International Journal of Multimedia and Ubiquitous Engineering
Vol.9, No.7 (2014), pp.281-296
http://dx.doi.org/10.14257/ijmue.2014.9.7.24

A Novel Retrieval Method for Multimodal Point of Interest Data

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Abstract

With the rapid development of mobile Internet, mobile geographic information service becomes more and more popular. Point of interest (POI) is the core content of mobile geographic information service, and it exhibits the properties of multi-source, heterogeneity and media convergence under the circumstance of multiple users and service providers. At the same time, users' retrieval demand is becoming complicated and personalized. Traditional spatial data retrieval method and its semantic expression cannot meet the needs of multimodal point of interest (MPOI) data access. In this paper, a novel retrieval method for MPOI which includes offline and online phases is proposed. In the offline phase, a two-step POI fusion algorithm and a Geo-ontology model were adopted to preprocess the MPOI data. In the online phase, a retrieval process is presented to do the practical retrieval. This method not only satisfies the requirement of multimodal fusion and semantic sharing in the mobile Internet, but also supports cross-modality multimedia retrieval. Experimental evaluations validate the performance of the proposed method.

Keywords: *Mobile Internet, Multimodal Point of Interest, Data Fusion, Geo-ontology Model, Data Retrieval*

1. Introduction

With the rapid development of mobile Internet technology, companied with the popularity of mobile terminals, people are more and more interested in obtaining and sharing information via mobile terminal. As a result, higher requirements on mobile geographic information service (MGIS) are raised [1]. Point of interest (POI) is the core content of MGIS. Its descriptive information becomes multi-source and heterogeneous gradually. The content of the POI data may come from different providers and usually combined by different media types, such as text, image, audio, and video. In this paper, we define it as multimodal point of interest (MPOI). To offer an effective retrieval in the mobile Internet plays a fundamental role in driving the development of MGIS patterns and contents in the new period [2].

2. Related Work

Heterogeneous multi-source multimodal POI retrieval involves multimodal POI description information in the actual process of retrieval. Therefore it belongs to the category of multi-media retrieval. The current POI retrieval is mainly based on keywords. From the initial retrieval based on keywords to information retrieval based on content, multi-media retrieval has achieved a series of research and application results, including QBIC(Query by Image Content)，Photobook，VideoQ and Informeida, *etc.* [3]. However, the current multi-media retrieval technology based on content is only for single modal media, and cannot meet user's cross-media retrieval demands. In recent year, some scholars focus to cross-media

ISSN: 1975-0080 IJMUE

retrieval. S. L. Michael is the first scholar who carried a comprehensive research on cross-media retrieval process. For the core techniques in the cross-media retrieval process, including user-based characteristics, semantic study, similarity calculation and high efficiency index etc. They carried on a comprehensive analysis and put forward the direction of the future development direction and major challenges [4]; S. Sharma integrated GIS and cross-media retrieval technology and realized an Interactive Multimodal Tourist-Guide System (IMTS) [5]; P. Bellini focused on the mass media data in the social network and established an index modal to realize cross-media retrieval [6]; Using text word histogram and SIFT histogram of the image, combined with Latent Dirichlet Allocation subject model, N. Rasiwasia implemented the cross-media retrieval [7]; Based on the large-scale visualization concept annotation, R.H. Hong implemented a multimedia question answering system [8]. Earlier research in China, focus on cross-media of the frontier is the Artificial Intelligence Research Institute, Zhejiang University. They revolved around how to express cross media data and measure the correlation and carried extensively research [9-11]. The researches mentioned above have solved the measurement problem between the cross-media data to some extent. However, there are some deficiencies as follows: (1) The researches are mainly focus on how to deal with the low-level feature in multi-media data, but not solve the problem of "semantic gap"; (2) The researches haven't took full consideration of context information [12], such as position information and spatial information in the retrieval process.

3. Basic Idea

The concept of ontology comes from philosophy. It is introduced to the field of geographic information science as the concept of Geo-ontology. As a formalized, explicit specification of a shared conceptualization in the field of geographic information science [13], Geo-ontology can be used to describe the detailed contents and hierarchical relations of geographical spatial concepts (at different levels and application directions) [14]. Because of its advantage on the expression of semantic information and spatial relationship, it is suitable for the MPOI data retrieval.

Therefore, we propose a Geo-ontology based retrieval method for MPOI data which includes offline and online phases. In the offline phase, a two-step POI fusion algorithm and a Geo-ontology model are adopted to preprocess the MPOI data. In the online phase, a retrieval process is presented to do the practical retrieval. This method not only satisfies the requirement of multimodal fusion and semantic sharing in the mobile Internet, but also supports cross-modality multimedia retrieval. Figure 1 shows the framework of the proposed method.

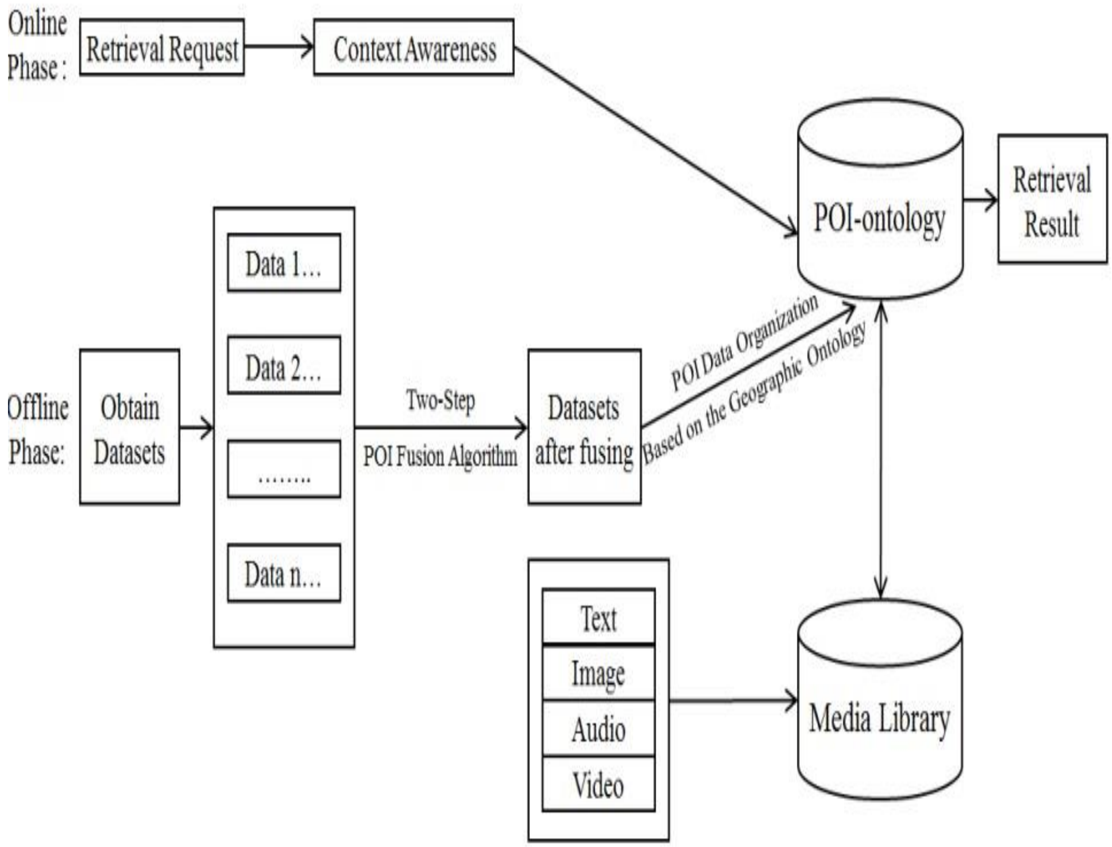


Figure 1. The Framework of the Proposed Method

4. Geo-ontology based Multimodal Point of Interest Retrieval Method

4.1. The Characteristics of the Multimodal Point of Interest Data

The MPOI data belongs to the field of spatial data. Like the traditional spatial data, it has both spatial attribute and non-spatial attribute. Through our analysis of the mass MPOI data existing in the mobile Internet, we find out that it has some features as followed:

(1) It is multi-source and massive.

The MPOI data comes not only from well-known websites (data formats from different website are usually different), but also from the sharing of mobile users. The data from multiple sources makes the MPOI data heterogeneous.

(2) It is multimodal.

The forms of MPOI data are abundant, including traditional text descriptive information (such as name, type, longitude, latitude and user evaluation) and multimodal descriptive information (such as image, audio and video).

(3) The relation of different MPOI data is complex.

Different MPOI data not only has the spatial relation (such as topology relation, position relation and distance relation), but also has the semantic relation (such as neighborhood relation, association relation and dependency relation).

(4) The application of the MPOI data depends on the mobile Internet.

In the daily life, the practical usage of MPOI data is usually in the mobile Internet, which leads to the problems of data storage and data transmission.

4.2. Two-Step Point of Interest Data Fusion Algorithm

In the mobile Internet, MPOI data is multi-source and heterogeneous. In order to multiplex POI information and save storage space, it's necessary to fuse available POI datasets before retrieval. Existing fusion methods can be mainly divided into three types: based on spatial location, non-spatial properties and both [15]. The classic algorithm based on spatial location is One-sided Nearest Neighbor algorithm [15], and the one based on non-spatial properties is Levenshtein Distance (LD) [15]. The last type has an overall consideration on spatial and non-spatial similarities among POI objects, which greatly improves the fusion accuracy. COM-NWT algorithm proposed in literature [15] realizes POI data sets fusion by spatial location and name similarity measurement on both low and high threshold values. Compared with methods of the first two types, it improves fusion accuracy as stated above. However, it ignores the fact that some POI may have the same longitude and latitude. It will lead to lower accuracy. In addition, a complex calculation process reduces the fusion efficiency. Hence, this paper puts forward a two-step POI fusion algorithm, as a perfection of COM-NWT algorithm to improve fusion accuracy and efficiency.

Here is how the algorithm works. In step 1, One-sided Nearest Neighbor algorithm is applied on data records in two POI data sets, and then we can get a primary fusion set [15]. In step 2, LD algorithm is applied on POI data record pairs in the above fusion set, which is to calculate geographic similarity decided by name and address fields. Then we can get the final fusion set and simple set [15].

As different data records may have the same coordinate values in step 1, this algorithm saves all nearest neighbor records, in case of deleting correct fusion sets by mistake. In addition, step 2 only focuses on measuring geographic similarity on the primary fusion set from step 1. As for the records excluded out of the set, the geographic location difference determines the fact that they cannot belong to the same POI object. Hence, fusion efficiency is improved in the precondition of accuracy. Table 1 is the algorithm description.

Table 1. Description of Two-step POI fusion algorithm

	Two-Step POI Fusion Algorithm
Input:	POI dataset *A* and *B*, threshold value ε_1 and ε_2
Output:	Fusion set *F* and simple set *S*
1:	Assign both *F* and *S* as null sets, *SA* as *A* and *SB* as *B* (*SA* and *SB* are intermediate variables here).
2:	For every variable $a \in A$, calculate its nearest neighbor among *B*, where *n* is a positive integer.
3:	If $dis(a,b_1) < \varepsilon_1$, $F = F + \{(a,b_1)\} + \{(a,b_2)\} + ... + \{(a,b_n)\}$, $SA = SA - \{\mathrm{a}\}$, $SB = SB - \{b_1\} - \{b_2\} - ... - \{b_n\}$, where *n* is a positive integer.
4:	For each element (a,b) in *F*, we calculate geographic similarity $sim(a,b)$ by LD algorithm. If $sim(a,b) < \varepsilon_2$, then we assign $F = F - \{a, b\}$, $SA = SA + \{\mathrm{a}\}$, $SB = SB + \{\mathrm{b}\}$.
5:	Assign $S = SA + SB$.
6:	Return *F*, *S*.

Step 1 mainly concentrates on calculating the distance between data records belonging to different data sets. If two sets have *m* and *n* records respectively, then the time complexity in this step is $O(m*n)$. Step 2 mainly focuses on measuring geographic similarity on the primary fusion set from step 1 according to LD algorithm. Assuming the amount of elements in the primary fusion set is *s* in step 1, we need to apply LD algorithm *s* times in step 2, with a time complexity of $O(l*l)$ each time, where l represents the average length of geographic property field. Hence, the time complexity of step 2 is $O(s*l*l)$. So the whole time complexity is $O(mn+sl^2)$.

4.3. Building Geo-ontology Model

Geo-ontology abstracts the knowledge, information and data in the field of geographic information science as an object or entity. The object or entity is widely accepted. Then they can form a system according to their relation. In this way, Geo-ontology services for establishing the relation of geographic information system and geographic reality, also for sharing and organizing the geographic information [14]. According to the principle of building Geo-ontology, we define the Geo-ontology as a quadruple model:

$$Geo\text{-}o = (C, R, I, A) \quad (1)$$

In (1), *Geo-o* represents the Geo-ontology, *C* indicates the set of concepts in the model, *R* means the relation of the concepts or the relation of the instances (including the class inheritance relation, the spatial relation, and the semantic relation), *I* expresses the set of instance, and *A* denotes the set of inference axiom.

Particularly, as the core of the entire model, instances' property expression has two parts in ontology, data property and object property [16]. In the quartet model, data Property is affiliated with *I*， and object Property with *R*. We take extended vocabulary and chain store semantic relation as examples to describe property expression in ontology at below.

(1) Extended Vocabulary: Retrieval accuracy is affected by the existence of polysemy and synonymy in general information retrieval system, which can be solved by extended vocabulary to a large extent. The basic thought is to define a set of keywords related to instances, in combination with data property and cardinality. While users are doing actual retrievals, retrieval requests can be matched to instances' extended vocabulary to get results.

(2) Chain Store Semantic Relation: It's necessary to strictly define relations among POI instances, in order to have a better retrieval result on multimodal POI data. Chain store relation is a common semantic relation among POI data. With the definition of object property "isChainStoreOf", we can control chain store semantic relation among instances. In addition, by setting "isChainStoreOf" as transitive and symmetric, reasoning based on Chain store semantic can be realized at retrieval stage.

We use Upper Level ontology design mode and Seven-Step method to build the POI ontology in the protégé environment. According to Geo-ontology model, the characteristic of MPOI data and the needs of the practical implication, the POI ontology is built. At the same time, the hierarchical structure of POI ontology concept is based on ESRI Company's POI classification document [17]. The concept structure of the ontology is shown in Figure 2.

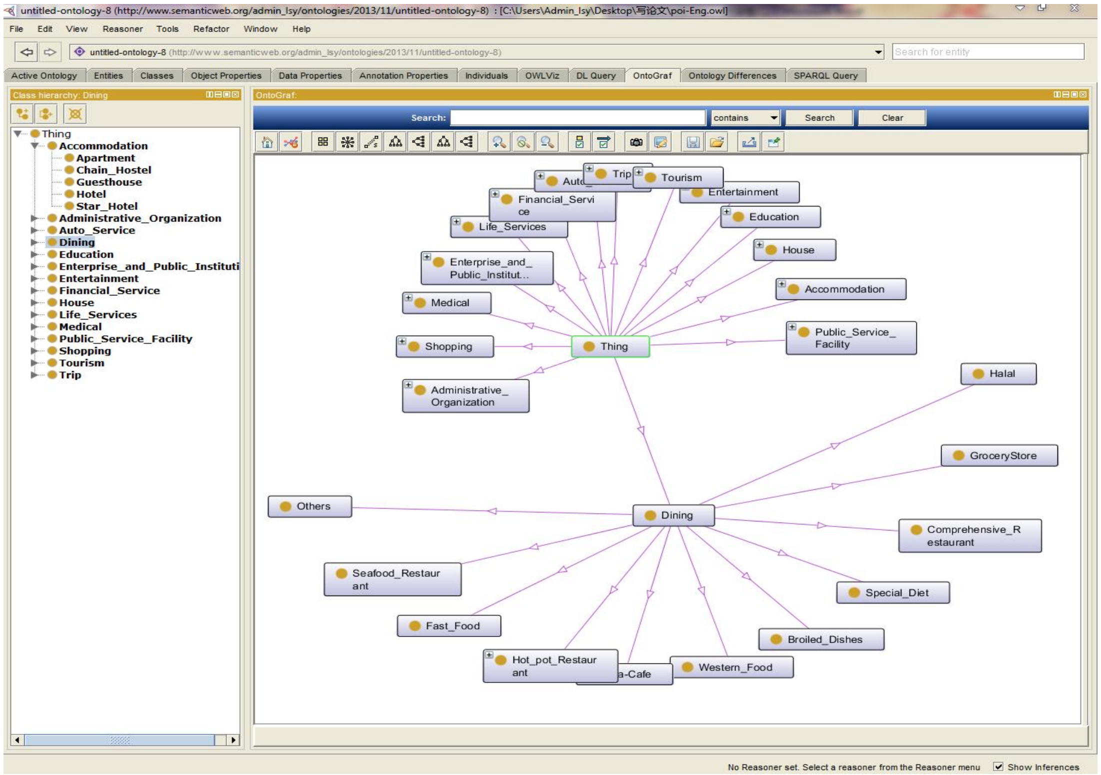


Figure 2. Concept structure of POI Ontology

4.4. Mapping Relation of Geo-ontology Instance and MPOI Data

Multi-source heterogeneous MPOI data has semantic difference, which goes against the uniform organizing and sharing. However, the geographic entity, which is described by the Geo-ontology, has obvious hierarchical affiliation relation and plentiful semantic relation. The realized and conceptualized MPOI data can be abstracted out as an instance of a concept node in the Geo-ontology. The spatial relation of MPOI data also can be described by the Geo-ontology. Thus, we can uniformly describe and map the MPOI data in a reliable and standardized way. Then the cognitive differences caused by the multi-source heterogeneous problem can be eliminated. The Geo-ontology entities (which has semantic description, relation description, extended vocabulary, and one of the many types of media cluster center), can be mapped to the MPOI objects. Figure 3 describes the mapping relation of the MPOI objects and the Geo-ontology entities.

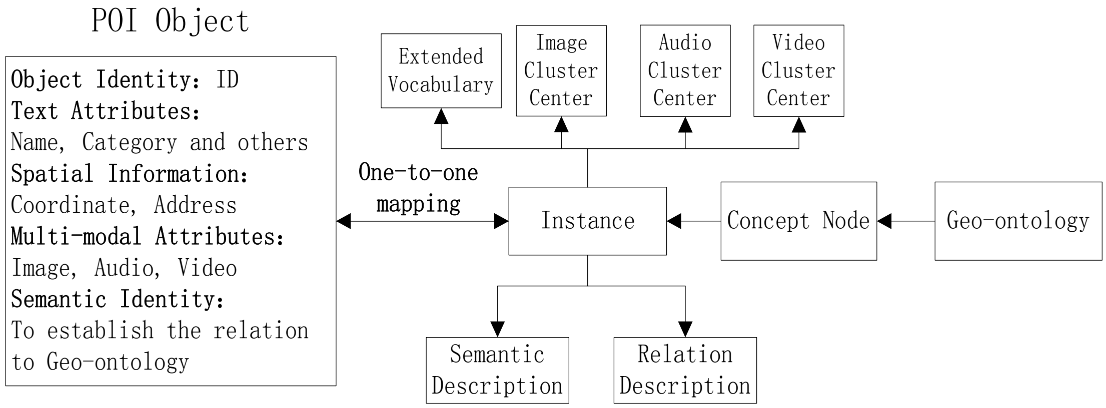


Figure 3. The Relation of the Geo-ontology Instance and the MPOI

Particularly, to effectively organize MPOI data, it's necessary to extract low-level features of types of media objects and cluster them with K-means algorithm. Then we can get several centers and save them. In the subsequent retrieval step, it just needs to call corresponding similarity calculation functions to measure low-level feature similarity among multimedia objects. Table 2 shows the selected low-level features of each type of media and their corresponding similarity calculation functions [18].

Table 2. Features and Similarity Calculation Functions of each Type of Media

	Features	**Similarity Calculation Functions**
Image	256Dhsv color histogram 64-d LAB color coherence vector 32-d Tamura Tamura Orientation	Euclidean Distance
Video	Shot segmentation， creating key frame with K-means clustering algorithm	To calculate video similarity from multiple angles of view
Audio	Centroid Roll off Spectral Flux RMS	Cosine Clustering

4.5. OWL Description of Instance Object

For understanding of Geo-ontology by the computer, there must be an ontology language to express the model in a formalized way. This language should have a good-defined grammar, high-efficient inference support, formalized semanteme, sufficient ability of expression and convenient presentation. OWL language, based on RDF and RDFS, is a sufficient ontology-expression and inferable language. And it has a lot of characteristics, such as local scope, class disjoint, cardinality constraint and particularity. Thus, the OWL language is generally used to describe the ontology [19].

Here, the POI ontology instance describes the semantic and the relation information with other POI. The semantic information mainly contains the category of POI. The relation information chiefly contains spatial relation and semantic relation.

Take the "Jiafu_Hotpot (Huangjueya)" in the "Hot_pot_Restaurant" category as an example. Its OWL description is shown in Figure 4.

```
<!-- http://www.semanticweb.org/admin_lsy/ontologies/2013/11/untitled-ontology-8#Jiafu_Hotpot(Huangjueya) -->

<owl:NamedIndividual rdf:about="http://www.semanticweb.org/admin_lsy/ontologies/2013/11/untitled-ontology-8#Jiafu_Hotpot(Huangjueya)">
    <rdf:type rdf:resource="http://www.semanticweb.org/admin_lsy/ontologies/2013/11/untitled-ontology-8#Hot_pot_Restaurant"/>
    <Latitude rdf:datatype="&xsd;double">106.611315</Latitude>
    <Longitude rdf:datatype="&xsd;double">29.540096</Longitude>
    <ImagePath rdf:datatype="&xsd;string">E:/images/Jiafu_Hotpot(Huangjueya)</ImagePath>
    <Address rdf:datatype="&xsd;string">No.2 of Road Chongwen</Address>
    <isChainStroeOf rdf:resource="http://www.semanticweb.org/admin_lsy/ontologies/2013/11/untitled-ontology-8#Jiafu_Hotpot(Shangxin_Street)"/>
    <isNearAt rdf:resource="http://www.semanticweb.org/admin_lsy/ontologies/2013/11/untitled-ontology-8#CQUPT"/>
</owl:NamedIndividual>
```

Figure 4. The OWL Description of Instance Object--"Jiafu_Hotpot (Huangjueya)"

4.6. Geo-ontology based MPOI Data Organization Framework

The designed Geo-ontology based MPOI data organization framework is shown in Figure 5. In this framework, we collect MPOI data from mobile Internet. After realizing, analyzing, abstracting, and conceptualizing, we map the data to POI objects in the spatial database. Then we organize the MPOI data through the mapping of the geographic entity to the Geo-ontology instance object. This kind of organizing method can conveniently manage the semanteme and the spatial relation of the multi-source heterogeneous MPOI data. As a result, the following MGIS can be realized.

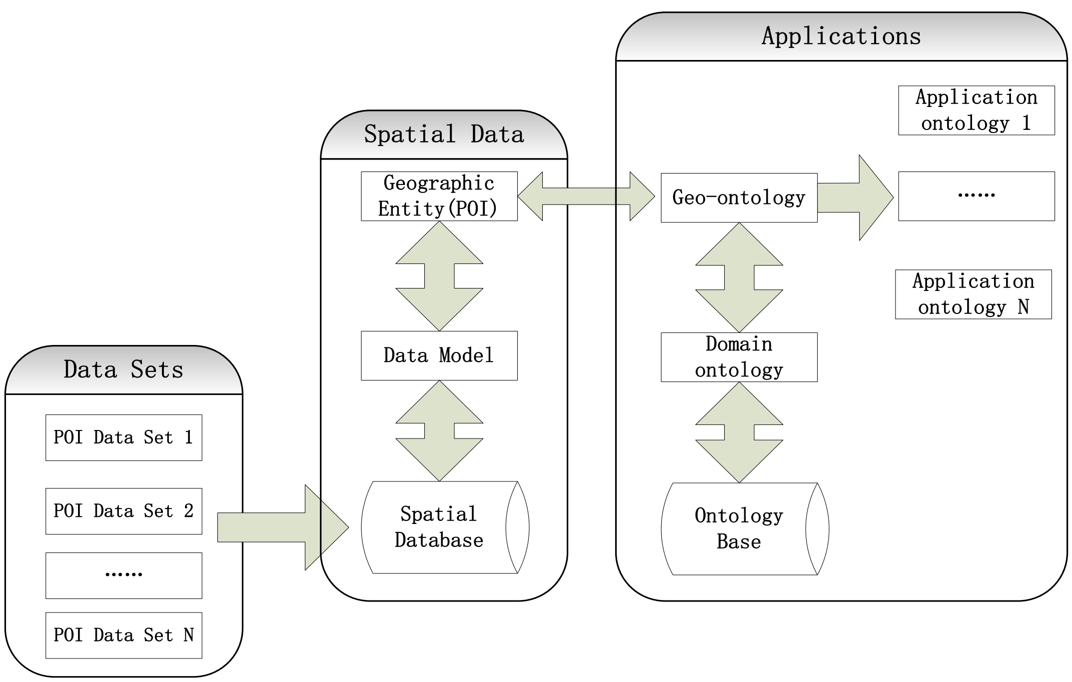


Figure 5. MPOI Data Organization Framework

4.7. Geo-ontology based MPOI Data Retrieval Process

After preprocessing the multi-source heterogeneous data in the offline phase, we come to the actual retrieval of online stage. The online phase process of the Geo-ontology based MPOI retrieval method is as shown in Figure 6. The specific process is described as follows:

Step1: Users submit the retrieval requests;

Step2: Call context-aware module for data acquisition;

Step3: Judge the category of the retrieval requests. If it is text, go to Step4. Otherwise, go to Step5;

Step4: Match the retrieval requests and instances in POI ontology based on extended vocabulary, and then get the result set ***R1***. If ***R1*** is null, end the process. Otherwise, go to Step6;

Step5: Extract the low-level features of the retrieval requests, measure the similarity between them and corresponding media centers of POI instances in ontology library, and then get POI instances whose similarity is larger than threshold value, form result set ***R1***. If ***R1*** is null, end the process. Otherwise, go to Step6;

Step6: Sort ***R1*** through context-aware data fusion to get a new result set ***R2***;

Step7: Determine if semantic reasoning is necessary. If not, ***R2*** is returned as the retrieval result and then the process ends. Otherwise, go to Step7;

Step8: Call the semantic reasoning mechanisms for the results in ***R2*** to generate ***R3***, end the process.

5. Experimental Evaluation

In order to verify the effectiveness of the proposed Geo-ontology based MPOI retrieval method, the text and image retrieval requests are taken as examples. The context-aware process is mainly used to aware location. The data sets were gotten from Dianping[1] and Meituan[2] by reptiles. Experimental environment for running is Intel (R) Core (™) i3-3220 CPU@3.30GHz, memory 8.00GB, the operating system is Microsoft Windows 7 Professional Edition. The development environment includes Visual C++6.0, JDK 1.7.0_51, Eclipse standard Kepler Service Release 2, apache-jena-2.11, JavaCV 0.2, OpenCV 2.4.2 and protégé 4.2.0.

[1] http://www.dianping.com/
[2] http://cq.meituan.com/

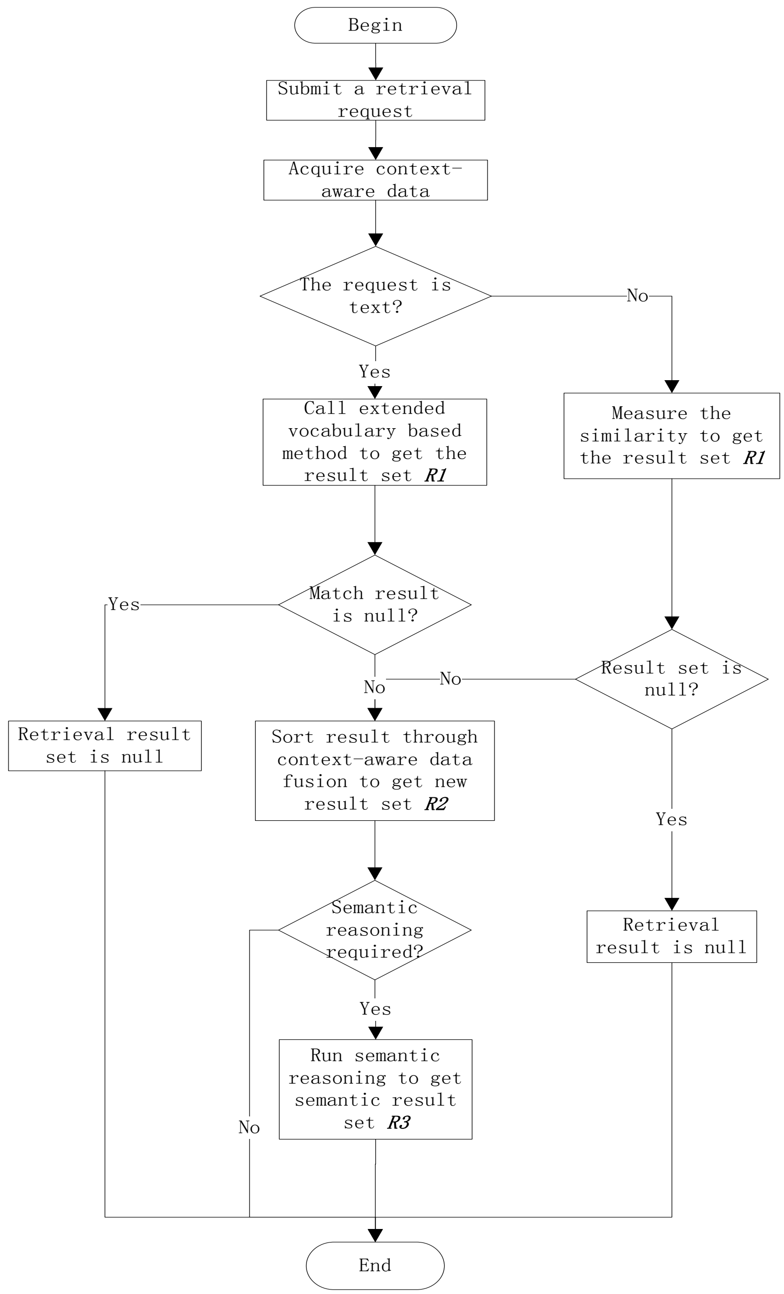


Figure 6. The Flow Chart of the Online Phase

5.1. Performance of Two-Step Point of Interest Data Fusion

Precision rate, recall rate and F1 are the international authoritative and universal evaluation criteria to measure the quality of information retrieval and classification algorithms. Precision rate and recall rate are affected by each other. Ideally we hope that both of them can have high values. However, they generally move in contrary directions. Hence, we should try to improve precision rate in the precondition that recall rate stabilizes at a high value. F1 is a comprehensive evaluation index, whose value can response the performance of the algorithm directly [15]. To verify the effectiveness of the proposed algorithm, F1 and runtime are used as the evaluation criteria. According to several trials, the threshold of the One-sided Nearest Neighbor phase is determined as 0.0, and the threshold of LD algorithm is 0.6.

Experiment 1: The performance comparison of two-step POI fusion algorithm and COM-NWT under different coincidence degree [15].

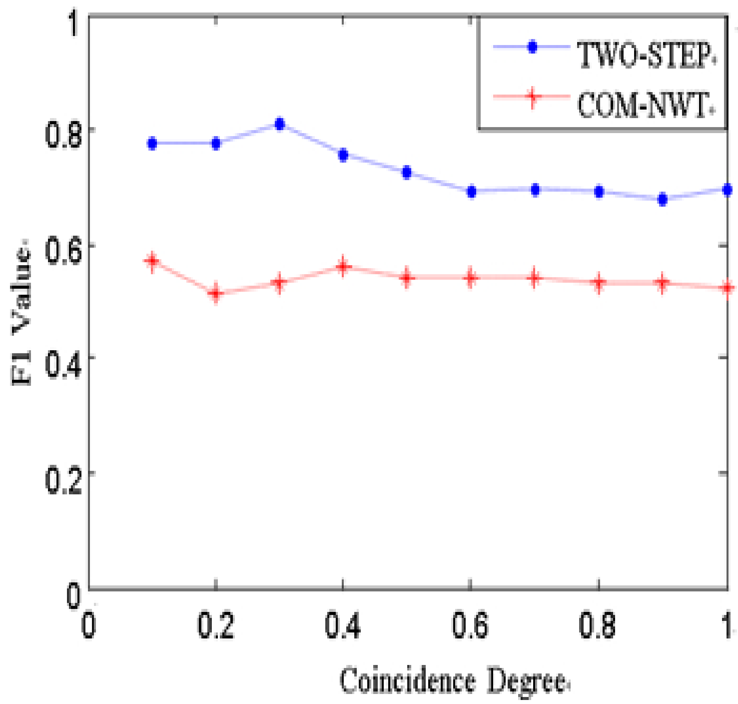


Figure 7. The F1 Value of Two Algorithms in Different Coincidence Degree

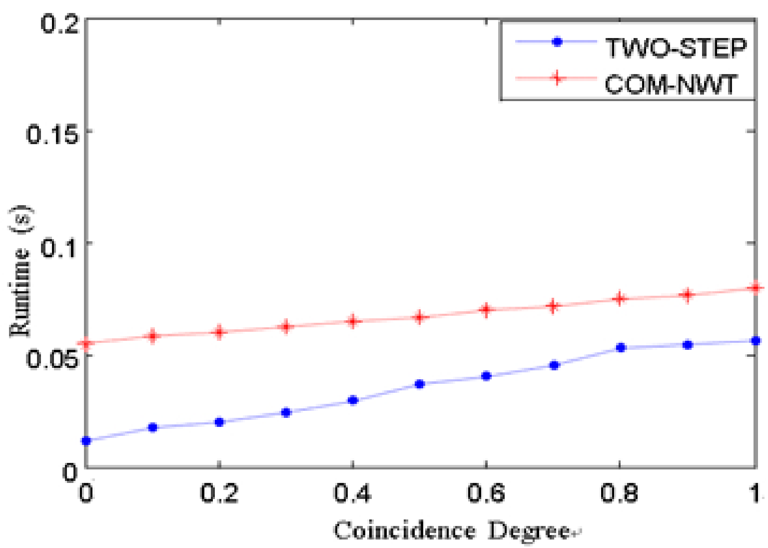
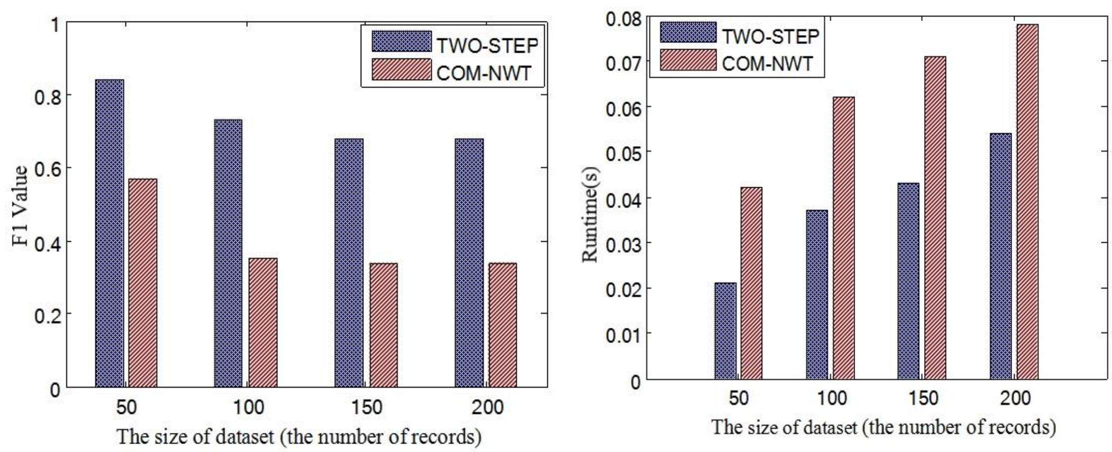


Figure 8. The Runtime of Two Algorithms in Different Coincidence Degree

According to Figure 7, the F1 of two-step POI fusion algorithm under different coincidence is higher than that of COM-NWT in certain extent. It shows that the proposed algorithm can provide better integration, and the algorithm is not sensitive to coincidence, which is able to meet the needs of different coincidence degrees. As shown in Figure 8, at lower coincidence degrees, the running time of the proposed algorithm is much shorter than that of COM-NWT. As the degree of coincidence increases, the running time of the proposed algorithm is tending towards stability and it's always lower than that of COM-NWT.

Experiment 2: The performance comparison of two-step POI fusion algorithm and COM-NWT under the same coincidence degree with different data set sizes.



(a) F1 Value (b) Runtime

Figure 9. Performance Comparison with Different Data Set Sizes

Figure 9 shows the performance of two algorithms at the 0.5 coincidence degree with different data set sizes. According to (a), in different data set sizes, the F1 of the two-step POI fusion algorithm is able to maintain a higher value. According to (b), as the data set size increases, the running times of the two algorithms are gradually increasing, but the one of the two-step POI fusion algorithm is always lower than that of COM-NWT.

The above experiments prove that the two-step POI fusion algorithm achieves improvement on overall performances, compared with COM-NWT algorithm. On the aspect of effectiveness, all nearest neighbors are saved in step 1 in case of deleting correct fusion results by mistake. In addition, the geographic similarity in step 2 is decided by both address and name property, which is able to eliminate the defect of determining non-spatial properties similarity with only name field. As for runtime, when measuring the geographic similarity, step 2 doesn't consider the simple sets generated in step 1, and also removes the measurement of low threshold name property similarity [15], which has high complexity but low effectiveness. In this way, fusion efficiency is improved.

5.2. Applications of Geo-ontology based MPOI Data Retrieval

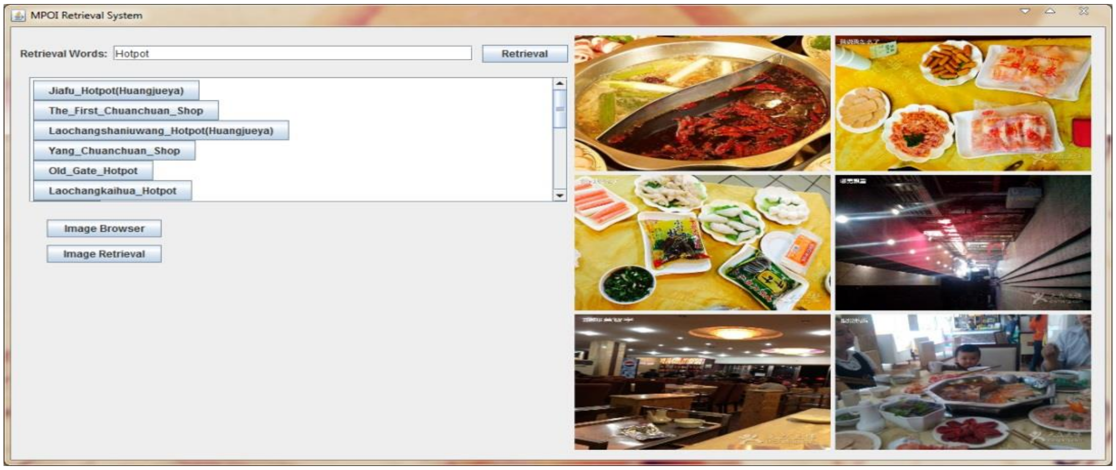


Figure 10. Retrieval Result

Figure 10 shows the retrieval result when the text retrieval request "Hotpot" is submitted at the new gate of Chongqing University of Posts and Telecommunication. Because of the extended vocabulary, the chuanchuan shops and shabu-shabu shops are also listed in the result. The images in the right part are the corresponding image results of Jiafu_Hotpot(Huangjueya). We can also submit an image retrieval request at the lower-left corner. It is clear that the results are all desirable and the proposed method can implement cross-media retrieval. At the same time, a large number of experimental results show that the proposed method can realize the location-aware based retrieval and the semantic reasoning mechanism based retrieval.

6. Conclusions

Traditional multimedia retrieval methods cannot meet the needs of the MPOI data access in the mobile Internet. In this paper, we analyze the data characteristics of MPOI in the mobile Internet, and propose a Geo-ontology based retrieval method for MPOI data. It's proved by the experiment results that the method can realize MPOI retrieval effectively and support customized retrieval. In the future, we need to establish context-aware model and also consummate semantic and spatial relation which can bring a better MPOI retrieval. We hope that all the work can provide certain references for the development of geographic information service in mobile Internet.

Acknowledgment

This work is supported by National Natural Science Foundation of China (41201378), Natural Science Foundation Project of Chongqing CSTC (cstc2012jjA40014), and Doctoral Startup Foundation of Chongqing University of Posts and Telecommunications (A2012-34).

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