GEOGRAPHIC SPATIAL SEMANTIC TRANSLATION METHOD USING SUBDIVISION GRID CODING

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ABSTRACT

In the application of geographic data inquiry, traditional search engine put up with queries using keyword matching method mostly, which, however, can hardly get the most accurate and expected answers for users, because spatial semantic queries described by human natural language are difficult for computers to understand. To solve this problem, a method of semantic translation in geographic space using global subdivision grid is put forward in this paper. By summing up the geographic spatial semantic expressing pattern, extracting spatial keywords from searching sentence, finally establish the relationship between spatial semantic meaning and spatial data results. Experiments are also designed and implemented, which results show that method in this paper could accomplish the geographic spatial semantic translation with fair accuracy.

Index Terms—geographic spatial semantic meaning, semantic translation, subdivision grid code

1. INTRODUCTION

In the field of geographic information application, it’s necessary to search for data based on geographic location, objects or events, such as restaurants around the Peking University, or gas stations along Victory Street. When we input these sentences in the search engines, the returning results are those who contain all or several keywords in the query. However these are usually not the exact answers we want, because computers could hardly process the question like human brain, especially when it relates to spatial relations. Therefore, a direct mapping relationship between spatial semantic meaning and spatial data should be built up before acquiring geographic information effectively and correctly according to natural language.

2. SEMANTIC TRANSLATION METHOD USING SUBDIVISION GRID CODING

2.1. Subdivision Grid Coding

Global Subdivision Models aim at dividing the earth surface into meshes of equal shape and area, so that they can solve worldwide, multi-resolution problems merged with spatial indexing methods [1]. So far, Global Subdivision Models proposed by researchers include the quaternary triangular mesh(QTM) model [2], Spherical Hexagon Grid System [3], etc. GeoSOT, which is one of the Global Subdivision Models, constructs a kind of quad-tree subdivision grid based on integer coding [4], using mesh-set to represent objects on earth[5]. Its 2-dimension-binary code has definite geographic meaning, a 32-bit binary value stands for the latitude or longitude of a position, which structure gives the subdivision code an advantage on algebra calculation efficiency (see Fig.(1)).

In this research, we use GeoSOT location identification method (C₀, M, N) to express geographic objects and the query space. C₀ is the grid on the corner of an object or space (expressed as (C₀L, C₀B) using the 2-dimension-binary code), M and N are the distances in the direction of latitude and longitude (see Fig.(2)).

![Fig.1 GeoSOT 2-dimension-binary code structure](image1)

![Fig.2 GeoSOT location identification method](image2)

2.2. Geographic Spatial Semantic Translation

According to the activities of human and the earth in geographic spaces, an effective searching sentences in natural language usually includes location, direction, distance and topology information. For example, in this searching sentence “2km to the east of the Peking University”, location
is the Peking University, direction is east, distance is 2km, and topology is just “at” the place. These 4 kinds of information are named geographic spatial semantic elements, which construct the geographic spatial semantic expressing pattern:

\[[\text{Location}] + [\text{Direction}] + [\text{Distance}] + [\text{Topology}]\]

Not all the 4 elements are necessary in one query, such as “hotels around the Peking University”, and that is called fuzzy query. Under another circumstance, some of the elements may occur more than once in one query, which should be divided into two or more basic queries. For example, “within a radius of 500m of the place which is 2km to the east of the Peking University” includes 2 basic searching sentence. One is “2km to the east of the Peking University”; and the other is “within a radius of 500m” whose semantic elements are respectively “the place which is 2km to the east of the Peking University”, “360°”, “500m”, and “topo containing”.

Semantic translation means the mapping technique and method from users’ semantic query to expected geographic data. So far, there are some researches trying to transform geographic spatial semantic elements to latitude and longitude or subdivision code. For instance, geographical name databases[6] can convert a place name to latitude and longitude such as GNIS created by USGS as well as subdivision code such as GeoXwalk by Essex University. Some geocoding methods can convert direction, distance and topology into latitude and longitude[7], and then into subdivision code. However, there is no research on how to directly build up the relationship between these 3 geographic spatial semantic elements and subdivision grid.

2.3. Mapping Relationship between Geographic Spatial Semantic Elements and Subdivision Grid

In order to implement the semantic translation using the algebra calculation of subdivision grid code, geographic spatial semantic elements must first build up the mapping relationship with the subdivision grid, that is to say, spatial semantic elements expressed in natural language should be converted to standard form of GeoSOT parameters.

**Location:** If the position is given in the form of (longitude, latitude), we can get the GeoSOT grid code according to the converting rule of GeoSOT subdivision grid. If it is given by a place name, we can get its position according to geographical name databases, and then express it by (C0, M, N). Considering the query process, define the center grid of a location as the start point, and its GeoSOT code C0’ is calculated by formula (1).

\[C_0' = (C_0L', C_0B') = (C_0L + [N/2], C_0B + [M/2])\]  \(\oplus\)  \(\text{is the displacement operator of a grid on positive direction defined in GeoSOT algebra.}\)

Under most levels, Code \(\oplus 1 = \text{Code} + 2^{32} \times \text{Glevel(Code)}\), \(\text{Glevel is the subdivision level of grid.)}\)

**Topology:** Topology means the relationship between the searching area (subdivision grids) and the expected spatial data, so it should be equal or containing under most circumstances. It decides the parameters’ meaning in direction and distance elements.

\[\text{Topology} = \begin{cases} 0 & \text{equal} \\ 1 & \text{containing} \end{cases} \]  (2)

**Direction:** No matter in what form it is given, it has to be transformed into angle of deflection. In the case of equal, it means the searching direction \(\alpha\) starting from the positive direction of M to that of N. In the case of containing, it means the searching area is a sector with an angle range of \([\alpha, \beta]\).

\[\alpha = \begin{cases} 0^\circ \leq \alpha \leq 360^\circ, & \text{Topology} = 0 \\ \{\alpha, \beta\} & \text{Topology} = 1 \end{cases} \]  (3)

**Distance:** Distance is mapped to the number of grids under certain GeoSOT subdivision level. When topology relation is equal, it means the length between \(C_0'\) and the target grid \(C_0^*\). The number of grids displacement on M and N are relatively \(m\) and \(n\) in formula (4) (cell\_size is the size of grid). When topology relation is containing, distance means the radius of searching area (see formula (5)).

\[\begin{align*}
m &= L \times \cos \alpha / \text{cell\_size} \\
n &= L \times \sin \alpha / \text{cell\_size} \\
r &= \left| \frac{L}{\text{cell\_size}} + 0.5 \right| \end{align*} \]  (4)  (5)

2.4. Spatial Semantic Searching Method on Earth Surface

Considering that our daily activities are mainly on the surface of the earth, take the spatial semantic query on earth surface as an example to illustrate the searching method (Fig.(3)).

**Step1.** Get geographic spatial semantic elements according to the expressing pattern from natural language query sentence using tokenizers such as The Stanford Parse or The Berkeley Parser.

**Step2.** Translate the geographic spatial semantic elements into GeoSOT parameters according to its mapping relationship with GeoSOT subdivision grid (formula (1)-(5)).

**Step3.** Calculate the searching area using the algebra calculation of GeoSOT grid code. When topology relation is equal, it should be displacement operation with \(m\) grids on M direction and \(n\) grids on N direction. The target center grid code is \(C_0^* = (C_0L' \oplus n, C_0B' \oplus m)\) (Fig.(4a)).
When topology relation is containing, it should be buffer operation with buffer radius \( r \). The searching area grids can be calculated using the Buffer operation of GeoSOT (Fig. (4b)).

**Step4.** Retrieve target data from database according to the grid code.

When topology relationship is equal, search all the objects covering the target center grid \( C_0^* \).

When topology relationship is containing, search all the objects within the buffer of grid (Yellow grids in Fig. (4b)). Thanks to the succession properties of GeoSOT code between different levels, the retrieving process is proved to be more efficient.

<table>
<thead>
<tr>
<th>Grid Size</th>
<th>Length on Equator</th>
</tr>
</thead>
<tbody>
<tr>
<td>1˚</td>
<td>128km</td>
</tr>
<tr>
<td>4’</td>
<td>8km</td>
</tr>
<tr>
<td>32”</td>
<td>1km</td>
</tr>
<tr>
<td>4”</td>
<td>128m</td>
</tr>
<tr>
<td>1/4”</td>
<td>8m</td>
</tr>
</tbody>
</table>

### Table 1 Level of the Semantic Translation Subdivision Grid

We do some experiments using the semantic translation method in this paper, and show the translating results in subdivision grids.

Choosing ICTCLAS (by Chinese Academy of Sciences) as the tokenizer, test spatial semantic queries with two kinds of topology relations. When the query sentence is “2 km to the east of the Peking University”, the parsing result is “2/m km/n to/pba the/rzt east/nz of/p the/rzt [Peking University]/nt”. The semantic translation result is “Peking University, east, 2 kilometers, topo containing” (Fig. (5b)). The target grids are shown and the data results are listed in the table in Fig. (6b).

When the query sentence is “Within a radius of 2 kilometers of the Peking University”, the parsing result is “Within/p a/rzv radius/n of/p 2/m kilometers/n of/p the/rzt [Peking University]/nt”. The semantic translation result is “Peking University, 360, 2 kilometers, topo containing” (Fig. (5b)). The target grids are shown and the data results are listed in the table in Fig. (6b).

### 4. CONCLUSION

Due to the limit of traditional methods of searching spatial data, we put forward a new semantic translation method on the basis of a kind of Global Subdivision Grid called GeoSOT. By mapping geographic spatial semantic elements to subdivision grid directly and using the algebra of GeoSOT coding, we can construct the relationship between spatial query in natural language and expected geographic data. As a result, data can be retrieved quickly according to the grid code from databases. Therefore, our method is proved to be an efficient semantic translation method.
5. REFERENCES