A Digital Library System for Semantic Spatial Information Extraction from Images

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Keywords: Semantic Extraction, Spatial Context, Image, Camera, Sensors.

Abstract: Spatial information delivery is of high importance today for mobile applications. Knowledge about spatial objects includes not only location of the user, direction and time, but also knowledge of the semantics of the spatial objects. These semantics can be related to the user profile and user's interests at the time, which can be expressed using domain specific ontologies, such as cultural ontologies, nature ontologies, tourism ontologies and others. The system then should screen this information and deliver it to the mobile user device. The system uses as input digital images taken from a simple, modern digital camera. In this paper we present a digital library system for image storage, image handling and extraction of spatial information based on the semantics spatial information that the system manages.

1 INTRODUCTION

Cameras as powerful tools can be specific capturing devices. We are not discussing professional metric cameras from the scientific area of photogrammetry but simple cameras which are supported by other devices and sensors. Modern digital cameras can cooperate with GPS, camera orientation with respect to the geographic directions (north, south, etc.), distance measuring devices, camera directional (tilt, rotation, etc.). They can have Wi Fi access capabilities, and send the images to remote computers, or access information from information sources, including GIS information, related to the location or the objects of interest to them. In summary, they can act as very powerful input sensors, not just cameras. They can record the images together with position, direction, tilt and other parameters, which can be useful metadata for the image annotation. Subsequently, they enable different kinds of new applications.

The high focusing, zooming, resolution, and color range capabilities of the digital cameras makes their images extremely useful. The user can manage to extract automatic or semi-automatic spatial information and manipulate the contents of the images. These capacities provide powerful capabilities for several important application environments for personal and community shared use. The capabilities for clearer identification of objects within images allow a better automatic or semiautomatic communication with other information resources (like GISs, cultural and tourism digital libraries, etc.) To explore the images' full potential in document management applications, we need to integrate them with other sensors, as well as with other data types, applications, and services.

In this paper, we present a system for spatial information extraction, for management of images of a Digital Library based on the user context. This work exploits the modern digital cameras' potential for capturing contextual parameters through the use of sophisticated sensor devices, information found in specially annotated semantic maps and industrial standards. The system implementation provides an image database that allows users to store and view their images. Along with the images, the users can view personalized semantic maps, annotated with semantic objects described using ontologies. These maps are supplied from a remote server. The objective is to effectively manage and associate the spatial information and semantic objects contained in both the semantic maps and the images. In addition, the system uses several algorithms to

Foukarakis M., Ragia L. and Christodoulakis S..
A Digital Library System for Semantic Spatial Information Extraction from Images.
DOI: 10.5220/0005365901650169
In *Proceedings of the 1st International Conference on Geographical Information Systems Theory, Applications and Management* (GISTAM-2015), pages 165-169
ISBN: 978-989-758-099-4

enable the automatic annotation of the images. Images with position only information or both position and direction information can be visualized on top of the maps and be associated with semantic objects. We demonstrate our system providing examples from the domain of tourism, archaeology, and tourism related to coastal erosion problems, emphasizing the practical applications of this work.

2 RELATED WORK

The paper is based on standards and software that already exist and are widely used: Exif and NMEA 0183 (Exif 2010, NMEA 0183 2002). Google Earth is a platform for geographic data which provides flexibility and lots of useful functionalities for spatial information processing (Google Earth 2014). There are examples from the industry that handle a massive amount of images and annotate, retrieve and organize lots of images like Picasa (Google) and Flickr (Yahoo!). Other prototypes propose technologies to improve and facilitate image retrieval and organization for personal use (Naaman *et al,* 2005, Viana *et al.,* 2011).

The usage of ontology terms to describe semantic content of images has been discussed (Hyvönen *et al.,* 2002, Kallergi *et al.,* 2009). Image annotation using ontologies has been introduced in different approaches demonstrating the important role of the ontologies for better image understanding and querying (Bannour and Hudelot, 2011). Other approaches propose the usage of semantics for image retrieval (Vogel and Schiele, 2007).

In this paper we emphasize the idea to integrate the captured contextual information on a digital image which has been taken from the digital camera at the same time with the image (context of capturing). The retrieval and the visualization of the personalized semantic information based on the user context can then be supported by the system.

3 SEMANTIC SPATIAL INFORMATION PROCESSING

Semantic information processing and semantic interoperability with other applications in a service oriented infrastructure is of central importance to the industry today. Use of industrial standards in the different application domains, as well as use of community accepted ontologies are needed in such an environment. Interoperability support using ontologies and standards is also very important in the open internet environment today.

The main characteristics that the system is based on are:

1. Semantic information processing
2. Semantic interoperability with other applications in a service oriented infrastructure
3. Use of industrial standards
4. Use of community accepted ontologies
5. Automatic image annotation
6. Personalization
7. Simplicity and automation in the information capturing

The objective is to create the infrastructure for integrated transparent management of semantic spatial multimedia information that includes maps, semantic objects in maps, images and semantic objects of the spatial environment captured in images. The system takes into account multi-sensor digital camera capabilities and semantic spatial information encoded in semantic maps to automatically associate digital image contents with semantic spatial information and allow powerful functionality and visualizations.

Applications implementing the main ideas presented here have been developed. The system utilizes a modern digital camera integrated with a sensor capturing position and direction parameters and processes the information embedded in the images in order to associate image contents with semantic information located in semantic maps.

The application provides a simple interactive map interface and the ability to visualize objects of interest and photos on top of the map. The user can select and view information about semantic objects contained in pictures and also view detailed picture information located either in the image metadata or provided by the system's automatic annotation capability.

Viewable information about a semantic object includes:

- Name
- Semantic type (for example "St. Nikolaos Church" can be of type Church)
- Domain (or ontology - for example "Knossos Ruins" belongs to the Archaeology domain)
- Description
- Map representation (as a geometric shape)
- List of images depicting the semantic object

Viewable information about an image includes:

- The image itself
- Metadata (camera model/make, date, focal length, comments etc.).

- Semantic objects contained in the image (as either a list or superimposed on the image if possible).
- Map representation (using a circle to represent position and a conic shape to represent direction and angle of view).

To provide the above functionalities and visualizations, various algorithms have been implemented. The system implementation stores the images and the semantic maps in a relational database (Christodoulakis *et al*,. 2009) and provides retrieval functionality for both. The maps are acquired from a semantic map server and can be personalized according to user interests. For example, if the user is interested in the archaeological or cultural sites of Crete but not in its geographic features, the server can then provide a version of the map of Crete without the geographic semantic objects. Ontologies play an important role in our system. The system is interactive and the user can add its personal ontology tree where ontologies have a number of semantic types and semantic objects belong to these types, forming a hierarchy.

Figure 1: High resolution image segmentation with the single detected sky region. The algorithm has merged the regions that were not smooth, creating a single region for the sky. The skyline can then be easily extracted to be used for image registration and produce the final result.

A very important functionality of the system is that it associates map information with the geospatial parameters recorded in the images, transforming them into interactive windows to the outside world. We have adopted the approach described in Christodoulakis *et al.,* 2010 to accomplish this. This approach calculates the 2D spatial view from the position and direction of image taking and then with a defined procedure that includes image segmentation (Figure 1), region recognition and image registration, it allows the visualization of (interactive) semantic objects and their location in the image by superimposing their shapes on top of the image.

4 APPLICATIONS

The user interface of the software that has been developed to demonstrate some aspects of the functionalities offered by the system is shown in Figure 2. The user can impose constraints on what type of semantic objects are of interest (according to their hierarchy) and the system will only show objects that satisfy the constraints. The user can request to see all semantic object footprints that are visible for a given image, according to the image's location and direction. The user can also receive a list of images that depict a specific semantic object. Viewing the images on top of the map and information on each semantic object present is also supported.

We explored the usefulness of the system in the tourism domain. A semantic map of the city of Chania was used and the knowledge base contained semantic objects that describe tourist attractions, useful locations, churches and known roads. After taking images of the city using a modern digital camera equipped with location and direction sensors, the images were transferred to the system's database and were automatically annotated with information from the semantic map. The image contents could then be queried upon.

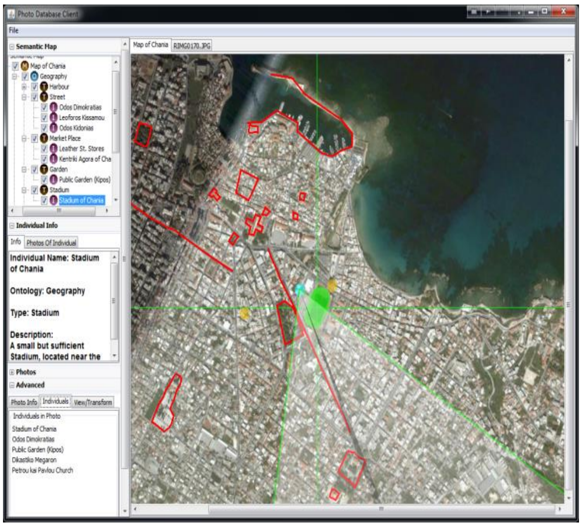

Figure 2: An example of the system user interface.

The location from which the pictures where taken and the direction of the pictures can also be displayed on top of the map.

Another very useful application where we can use our system is to show the coastal erosion related to tourism areas. The data for the coastal erosion can be fed from local authorities and the user of the system can import his/her private images with GPS information and image metadata. The location of interesting hotels in connection with their private beaches can be displayed on the semantic maps and the user can have additional information about the current status of the beach. For example, a comparison between the new data of semantic maps about the sea level rise from the local offices with the individual images can immediately depict areas where an indirect erosion and loss in beach sand coexist. Another application of our system can be the display of the existing sea level rise along the open coastal areas where specific human activities are reduced. The main advantages of our system in such an application is to find answers to individual questions. The system has a friendly user interface which enables the users to integrate data from external resources and import their own private data. Then a personal scenario about interesting subjects can be created

In an application of cultural heritage, the system can also be used to efficiently manage, interpret and incorporate spatial information. Several benefits could be obtained with the usage of our approach: a) Existing documentation can be imported and visualized in this work. Cultural heritage documentation consisting of images, drawings and sketches can be retrieved and saved. For example, existing drawings that show an archaeological site can be represented as a semantic map. The footprint of an archaeological monument can be visualized in an existing map. Images with contextual metadata that display an ongoing excavation can be downloaded and visualized with other related documentation. Retrieval matching can be based on spatial information but also on semantic descriptions related to a semantic map. Note that in this application more than one semantic map may exist, for example showing the same location at different time intervals. Figure 3 shows an archaeological drawing that has been processed and converted into a semantic map Entities such as rooms, walls, buildings etc. that are in the knowledge base and contain GPS coordinates are drawn and visualized on top of the map. b) Multiple data can be simultaneously processed and saved. Using the old and new taken images with the GPS information, inconsistencies about an object of interest, e.g. archaeological monument, can be detected and identified. c) An efficient analysis requires some kind of data organization that can be realised in this system. An appropriate analysis of relationships among spatial data from different sources can be performed. A query makes use of spatial and temporal criteria combining context of archaeological data. For example, a personalized Semantic Map reflecting the interests of a user can include all the digital images with the context of “restoration of all Byzantine archaeological monuments that happened in the last year”.

Figure 3: An archaeological drawing converted into a semantic map with semantic object footprints. Drawing taken from Kanta *et al.*, 2012.

5 CONCLUSIONS

The system presented in this work provides an integrated transparent management of semantic spatial information processing. A basic contribution of this work is that integration of inexpensive sensors with the camera is now feasible and it can result in semantic management of image contents. The main advantages of the system are its adoption of industrial standards and commonly used ontologies for the purpose of image annotation and the association of semantic map spatial information with the images.

The system uses automatically captured parameters by GPS and compass as well as contextual knowledge from 3D maps and geographic ontologies to produce good 2D representations of the scene visible in the direction of the camera.

In conclusion, the system provides a rich, transparent, and integrated functionality for managing a personal database of digital images and digital maps, in a semantic spatial information extraction. The images are associated with semantic objects present in semantic maps, events defined by the users and persons participating in these events. The contents of the database can then be seen as an interactive living memory of the trips or activities performed by the users, even years after the completion of these events.

Current work in this area involves the accurate registration of the images captured by the camera to detailed earth elevation data so that far objects in distance can be automatically and accurately located on top of pictures. Experimentation in different settings is important to validate the results.

ACKNOWLEDGMENTS

The authors gratefully acknowledge support from the EU project ASTARTE - Assessment, STrategy And Risk Reduction for Tsunamis in Europe. Grant 603839, 7th FP (ENV.2013.6.4-3).

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