# Spatial Information Retrieval from Images using Ontologies and Semantic Maps

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**Abstract.** Cameras provide integrated GPS technology which makes them a powerful sensor for geographical context related images. They allow wireless connection to computers and the images can be automatically transferred to a PC or can be integrated into a GIS system. In this paper we propose an approach for spatial information retrieval from images using the concept of ontologies and semantic maps. The term of ontology is used in our case to describe spatial domain knowledge to enhance the search capability and image annotation. The objects are represented by their location in semantic maps. We describe a developed prototype system with a database design for ontologies and semantic maps. We demonstrate the automatic image annotation and the visualization of the spatial queries. The system is oriented to the area of culture and tourism and provides a user friendly interface.

**Keywords:** ontology, semantic, image retrieval, spatial search, database design, automatic image annotation, tourism application.

## 1 Introduction

Images are a powerful visual aid for displaying different kinds of information. With the use of digital cameras, a huge amount of images are produced. The development of powerful digital cameras has lead to the connection of the cameras with other devices like GPS receivers. The cameras have new capabilities like Wi Fi connection to remote computers and the images can be directly transferred. The users can also save in the cameras during pre-processing some information about the images, the environment that will be photographed, or about some interesting objects. The modern cameras produce images of high resolution with great quality and provide powerful tools for performance enhancement.

The images with their GPS information can serve as a useful tool for spatial information extraction. With an appropriate framework, the users can achieve an automatic spatial information retrieval. The semantic context of the images can be extracted and saved and, in principle, every user can have access to it and display it. This challenges the users to find new ways to use the above information for professional and personal reasons in a flexible and easy-to-use process.

Spatial information retrieval is concerned with the selection of geo-related information. It is the aspect of information retrieval that emphasizes the spatial context. The goal of this paper is to describe an approach for spatial information retrieval using the semantics and the location of information objects. Our approach is based on the assumption that the objects with their locations are represented on the basis of exact coordinates. There are spatial relations between objects which are metric (distance) or ordinal relation (direction). We use ontologies to overcome the problem of semantic heterogeneity and semantic maps in order to identify objects that have semantic meaning in a specific location. We describe a prototype for spatial information retrieval by integrating the images with semantic information. The current prototype is demonstrated for culture and tourism purposes.

### 1.1 Related Work

Spatial information retrieval is widely used in different kind of applications, like environment protection, urban transportation, etc. [10]. In general, it is related to spatial queries that refer to location, interesting objects, features of objects, or historical information. There are different approaches for spatial information retrieval depending on the data sources. In the area of Digital Libraries, a system for automatic processing is introduced for geospatial information [11]. It is based on the place names, their attributes and some spatial relationships between the objects. The indexing and retrieval methods for geo-referenced information in Digital Libraries to provide efficient access has also been examined [12].

The use of ontologies for image annotation is proposed in different approaches [6, 7, 8]. The main goal of using an ontology is to use the background knowledge in terms of assigning words for improving the automatic image annotation, indexing, searching and retrieval. In the Geographic Information Systems society, the ontological modeling of spatial objects and relationships is a useful method for search and analysis of spatial data [13]. An upper level ontological modeling is also proposed for thematic, temporal and spatial queries in the spatial domain [14]. Another approach proposes the use of ontology of place which combines coordinate data with spatial relationships between places [3]. For spatial information retrieval on the web, the ontological modeling with machine learning techniques for the extraction of geographic information of web documents has been introduced [2]. For the same purpose, the domain and geographical ontologies are supposed to enrich the web documents with well defined meaning and to expand the spatial query techniques [9].

In the application of culture and tourism there are tools that provide geographic information functionalities by combining the location and topological relationships of spatial objects and use maps to present them [15]. There are also systems which use the GPS information to provide multimedia tourist information [4].

## 2 An approach for spatial information retrieval

A very big problem with annotation and indexing of (multimedia) information is the inconsistency of the names used for the annotation. If text words are used for annotation of an image there will be problems of different spellings, problems of synonyms, problems of knowing or remembering a word that has been used for annotation. In addition, different people will use different words to index the same object or different words to search for it. The result is that the search very often fails giving small recall and precision.

### 2.1 Ontologies

Ontologies have the advantage that they are "common conceptualizations of a knowledge domain", which means that they are accepted terms by a community for describing the knowledge of a domain. If an ontology is known and used by everybody for annotating information and searching for information, then all the above problems of search are eliminated. Thus the use of ontologies for annotation and search is very important for the community of users.

### 2.2 Semantic Maps

Semantic maps are digital maps which have the capability to associate for each pixel of the map its coordinates. These objects have their location based on the two dimensional coordinates of GPS positions associated with their spatial footprints and a common conceptual meaning. They are important because they give semantic information about objects. This information typically includes the type of the object and the name of the object. Both the type and the name exist in an ontology of objects which is of a particular kind.

In particular the semantic map is essentially a database of important objects in a geographic space which have representations on maps. With each important object the GPS coordinates of its footprint which gives the location are recorded in the database along with the name of the object (and possibly additional information about it). At the time of image taking the GPS coordinates of the user are recorded also in the camera.

Semantic maps use the concepts of one or more ontologies to annotate important objects of the real world that have a map representation. In addition to the names that they use (which are taken from the ontologies), they also register their location of those concepts. The advantages of the semantic maps are:

- they can be searched using ontology terms,
- they can visually show on the top of a map the location of important objects of the area (allowing interaction with them),
- they can visually show on the top of a map image the location of the important artifacts of an area,
- they can inform the user about the existence of an important artifact near his current location and
- they can also provide to the user all the information about the artifact, like its kind (ontology name), its type and information about the specific instance.

They are used later on for the detection of the nearest to the user object of the Semantic map, and the transfer of its attributes (name, descriptions, etc.) to the image attributes of a database.

## 3 The Developed Prototype System

The objective of the prototype developed is to show the use of ontologies and semantic maps in the automatic annotation of images taken by a user while traveling as a tourist.

In this approach we consider the Entity Relationship Model (ER) [1] as a basis for a successful use of a powerful ontology and semantic map server. The ontology database contains a number of ontologies (fig. 1). Each ontology is composed of a hierarchy of semantic types. A semantic type has a name and a set of semantic attributes. The semantic attributes may be different for each type and they may have a name and a value. It can accommodate ontologies of different kinds. Each ontology has a unique identifier and an ontology name and a number of semantic types. Each semantic type may have instances, usually called individuals in the semantic language terminology. Since there may be more that one objects with the same name the system should guarantee unique identification. The location of the object can be used to uniquely identify the particular object.

The semantic map database has a number of semantic maps (fig. 1). Each semantic map has a number of pixels of the map that correspond to GPS coordinates. Each semantic map also has a transformation matrix associated with it for transforming pixels to GPS points. It has information about semantic map individuals. A semantic map individual is an important object with a spatial location which is described by its GPS footprint which is actually the GPS locations of the polygon of its footprint on the map.

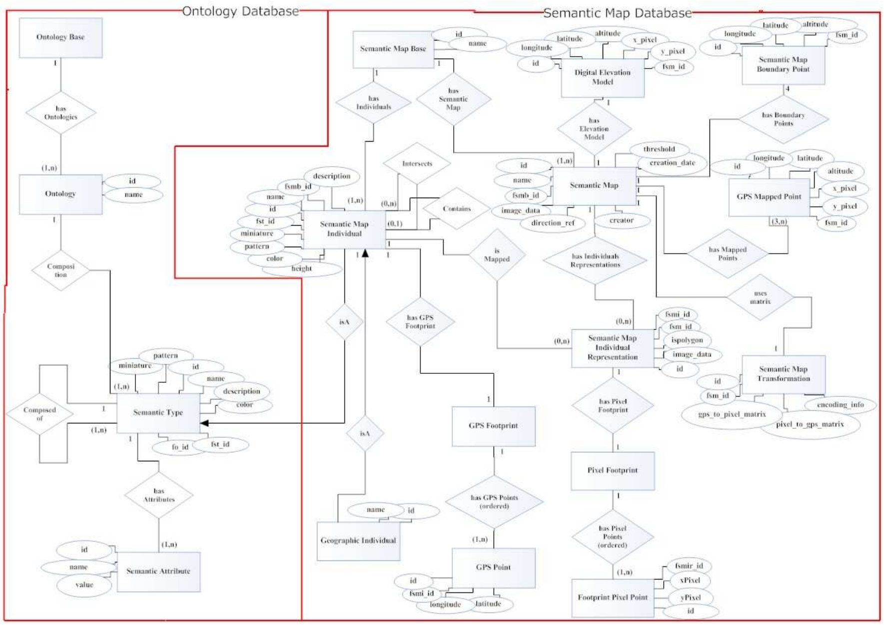


**Fig. 1.** The Entity Relationship Model of a Powerful Ontology and Semantic Map server.

Interfaces that are based on semantic map information can support spatial queries such as "*show the location of all the semantic objects on a map*", "*show the location of all the semantic objects of a particular kind on a map*", "*show me the nearest semantic object of a particular kind*", "*show me the name of the object nearest to my current GPS position*", "*give me all the images of a specific object*", etc.

## Design and Implementation of the Prototype

The prototype considers a user of a Ricoh camera equipped with a GPS receiver. The user walks around in a city and takes images of near-by buildings. Together with each image the GPS location is recorded. When all the images are downloaded from the camera to a laptop the software developed finds the GPS location from where the image was taken, it has access to a semantic map and calculates the distance to the nearest semantic object and uses the information about this in order to annotate the image.

We have applied this prototype in the city of Chania, Crete. The map of Chania was downloaded from Google Earth, as a platform for spatial information presentation [5]. Important semantic entities were recorded together with their location. An overlay layer was implemented to show the location and shape of every semantic entity on top of the map. As the mouse of the laptop moves on top of the map, the location of the mouse is also shown, and the nearest objects of the map to the mouse position are highlighted. Images taken while walking on the city can be automatically annotated when transferred to the laptop.

Another function of the implemented system allows to browse through the images that exist in the laptop and see their location, as well as all the semantic information that has been associated with them through the access of the semantic map. The screen below shows a demonstration of semantic maps (fig. 2). A Google map of the city of Chania has been downloaded and used as a basic image for creating a semantic map. With the image we associate GPS coordinates.

The ontology database contains an ontology of geographic locations (simple ontology constructed by us for demonstration purposes, but any formal ontology can replace it), and an ontology on archeology. The screen (fig. 2) shows the objects of the database shown projected with a red color on the semantic map.

The demonstrator allows the user to select with the mouse one of those semantic objects and see the images associated with it. In this screen shot (fig. 2) one semantic object has been selected and its object has been turned to green. When a semantic object is selected, the images that have been taken with the Ricoh camera become available. In the screen shot shown, the semantic object that has been selected from the map is an object from the ontology "geography" which has a type "public garden", and the name of the individual is "public garden of Chania". All this information is information that has automatically been extracted from the ontology and semantic map database based on the GPS coordinates of the camera.

This screen (fig. 2) shows some of the functionalities offered: the capability to have more than one ontologies in the database (like geography), each ontology has types (like Public Garden), and types have individuals (like public garden of Chania). It demonstrates the capability to create semantic maps that show all the individuals of all the ontologies as active objects that can be selected on top of the map. In this semantic map of Chania we can demonstrate semantic types from the ontologies geography and archeology at the same time. Alternatively it is easy to generate a semantic map (fig. 2) that will be personalized so that it only contains types (active objects) from the ontology geography. It demonstrates the capability to associate images taken with the Ricoh camera with semantic objects, and access all the images related to a semantic object with a simple interface. It also displays the capability to annotate the images taken with information that has been extracted from the ontology and the semantic maps.

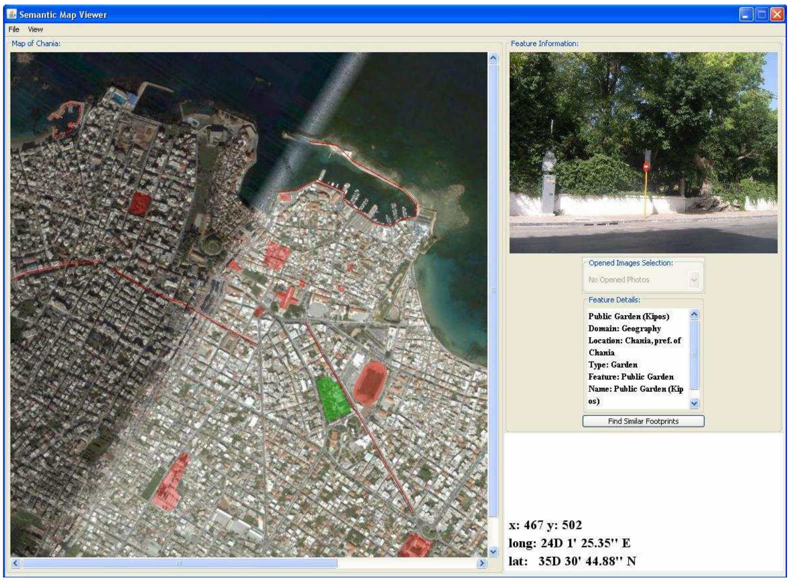


**Fig. 2.** A screen shot of a semantic map. The semantic objects belong to an ontology, they have a type and a name. They also have a location that is used to display the semantic objects of the ontologies on top of any map. The semantic objects are shown in red.

The same ontology browsing interface could allow the user to select certain types (like Byzantine churches and Venetian Forts) and ask the system to automatically create a semantic map with this information for the user. It's very important that the system can accommodate any number of ontologies with their types. There is no dependence from the specific ontologies used.

## 4 Conclusions

We presented an approach for spatial information retrieval from images in an open and user friendly environment. It provides the users the possibility to search and find spatial related information about interesting objects. The approach is based on the use of ontologies to overcome the semantic heterogeneity and semantic maps to better visualize and handle the extracted spatial information. For the implementation of the system we used a digital camera integrated with GPS location information. The demonstration is done for tourism and culture purposes. We experimented with the usage of the Ricoh 500SE camera with GPS capability to automate the information retrieval of the images.

We have also developed a complete database design for the server of ontologies and semantic maps. The prototypes demonstrate the automation in the assignment of annotation information related to important objects. The prototype has the capability to present the information of the semantic map database on top of maps, as well as to show the current GPS position of the user on top of the same maps. In addition, the user can select an object and see all the images.

We believe that the developed prototype can be used for more advanced applications in the future. It could be also an information system for tourisms. We are currently investigating more functionalities for spatial information retrieval and the improvement of the visualization to provide the user a better access and understanding of the results.

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