundamental Informatics, 2001, 46

[11] Yu QY, Liu DY, Xie Q. A Survey of Analysis Methods of Topological Relations between Spatial Regions. Journal of software, 2003, 14(4)

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