Exploring a Hybrid of Geospatial Semantic Information in Ubiquitous Computing Environments

Raghda Fouad[1], Mohamed Hashem[2], Nagwa Badr[3] and Hanaa Talha[4]

**[1] Faculty of Computer and Information Sciences, Ain Shams University
Abbasia, Cairo, Egypt**

**[2] Faculty of Computer and Information Sciences, Ain Shams University
Abbasia, Cairo, Egypt**

**[3] Faculty of Computer and Information Sciences, Ain Shams University
Abbasia, Cairo, Egypt**

**[4] Faculty of Computer and Information Sciences, Ain Shams University
Abbasia, Cairo, Egypt**

Abstract

Nowadays, geospatial information plays a critical role. Searching and obtaining geospatial information, however, is a difficult and time-consuming task. The Semantic Web promises to facilitate this by improving the capability to search for information by better expressing the meaning of search queries. Combining the two approaches to create a Geospatial Semantic Web is an idea that is gaining acceptance in both areas. Here, we present a prototype that promises to prove that the meshing of these two areas is a promising field in conjunction with information retrieval and ubiquitous computing. The aim of this prototype is to exploit geospatial semantic information retrieved from multiple data sources in a mobile environment. Our prototype uses three geospatial data sources: GeoNames, LinkedGeoData, and DBpedia. Experimental results show how the merging of the geospatial data sources and the use of more than one level of indexing is more effective in terms of recall and precision.

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1. Introduction

The idea of the Semantic Web [1] proposes that it is "a web of data that can be processed directly or indirectly by machines", thus bringing a higher degree of automation in exploiting and retrieving data in a meaningful and more useful way. Semantics is captured by associating formal descriptions to provide well defined meaning to data and other web resources so that information processing (retrieval or integration) can be based on meaning instead of on mere keywords. The W3C Semantic Web Activity Working Group [2] has been working on a series of standards such as the Extensible Markup Language XML, the Resource Description Framework RDF, and the Web Ontology Language OWL. Compared to normal keyword search, a semantic approach in search leads to higher quality of results and more relevant information.

On the other hand, the Geospatial Semantic Web provides better support for geographic information that the basic Semantic Web research has not addressed. In particular, there are three basic dimensions for geographic information on the semantic web: (a) Professional: which is structured geographic information stored in geographic databases which are indexed in web pages [3], (b) Naïve: which includes the retrieval of unstructured informal geographic information in web pages, and (c) Scientific: which is the geographic information science papers, models, and theories. Thus, establishing geographic information on the semantic web is a challenge worth research.

Another motivation behind this work is the fact that there is an increasing role and importance of ubiquitous computing and mobile environments in our daily lives. This implies the need for new solutions. Nowadays, the trend is leaning towards processing more and more information using mobile phones. The first reason is because mobile phones have increased in terms of power and space capacity and the second reason is that mobile phones serve as personal computers on the go, offering mobile users all the processing and information they need anywhere.

This paper is structured as follows: Section 2 describes the background of the work. In Section 3, we describe the proposed system's architecture. In Section 4, we demonstrate how the system is implemented. In Section 5, experimental results are shown. The last section contains concluding remarks and recommendations for future work.

2. Background

With the growth of the World Wide Web has come the realization that the currently available methods for finding and using information on the World Wide Web are often insufficient. In order to move the Web from a data repository to an information resource, a totally new way of organizing information is needed. The idea of the Semantic Web promises better retrieval methods by incorporating the data's semantics and exploiting the semantics during the search process. Such a development needs special attention from the geospatial perspective so that the particularities of geospatial meaning are captured appropriately. The creation the Semantic Geospatial Web [3] needs the development multiple spatial and terminological ontologies, each with a formal semantics; the representation of those semantics such that they are available both to machines for processing and to people for understanding; and the processing of geospatial queries against these ontologies and the evaluation of the retrieval results based on the match between the semantics of the expressed information need and the available semantics of the information resources and search systems. This will lead to a new framework for geospatial information retrieval based on the semantics of spatial and terminological ontologies. By explicitly representing the role of semantics in different components of the information retrieval process (people, interfaces, search systems, and information resources), the Semantic Geospatial Web will enable users to retrieve more precisely the data they need, based on the semantics associated with these data.

Geospatial information is critical to every user [4]. Accessing the correct information is a complex task that often requires that the user understand more about the geospatial domain than their knowledge provides. Enabling a query process that allows effective retrieval of the required information is a positive step. Analysts often need to deal with geospatial information in the course of their duties, such as ascertaining where events may occur and what facilities or logistically important environmental elements are present in an area of concern.

LinkedGeoData [5] transforms and publishes the OpenStreetMap data according to the Linked Data principles to add a new dimension to the Data Web: spatial data can be retrieved and interlinked on an unprecedented level of granularity. This enhancement enables a variety of new Linked Data applications such as geo-data syndication or semantic-spatial searches. The dynamic of the OpenStreetMap project will ensure a steady growth of the dataset.

DBpedia [6] is a community effort to extract structured information from Wikipedia and to make this information available on the Web. It allows users to ask sophisticated queries against datasets derived from Wikipedia and to link other datasets on the Web to Wikipedia data. It is a major source of open, royalty-free data on the Web. By interlinking DBpedia with other data sources, it could serve as a nucleus for the emerging Web of Data.

The GeoNames [7] geographical database contains over eight million geographical names and consists of 7 million unique features and 2.8 million alternate names. All features are categorized into one out of nine feature classes and further subcategorized into one out of 645 feature codes. The data is accessible through a number of web services and a daily database export. GeoNames is already serving up to over 11 million web service requests per day. GeoNames is integrating geographical data such as names of places in various languages, elevation, population and others from various sources.

3. Architecture

Earlier work [8] proposed a hybrid of three location-rich data sources to be accessed and queried by mobile users based on their location as received via the GPS module attached to the mobile device. On system startup, the current location of the mobile device is captured from the GPS device and is displayed on a map. Once this is done, the three location-rich data sources, GeoNames, LinkedGeoData and DBpedia are queried for nearby locations of interests based on the longitude and latitude of the current location. Then, the results for the three data sources are parsed merged and displayed on the map to aid mobile uses to disambiguate their current place.

Fig. 1 shows the final architecture of the discussed prototype to serve the searching process use case. This architecture demonstrates that the integrated data sources model can serve as a collective geospatial source to query the geospatial semantic web using a mobile device. The mobile user will use this prototype to explore the nearby landmarks around him according to the detected current location and to query the returned nearby results. Multiple levels of indexing are used to assure accuracy of the search results and moreover, better recall.

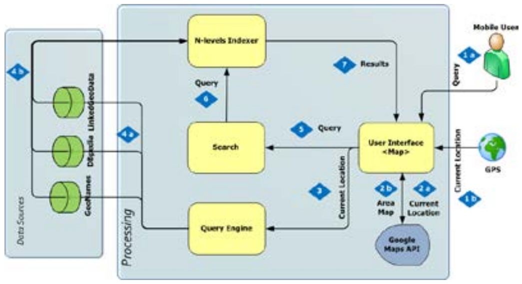

Fig. 1 Architecture of the Prototype for the Searching Process Use Case

The User Interface <Map> module accepts the mobile users' query along with the current location provided by the attached GPS device. Using the longitude and latitude of the current location, a map of the current area is displayed using a Google Maps API [9]. The Map module also serves a result viewer for the results returned from the N-levels Indexer module.

The Query Engine module uses the detected current location of the mobile user as inputs to reformulate the query to be sent to the three data sources. The Query Engine sends the requests to GeoNames, LinkedGeoData and DBpedia simultaneously to return the landmarks and places nearby the current location of the mobile user.

The N-levels Indexer module receives the results returned by each of the three data sources on its own. The first step is to parse the received outputs individually. Next, the N-levels Indexer module merges the parsed results into one set of results to be indexed into multiple levels for later use by the Search module.

The Search module accepts the query of the mobile user from the User Interface <Map> module. The Search module uses this search query to query the N-levels Indexer to return the search results matching the entered search query.

4. Implementation

The prototype's initial implementation is done on an iPhone, written in Objective-C [10] hosting an underlying Google Maps API. Experimental results of previous work examined precision and recall of the proposed prototype. For the aim of improving these information retrieval measures, we introduce semantic levels [11]. Semantic levels provide information about word meanings, as described in a reference dictionary, and named entities. Indexing will be performed at multiple separate levels: keyword, senses (word meanings), and entities. Our system will be able to combine keyword search with semantic information provided by the two other indexing levels.

Below is an attempt to detail the three indexing levels and to explain what every level does and how it works. Each level uses the results received from the data sources to index it in a different way thus providing more accurate results in the search process.

4.1 Keyword Level

The keyword level is the entry level in which the location is represented by the words occurring in its name. It will contain an inverted index structure that will link GPS locations (longitude and latitude pairs) with all the key words that are relevant to the location, that it, any key word that is contained in the name of the location as returned by any of the three data sources. For instance, the location with the following latitude and longitude pair (30, 31) is Maadi Grand Mall, a shopping mall in Maadi, a district in Cairo, Egypt. The following location will be indexed as shown in Fig. 2.

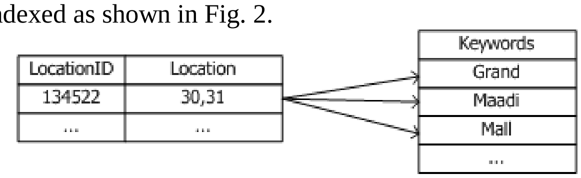

Fig. 2 Linking between Locations and Keywords in the Keyword Level

4.2 Word Meaning Level

This level is represented through synsets words obtained by WordNet [12, 13], a semantic lexicon for the English language. Nouns, verbs, adjectives and adverbs in WordNet are grouped into sets of cognitive synonyms (synsets), each expressing a distinct concept. Synsets are interlinked by means of conceptual-semantic and lexical relations. WordNet's structure makes it a useful tool for computational linguistics and natural language processing.

Hence, each word of the query can be further expanded into its synonym words to generate more query words and thus more results, enhancing the recall of the search results. Fig. 3 displays an example of the relationship between the keyword (as entered by the mobile user) and its synset (synonym words) in the physical database.

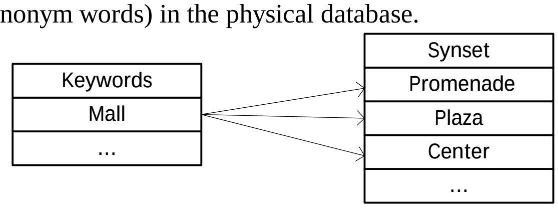

Fig. 3 Linking between Keywords and Synsets in the Word Meaning Level

4.2 Named Entity Level

This level consists of entities recognized into the location name text. The integration of named entities and domain ontologies permits some reasoning over location name text. The scope of the work entailed in this paper does not include this level at this time. Yet, this level is left for future works.

5. Experimental Results

5.1 Experimental Conditions

The proposed system is implemented in Objective-C using Xcode IDE, iOS SDK 4.1 and iOS simulator. Experimental environments consisted of a built-in GPS unit attached to the iPhone used.

5.2 Introduction to Experimental Results

Fig. 4 shows an example of mobile semantic retrieval using the proposed architecture. Fig. 4 (a) shows the initial screen of the proposed system with the map centered on the current location of the mobile user with a zoom extent of 1 kilometer. The current location of the mobile user is captured using the built-in GPS module in the used iPhone. The user enters the search query in the search area and presses the search button. The search query entered is composed of multiple words that describe a location that the mobile user is interested to find.

In Fig. 4 (b) the system displays the search results queried from the three geospatial semantic data sources: LinkedGeoData, DBpedia and GeoNames according to the mobile user's entered search query. The search process relies on the underlying N-Levels indexing process that is composed of the keyword level and the word meaning level.

Fig. 4 (a) Mobile User Entering Search Query, (b) Search Results

5.3 Information Retrieval Test

To evaluate the proposed system, we used 100 keyword queries and calculated the precision and recall of two systems; our proposed system and Siri [14], a personal assistant application for the iOS which uses natural language processing to answer questions, make recommendations, and perform actions by delegating requests to an expanding set of web services. The aim is to perform a comparison between the two systems. The 100 keywords were chosen so that they are all of known landmarks in California, America.

Precision is a test that shows how accurate the search results are in comparison to the entered keyword query. A result is deemed as relevant if the user thinks it is of any relevance to the keyword query entered in search process. Precision is calculated as the number of results deemed as relevant in comparison to the number of results retrieved. Recall is a test that shows how well the search results yields. Recall determines how many relevant results are retrieved in the search process. The more relevant search results are presented, the better the retrieval process is. Precision and recall measures complement each other, that is, the higher the precision of an information test, the lower its recall is and vice versa. This is due to the fact that the more results presented, the less accurate they are.

Fig. 5 and 6 below display a comparison between the recall and precision measures computed of the two systems.

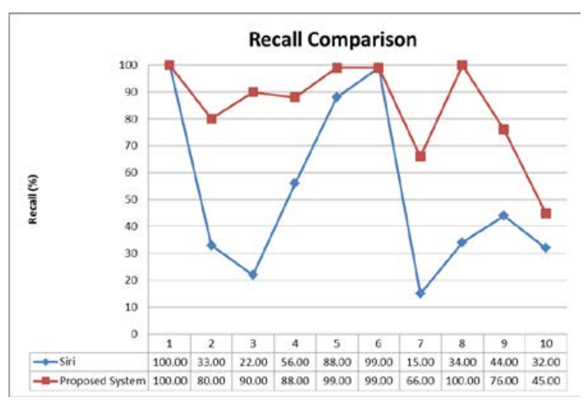

Fig. 5 Comparison between the Recall of our System and Siri

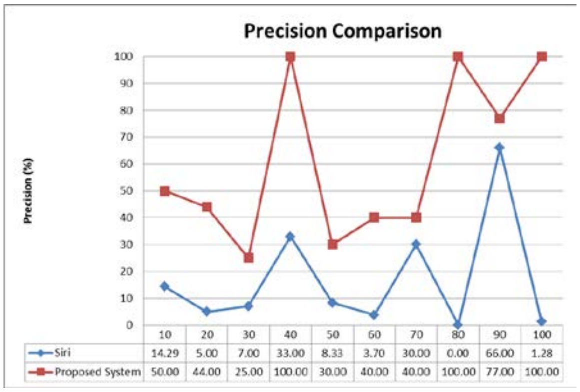

Fig. 6 Comparison between the Precision of our System and Siri

As the graphs above show, the precision of our proposed system exceeds that of Siri, that is because of the merging between the keyword search and semantic search in the N-levels indexing process. Moreover, the word meaning levels provides for more query expansions for the entered query which improves the recall of our system.

6. Conclusions

We have introduced an implementation of a prototype that aims to explore and examine the geospatial semantic information available and make the best use out of it. The prototype is composed of a location-centric mobile client application that provides the mobile user with rich location information around them. Based on the current GPS position of a mobile device, the application renders a map indicating the mobile devices current location and nearby locations of interest from the three data sources, GeoNames, LinkedGeoData and DBpedia.

Furthermore, the mobile user can search for locations of interest and view the search results in a timely manner. Starting from this map, users can explore information about locations and can navigate interlinked data sources.

Future work includes the expansion of the multi-level indexing to include the named entity level that consists of entities recognized into the location name text. The integration of named entities and domain ontologies permits some reasoning over location name text.

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