Geospatio-temporal Semantic Web for Cultural Heritage

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Chapter in book: Digital Culture and E-Tourism: Technologies, Applications and Management Approaches. Miltiadis Lytras, Ernesto Damiani, Lily Diaz and Patricia Ordonez De Pablos (editors), IGI Global, 2010 (estimated).

Inside Chapter/Abstract

People frequently need to find knowledge related to places when they plan a leisure trip, when they are executing that plan in a certain place, or when they want to virtually explore a place they have visited in the past. In this chapter we present and discuss a set of methods for searching and browsing spatio-temporally referenced knowledge related to cultural objects, e.g. artifacts, photographs and visiting sites. These methods have been implemented in the semantic cultural heritage portal CULTURESAMPO *that offers map-based interfaces for a user to explore hundreds of thousands of content objects and points of interest in Finland. Our goal is to develop and demonstrate novel ways to help the user 1) to decide where to go for a trip, and 2) to learn more about the neighborhoods and points of interest during the visit.*

Keywords: Ontologies, Semantic Web, Cultural Heritage, Web-based Applications, Spatio-temporal Data, Geospatial Data

1. Introduction

There is a strong trend of building up more and more location-aware cultural heritage services (Dijk, Kerstens, & Kresin, 2009)—this is what cultural tourists need and are looking for when they visit different places. It has been suggested (Mulrenin, 2002) that museums should publish their activities, collections, services, and products in cooperation with cultural tourism agencies. Indeed, museums and other cultural institutions host rich collections that have the ability to attract tourists.

There are already several systems that publish cultural heritage content on a map. For example, WatWasWaar.nl publishes historical geographical information in the Netherlands (Liberge & Gerlings, 2008). Another example is Placeography[1] that allows users to share information about places. Furthermore, historical photos have been combined with Google Streetview to provide a possibility to compare historical and contemporary views[2]. PhillyHistory.org (Heckert, 2009) also provides a search facility for collections and map visualization, especially for nearby photos of a given location.

2. Background

Semantic Web and Ontologies for Cultural Heritage

Cultural heritage portals is an especially promising domain for the application of semantic web technologies (Hyvönen, 2009).The idea of the Semantic Web[3] (Berners-Lee et al., 2001) and in particular Semantic Web ontologies (Staab & Studer, 2009) is to offer a "common language" for applications and services to use when they speak about resources, e.g. places, persons, artefacts or events. Semantic Web technologies offer means to describe knowledge about different domains in a machine-processable form as ontologies (Allemang & Hendler, 2008). The

[1] http://www.placeography.org/
[2] http://www.paulhagon.com/thenandnow/nypl/
[3] http://www.w3.org/2001/sw/

goal is to build a "web of data" for machines that can be used to make the current "web of documents" more usable and intelligent for humans.

Ontologies define classes, individuals, properties and relationships that are used to represent things of the world. These things can be anything, like organizations, persons, places, time, or events. By using relationships, persons can be related to e.g. the places they have been born in, or to their birth times. Publishing ontologies on the Semantic Web enables people and organizations to use shared ontologies in annotating e.g. photographs, videos, music, and other types of cultural objects. Search engines can use relationships provided by ontologies in semantic searching and recommendation (Hyvönen et al., 2005).

Geospatial References and Relationships

A large proportion of cultural resources such as museums, monuments, photographs, videos, artefacts, and books are geographically referenced, and thus can be identified by search terms that refer to locations (Jones et al., 2001, Stuckenschmidt & Harmelen, 2004). This is because the objects are produced, found or used in the referenced locations, or have some other relationship to the location in question. By georeferencing the resources (Schlieder et al., 2001), spatial queries can be used to find interesting connections between places and related contents.

In recent years there has been effort to provide solutions for finding nearby points of interest, given a certain coordinate point, or more generally "relating spatial things together based on their distance in meters" (Auer et al. , 2009). Distances have been modelled with qualitative concepts, such as "far" and "close" (Frank, 1992). Given a certain query point, these notions have a quantitative interpretation, e.g., the circular area around the point with some radius. The search results can then be ranked based on their distance from the center.

Places also relate to each other in different qualitative ways. Traditionally this has been modelled using spatial relations such as topological relations (overlaps, disjoint, etc.) (Egenhofer, 1989), and relations expressing directions (north of, south of, etc.) or distances (far, close) (Frank, 1992). Places relate to each other also due to the cultural connections between them (Kauppinen et al., 2009) or because they share something, for example a common twin town (Auer & Lehmann, 2007). Relationships between places can be utilized e.g. in spatial query expansion (Jones et al., 2003, Tuominen et al., 2009).

Geospatial Web and Applications

There is a growing number of projects that use location-based content in the cultural heritage domain (Dijk et al., 2009). For example, the Explora Project (Parks Canada) has produced a system that offers specific points of interest (POI) with related text, navigation points, quizzes, maps, and content organized by theme (Tarasoff, Hutcheson, & Rhin, 2009). Further on, cultural heritage collections have been put on a map e.g. in (Liberge & Gerlings, 2008). Placeography[4] allows users to share information about places, e.g. the history of and stories about a house, a building, a farmstead, public land or a neighbourhood. The project called "Then and now"[5] uses historical photos in combination with the Google Streetview to provide a possibility to compare historical and contemporary views. An example of providing search of collections and map visualization for nearby photos of a location is PhillyHistory.org (Heckert, 2009). The *Geospatial Semantic Web* aims to bring together georeferenced content and the Semantic Web (see e.g. Becker & Bizer, 2008). All in all, this term *Geospatial Semantic Web* depicts the idea of the current state-of-the-art, where *Geospatial* means that places play an important role in building the next generation web and where the *Semantic Web* provides the way to refer to these places and to be

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4 http://www.placeography.org/
5 http://www.paulhagon.com/thenandnow/nypl/

able to explicate relationships. Table 1 summarizes contributions of some papers related to the Semantic Web, geospatial web, location-awareness and applications of these fields of research.

Issue	References	Main contribution
Semantic web	Berners-Lee et al., 2001	The introduction of the semantic web
Geospatial web	Hart & Dolbear, 2007	Overview of challenges
	Scharl, 2007	Media platforms and geotagging
	Stuckenschmidt & Harmelen, 2004	Overview of spatial relationships
	Becker& Bizer, 2008	Geospatial Semantic Web
Location-awareness	Tarasoff et al., 2009	Nature routes with POIs
	Dijk et al., 2009	User experience
	Auer et al., 2009	Nearby search utilizing semantic web
	Dolbear & Hart, 2006	Nearby search that uses context
	Hinze & Voisard, 2003	Nearby in space and in time for events
Applications	Liberge & Gerlings, 2008	Cultural heritage on maps
	Heckert, 2009	Nearby photos on a map
	Hakimpour et al., 2007	Event suggestion

Table 1. A literature review concerning research related to theories and applications of the geospatial Semantic Web.

3. Modeling and Reasoning about Cultural Heritage Content

Problems of Traditional Approaches

A problem encountered when searching for geo-referenced content is that annotations contain references to locations on different levels of granularity. A museum object may refer to Paris while another item refers to France. Having no explicated relationship between Paris and France will result in lower recall, when searching e.g. for artefacts manufactured in France—artefacts made in Paris may be missed. On the other hand, if the part-of relationship is explicated, a machine can find or recommend objects at different levels (searching for French photos returns also photos of Paris). This issue is being tackled by techniques of the Geospatial Semantic Web.

Another problem is that historical collections typically contain references to historical names of places. Those places might have changed their names, or have been merged with other places or split into parts with different names. This causes semantic mismatches between place names from different times. For example, in one annotation a reference is made to (historical) Bombay while in another annotation a reference may be made to (contemporary) Mumbai. In our approach we will make use of geospatial and spatio-temporal ontologies to provide mappings between places to overcome the above-mentioned problems.

Providing models and methods to deal with historical places will contribute to a temporal Geospatial Semantic Web what we will call *Geospatio-temporal Semantic Web.* We will use this term to refer to ideas that combine the Geospatial Semantic Web with the temporal dimension in one way another.

On the Geospatio-temporal Semantic Web, old maps (and names on it) could be of substantial benefit when using visualizations in annotating or when searching content using maps in semantic cultural heritage portals. Using several simultaneous temporal map views is useful when comparing geospatial information from different eras (e.g., how construction of cities has evolved) or from different thematic perspectives (e.g., viewing a topographic or geological map on top of a satellite image). Providing historical layers and linking them to rich sets of cultural objects is missing from traditional portals: these objects include, e.g., artefacts and pieces of art in museums, historical aerial photographs, collections of other georeferenced photos, and Wikipedia[6] articles.

It is fairly straightforward to find nearby points of interest with respect to a certain coordinate point. However, the results are in many existing applications restricted to information about outdoor sites (e.g. museums as buildings) and no further linking to related resources is provided (e.g. to paintings in the collections of those museums). In our approach we will provide such linking to related ontologically annotated content as well.

A problem in searching for nearby sites is that geography in many places is very demanding, which can make finding nearby points of interest (POI) based on spatial distances misleading. For example, a city with large blocks of buildings (e.g. Beijing), a crossing river (e.g. Paris) or steep geography due to elevation (e.g. Genève) may make the task of moving from a point *a* to another point *b* a challenging experience: it is just impossible to go through some buildings, cross a river when a bridge is not available, or climb steep mountains without transportation or good equipment at hand. Even if a POI is within a short distance by air ("as the crow flies") it may not be achievable by walking or driving from a given point. In these cases it is more practical to query POIs within a given *temporal distance*, i.e., within some time span of reach relative to the means of transportation.

While earlier works have contributed to building the Geospatial Semantic Web, we intend to go beyond that by contributing also to the Geospatio-temporal Semantic Web. In this chapter we discuss, based on our work on building semantic portals for cultural heritage, some novel methods and ideas for dealing with the temporal aspects of the Geospatial Semantic Web. It will be explained, what kind of functionalities can be offered using these methods in the area of cultural heritage to 1) provide recommendations of spatio-temporally relevant content to end-users, to 2) provide visualizations of maps from different times and to link them to relevant cultural content, and to 3) provide spatially and temporally relevant nearby search with semantic recommendations to related content.

Scenario

We will go through the mentioned problems and their solutions by using a scenario. In the scenario we have Tanja, a 25 year-old woman from Espoo, Finland. Tanja has invited his friend Glauco, a 25 year old man from Florence, Italy for a tour in Southern Finland. Tanja had a vacation in Florence the summer before and she met Glauco while they were visiting the Institute and Museum of the History of Science [7] (IMSS) specializing e.g. in Galileo Galilei's achievements and historical scientific instruments. Tanja and Glauco both share special interest in space, aviation,

[6] http://www.wikipedia.org
[7] http://www.imss.fi.it/

and nature photography. These will also serve as themes for Glauco's visit. Tanja wishes to introduce Glauco her current home town Espoo, and Imatra where she grew up and where her parents still live.

Cultural Objects of CULTURESAMPO

The material used to provide a test bench for the scenario in this research are annotations of cultural objects in the portal CULTURESAMPO—Finnish Culture on the Semantic Web 2.0 (Hyvönen et al., 2009). The material consists of heterogeneous cultural content, which comes from the collections of 22 Finnish museums, libraries, archives, and other memory organizations, and is annotated using various ontologies. All of these annotations are represented using the Resource Description Framework (RDF)[8] and a set of ontologies, including the Finnish Spatio-temporal Place Ontology SAPO.

The material, coming from almost 100 different collections, currently includes metadata about over 250,000 objects, e.g. artefacts, photographs, maps, paintings, poems, books, folk songs, videos, et cetera, and millions of other reference resources (concepts, places, times, etc.).

Finding Content Related to Places

We will first describe how CULTURESAMPO supports the *Geospatial Semantic Web* before going to the *Geospatio-temporal Semantic Web*. CULTURESAMPO provides a centralized geospatial view that can show all kinds of content related to a place, and organize this data in various ways in order to make sense of it. Figure 1 illustrates this view. On the left side of the figure, there is a Google maps view, upon which are shown by default all locations to which any content is related in any way. On the right is a search box, whereby the user can search for places by name using semantic autocompletion, and a browsable partonomy of places in the ontology. Selecting a place in this view centers the map view to the place desired and adjusts zoom according to the partonomical level of the place selected. For example, the whole country shown if a country is selected, and only much more limited neighborhood for a city selection.

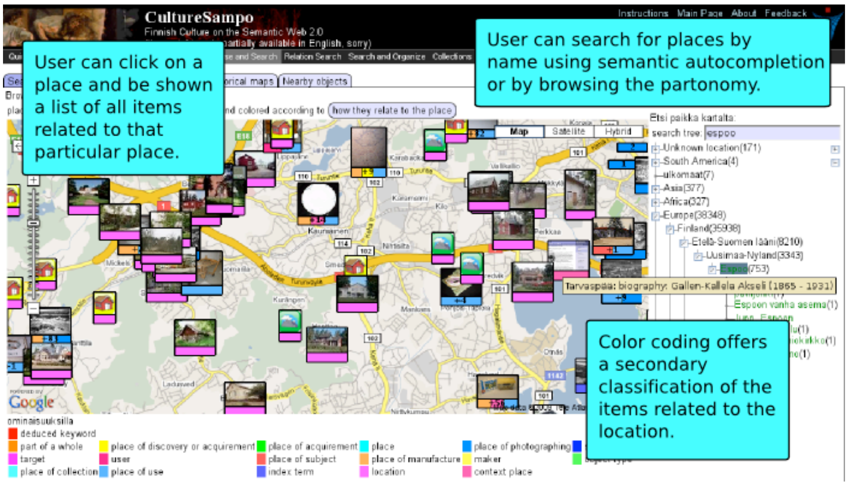

Figure 1: A geospatial view of content in the CULTURESAMPO portal.

[8] http:1/www.w3.org/RDF/

As the primary map view shows many kinds of items and place relations all at once, it is imperative to give the user the tools necessary to make sense of it all. To make it easier for the user to differentiate content types, kinds of geospatial relations, and to find interesting objects, the icons shown for the places are sample images of objects linked there (e.g. photographs or photographs of artefacts used at the location) or object type icons, if no pictures are available (e.g. historical places, poems, etc.). The details of the highlighted item are available on mouseover.

In addition, a color coding offers a secondary classification of the items related to the location. This can be selected by the user to be any property of the items, but by default the colors code the different relationships that the items have to the place (e.g. place of use or place of manufacture for artefacts, place of collection for poems, located in for museums and nature sites). The legend for this color coding is displayed in the bottom of the view. On top of the color coding on the locations, the corresponding number of items is additionally displayed.

To take a closer look at all these items, the user can just click on the place and is then shown a list of all related items. The list is accompanied with with explanations of items detailing the properties that relate that item to that particular place as well as the original annotated place resource, if the relation has been deduced through temporal or partonomic hierarchies. If the user is still overwhelmed by the presentation, she can additionally limit the items shown on the locations by the different roles. For example she can look only at items by their place of manufacture, or, if she is for example planning an actual visit, browse only items that are known to currently reside in the place depicted.

The Scenario Revisited

Tanja wants to give Glauco a general overview on cultural history in Espoo. For this, she points her browser to CULTURESAMPO's general place view. She types in Espoo on the place locator, and starts to mouse over the locations and culture shown. She clicks on any interesting pictures, icons or descriptions to browse additional items and gathers a selection of historic places, artefacts, biographies and other resources that she can use together to give Glauco an overall picture of cultural history in Espoo.

Annotating Content Related to Spatio-Temporal Places

Cultural heritage content, like objects in museum collections, refers to places because they are annotated using places in different roles such as *place of manufacture* or *place of usage*. Moreover, annotations contain references to locations that are topologically and mereologically close, i.e., they overlap, touch or are in partonomy hierarchies from different times. This is because spatial terms, i.e. geographical places, do not exist just in space but also in time (Kauppinen & Hyvönen, 2007, Jones et al., 2003). This calls for a *Geospatio-temporal Semantic Web*, where places are linked also to their historical counterparts and not just to other contemporary places.

A practical example of this is depicted in Figure 2 showing locations near the current border between Finland and Russia. A municipality called Imatra *overlaps* many historical municipalities, namely Ruokolahti, Jääski and Joutseno. On the other hand, all these three historical municipalities were neighbours of each other i.e. they *touch*. Some municipalities near the current border have also been in different partonomy hierarchies i.e. as *part of* Finland or as *part of* Russia.

Figure 2: A typical example of mismatches due to historical changes: a contemporary Imatra overlaps historical places Ruokolahti, Joutseno and Jääski.

In geospatial ontologies, the key properties of place instances are related to their spatial extensions. These properties include e.g. center points and polygonal boundaries. For example, in a geospatial ontology a country called "Finland" in year 1930 and in year 2009 should have different URIs. This is because Finland's boundaries during these different years differ (Finland ceded territories after the Second World War to Russia).

This is especially true for museum collections where objects have references to places from different times. Figure 3 depicts boundaries of contemporary (year 2009) municipalities in Finland. All the municipalities that have had some changes concerning their boundaries or names in the past are coloured with white. The unchanged municipalities are coloured with grey. As we can see, the majority of municipalities have overcome at least some changes and hence this sets a requirement to utilize the mappings between historical places and more contemporary places in query expansion. The hypothesis is that without using these mappings the recall will not be 100% when querying with the contemporary place names.

To provide these mappings we used the Finnish Spatio-temporal Place Ontology SAPO (Kauppinen et al., 2008). SAPO contains historical Finnish places (mainly municipalities), changes between them, and temporal properties (like when a location has existed) as well as spatial properties (like polygonal boundaries). Currently (in year 2009) SAPO defines 3180 mutual *overlaps* relations between historical municipalities. The *overlaps* relations between municipalities were generated using knowledge about changes, e.g. name changes, merges and splits between locations (Kauppinen and Hyvönen, 2007). In SAPO, graded regional overlap mappings are expressed using Turtle RDF format, see Figure 4 for an example. This example represents the fact that Ruokolahti (1940–1947) overlaps 60% of Imatra (1948–1973), and is overlapped by Imatra (1948–1973) with 7%. This means that if there are photos annotated using Ruokolahti (1940–1947) they have a 7% probability of being in the region of Imatra (1948–1973), assuming that the photos are evenly distributed.

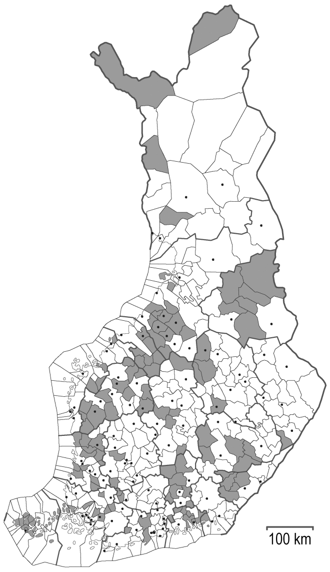

Figure 3: Unchanged (grey areas) and changed (white areas) municipalities in Finland from year 1865 until year 2009. Base map copyright National Land Survey of Finland (authorization no: 49/MML/09).

```
sapo:spatiotemporalmapping932
        spatiotemporal:argument1
                  sapo:Ruokolahti(1940-1947) ;
        spatiotemporal:argument2
                  sapo:Imatra(1948-1973) ;
        spatiotemporal:overlaps
                  "0.60" ;
        spatiotemporal:overlappedBy
                  "0.07" ;
        sapo:descriptionOfChange
                  "Imatra was formed in year 1948 of  villages from Ruokolahti., Jääski and Joutseno" .
```

Figure 4: Graded overlap mappings between temporal parts of places.

The temporal part of the place simply means the place during a certain time-period such that different temporal parts might have different spatial extensions (i.e. borders) (Kauppinen et al., 2008). For example, the place *sapo:Imatra* is a union of three temporal parts, defined using Turtle RDF in the example depicted in Figure 5. The recommendation engine may utilize the overlap mappings between places for recommending content from related places.

```
sapo:Imatra
    sapo:unionof
            sapo:Imatra(1948-1973) ,
            sapo:Imatra(1974-1976) ,
            sapo:Imatra(1977-) .
```

Figure 5: A place is a union of its temporal parts.

Results of Recommendations of Content Based on Topography

If a user is unfamiliar with historical place names of an area she is interested in, but knows the contemporary ones, then she is likely to use the contemporary ones as query terms. However, because historical cultural objects are typically annotated using historical names (terms) there is a mismatch between the query and annotations. By using a change history of places, a query can be expanded to include historical place names even if the query term is a contemporary one. Objects annotated with contemporary names do not cause any mismatch and can hence be retrieved also using simple string matching, referred to as the baseline in this chapter. Our hypothesis is that in terms of recall, the usage of a spatio-temporal ontology will perform better than the baseline without sacrificing precision too much. In this setting we assume that all objects annotated with a place that is within the boundaries of the query term are considered relevant. We also assume that objects are evenly distributed within the annotation places.

The aim of expanding the recommendations to include overlapping regions is to increase the recall of the query. For example, an aerial photograph taken in Ruokolahti in 1968 might be in the area of contemporary Imatra, because a part of Ruokolahti was merged to Imatra in 1977. However, without a mapping between terms Imatra and Ruokolahti the aerial photograph annotated to Ruokolahti would not be included in the results when querying for Imatra. The hypothesis is that by expanding the original query ("Imatra") to include also "Ruokolahti" the number of retrieved relevant results will increase (increased recall). Query expansion may, however, reduce precision. Considering the previous example, not all of Ruokolahti was merged to Imatra. This means that aerial photographs from Ruokolahti in 1968 have a certain probability of being in the area of Imatra. In other words, it is possible that they are not within the area of contemporary Imatra: this would cause the results to include irrelevant photos and hence reduce the precision.

We tested the recommendation method using two sets of annotated historical photographs from two different time periods. The intention was to test the effectiveness of the expansion method with respect to the age of the objects in question. First set was 12,433 aerial photos shot between years 1933 and 1999. Most of the photos depict urbanized areas, remarkable buildings or natural monuments. Another, older dataset was 3,206 natural historical photos between years 1870 and 1955. Each photo was annotated using a temporal part of a place.

The average of the baseline recall levels for the older dataset, the natural historical photos, was 59% meaning that on the average 41% of the relevant photos were not retrieved. The precision of the baseline was 100% until the recall level of 59%. By using only the complete overlap mappings from the spatio-temporal ontology, the recall increased to 71%, while retaining the precision at full 100%. By using all the overlap mappings, full 100% recall was obtained with the precision ranging decreasingly from 79% to 74% at different recall levels.

Similarly, the average of the baseline recall levels for the aerial photo set was 67% leaving on average 33% of the relevant photos out of the result set. Using the complete overlap mappings resulted in 87% recall without decrease in precision. Again, using all the overlap mappings resulted in lower precision ranging decreasingly from 92% to 86%, but the full 100% recall was obtained.

Scenario Revisited

In our scenario, Tanja wants to show Glauco nature photos of Imatra and its surroundings (remember that Tanja was born in Imatra). Tanja uses CULTURESAMPO to retrieve photos annotated with Imatra, but no natural history photos, directly annotated with Imatra, can be found. However, the semantic recommendation engine is able to expand the query to include also photos annotated with overlapping regions, such as Joutseno, Jääski and Ruokolahti. Figure 6 illustrates the results. Tanja notices that there are nice photos of two rapids, Vallinkoski and Imatrankoski, which both cross the current municipality of Imatra.

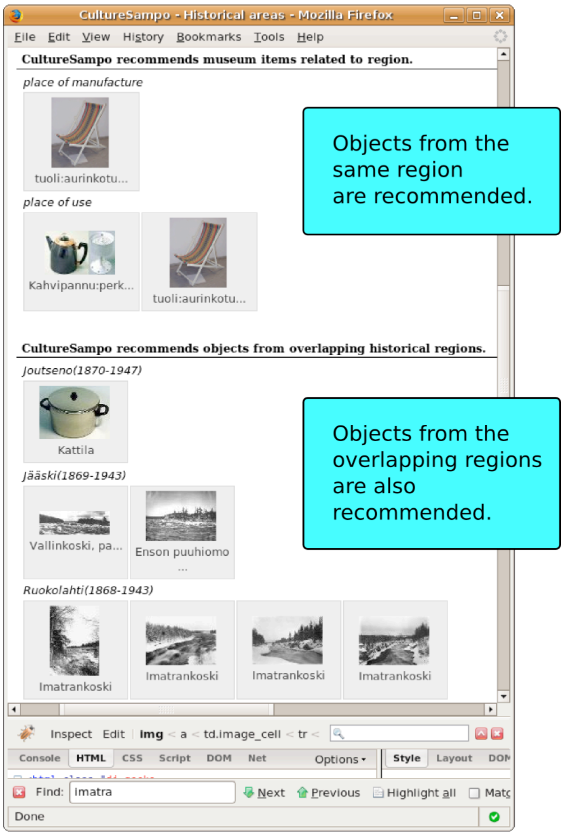

Figure 6: An example of recommendation based on topological relationships between places.

Modeling Historical Maps

Historical maps are needed in order to visualize historical geo-content annotated according to old temporal regions and place names. On the other hand, also the current view of places is usually needed at the same time to bridge the conceptual gap between regions of different eras.

To provide the historical view, we modelled a set of Finnish maps from the early 20th century covering the area of the annexed Karelia before the World War II. The maps were digitized and provided by the National Land Survey of Finland[9]. In addition, a map of the Espoo region in 1909, provided by the Geological Survey of Finland[10], was used.

Browsing of Maps and Related Content

Adding different kinds of layers on top of current maps and satellite images facilitates understanding of visiting sites and their historical layers. To provide this functionality, CULTURESAMPO visualizes several overlaying maps simultaneously using models. The use of several layers is a common (Berg et al., 2000) way to make maps more readable. The maps and satellite images of the Google Maps service were used as the contemporary view.

Figure 7 illustrates this functionality. The user can browse different places on the whole map area by selecting places in the menu on the left. On the right, a satellite Google Maps image of the contemporary Viipuri region is shown. In the middle, a smaller rectangular area is shown with a semi-transparent[11] old Karelian map that is positioned correctly and is of the same scale as the Google Maps image. This smaller view shows the park of Monrepos in Vyborg, a famous Finnish pre-war cultural site that nowadays is a part of Russia. The place cannot be found in current maps as it was, making it difficult for modern users to locate the place geographically. There are also articles of Wikipedia[12] and photos of the Panoramio[13] service overlayed on the map. The option whether to show them or not can be selected using the menu on the top left of the page. In order to move around, the user is able to use the zooming and navigation functions of Google Maps and the Karelian view is automatically scaled and positioned accordingly.

[9] http://www.maanmittauslaitos.fi/default.asp? site=3
[10] http://en.gtk.fi
[11] The level of transparency can be altered in the demonstration.
[12] http://www.wikipedia.org
[13] http://www.panoramio.com

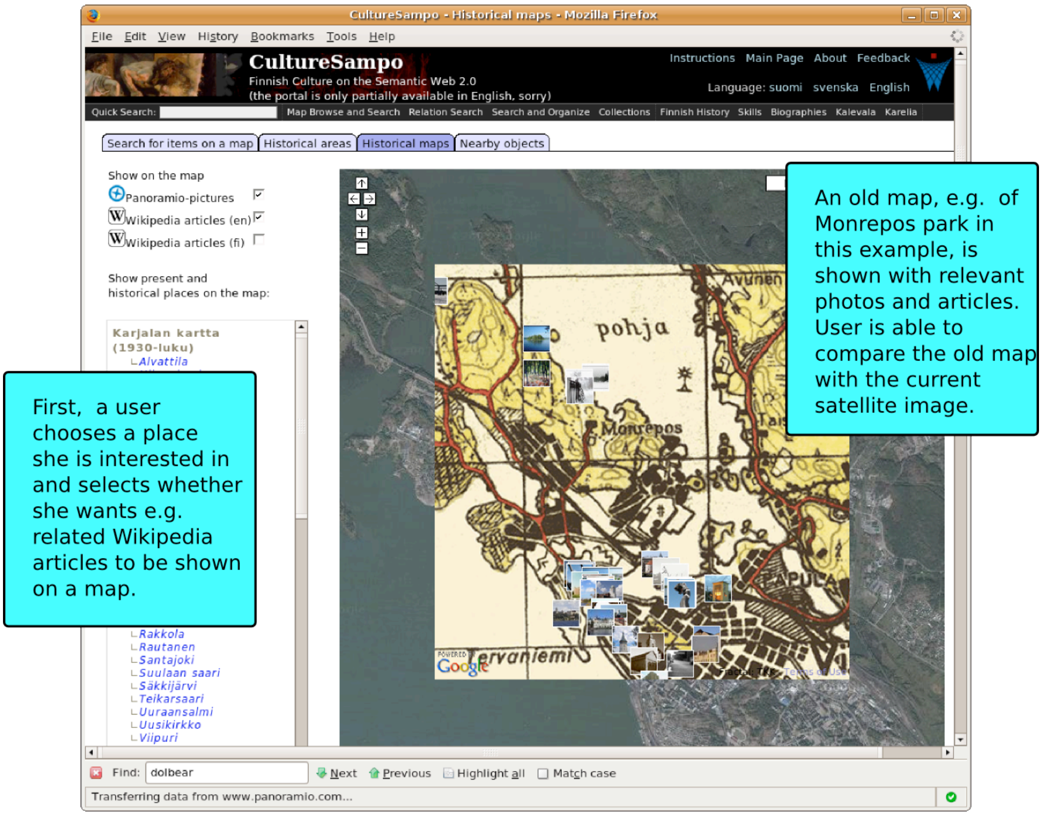

Figure 7: A historical map of containing the park of Monrepos layered with a contemporary satellite view, relevant photos and articles.

Scenario Revisited

In our scenario, Tanja goes to Imatra with Glauco. Imatra is located next to the current border between Finland and Russia. Tanja explains the history of Imatra to show how nearby territories were ceded to the USSR (nowadays Russia) after the Second World War. She shows Glauco old maps from the region in CULTURESAMPO . While browsing they stumble upon beautiful photos taken in the Monrepos park in Vyborg and read related Wikipedia articles. They decide to visit the Monrepos park the following weekend.

Finding Nearby Content using a Spatial Distance

The basic version of the method for retrieving nearby content expects a single coordinate point *p* given by e.g. a GPS-enabled device[14]. By nearby content we mean here either 1) outdoor visiting sites or 2) places that have been referred to in annotations of e.g. aerial photos. Next, the method expands the query of the single coordinate point to cover a circular area within some radius *r*, say, 1000 meters. This is done in two steps. First, a simple bounding box

[14] This is a well-justified assumption because an increasing number of mobile phones have GPS.

is created where each of the edges of the box have a distance *r* from the users location *p*, i.e. the distance to the "sides" of the bounding box from the given *p* is *r*. A SPARQL[15] query for RDF is then used for retrieving all the places inside this bounding box. In the second phase, places outside the radius *r* are pruned away from the results. Figure 8 illustrates this functionality where nearby POIs are retrieved using circular area search in the CULTURESAMPO portal. This functionality is also available for mobile applications to use via a public API[16].

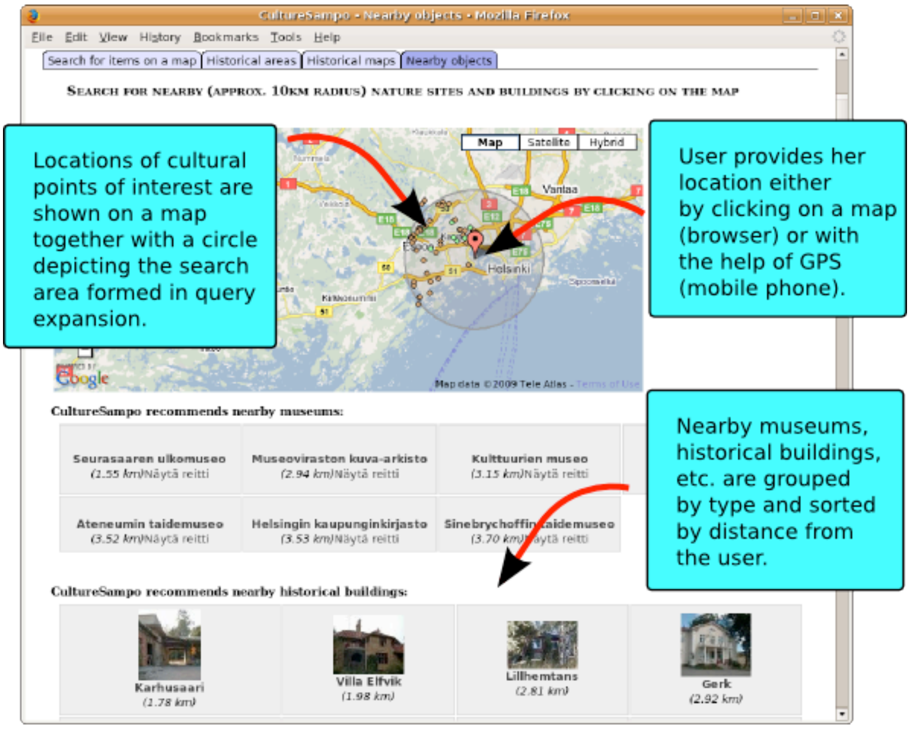

Figure 8: A given point, for example user's location, is used as a basis for a spatial distance -based query of nearby content.

An Improved Nearby Content Search using a Temporal Distance

Geography is challenging as points of interest (POI) for a user might e.g. be at different levels of altitude, on the other side of a river with no bridge, or behind several busy streets, thus blocking the access to the POI. See Figure 9 for an example of a city characterized by these challenges. Different shades depict areas that are within a 5, 10 or 15 minutes drive from the user's current location, marked with a red marker. The darkest area depicts those points reachable within a 0–5 minute drive, mid-dark area those within a 5–10 minute drive, and lightest area is reachable within a 10–15 minute drive.

[15] http://www.w3.org/TR/rdf-sparql-query/

[16] There is already one implementation made using this API and Nokia Web Runtime Widgets.

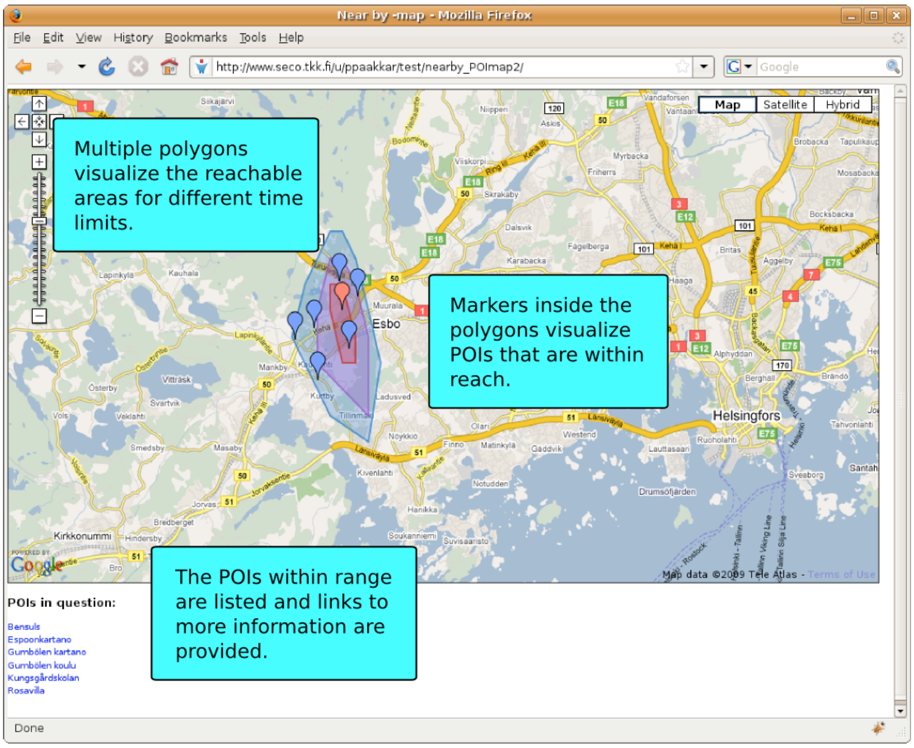

Figure 9: An example of using temporal distance -based nearby content search.

A Comparison of the Spatial and Temporal Nearby Searches

Two different nearby search map interfaces were evaluated by test users. Both map interfaces provided a search for the nearby objects when a certain point was selected from the map. The difference between the two kinds of searches was that the first one, a spatial map, showed the results of a search by spatial distance, i.e. air distance in kilometres, and the second one showed them by temporal distance, i.e. distance in driving time. In both maps the results were placed in three nested polygons. In the spatial distance -based map the polygons were circles and their radiuses were 1, 3 and 5 kilometres. In the driving time -based map the different polygons were 5, 10 and 15 minutes and their shapes were based on the found objects i.e. the shape was a convex hull of the coordinates of objects. The test data used in the evaluation were visiting sites of Espoo in the CULTURESAMPO portal. Interfaces were evaluated by six users, whose ages varied between 21 and 25. The methods used were 1) scenario based test tasks for users (Dumas & Redish, 1999), 2) thinking-aloud method (Nielsen, 1993, Boren & Ramey, 2000), 3) observation and 4) interviews. Users were first introduced with the interfaces and next they were given a scenario-based task. They were asked to do the same task with both interfaces. After that the users were interviewed about 1) the experiences of the two different interfaces, 2) their opinions about the overall concept of using maps for nearby search, and 3) also about future development ideas.

The results were as follows. All six users had some uncertainty when choosing the visiting site when using the spatial distance -based nearby search. They felt that it was difficult to choose the visiting site only based on the distance in kilometres. This means that they wanted to play it safe, so that they would have some time to spend at the destination. As a result, they chose objects that were quite near the start point or objects that were situated near big highways, and so could be reached quickly.

When using the temporal distance -based search, where the distance was based on driving minutes, the users were more certain about their choices, because they knew how long it would take to drive there and how much time would be left for exploring the destination. Most of the users chose a destination that is further away (in kilometres) than their choice with spatial distance -based search. One user chose same destinations in both spatial and temporal distance based search.

Five users preferred to use the temporal map and one user would use the temporal map if he had a tight schedule. One user mentioned that the spatial map was simpler, but the temporal map was still better because the distance in minutes was more relevant to her than the distance in kilometres. All six users thought that the near-by search concept would be useful. The users mentioned several purposes for using the system, including e.g. seeking for sights on a holiday or seeking for music or sport events near home.

The users were also asked if they had some ideas to improve the nearby map application, and they were also asked opinions about some of our future ideas. Four of the six users told that they would like to know how to get to the destinations by public transportation and they suggested that the map could be integrated with an online journey planning service of the Helsinki region public transportation. One user mentioned that she would be interested to know if the destination had some services or tour guides available and what their opening hours were. Two users suggested that the travelling time to the destination should depend on the time of the day, taking into account traffic. All users liked the idea that the application would take into account weather, i.e. if it was raining the system would suggest indoor destinations. One user said that some people would still like to see the destination despite the weather, so the system should not remove the outdoor destinations from the results when e.g. raining. Another user said that the current weather would not matter if you are e.g. searching for the visiting sites 3 weeks before a trip. Users were also interested to know other users' experiences and ratings of the destinations.

The Scenario Revisited

In our scenario, Tanja and Glauco are back in Espoo from the trip to Imatra and the park of Monrepos in Vyborg. Glauco's plane back to Italy is leaving in a couple of hours. Tanja wants to quickly show some of the fabulous scenery in Espoo. Tanja uses CULTURESAMPO to find out nearby points of interest. First she uses the nearby search to find out attractions within a 10 kilometres range. She realizes that they are in a hurry and hence she decides to use the temporal distance -based search to find out where they actually can get to in 15 minutes by car. They quickly visit the Espoonkartano manor to see its beautiful gardens, a dam, and an old arch bridge before proceeding to the airport.

Future Trends

It is likely that sharing and publishing knowledge related to places will grow in the future with the help of the users: information and experiences about routes and POIs—be it hiking trails, cultural itineraries, gastronomic findings or simply interesting walking tours—can be put online for others to utilize e.g. in their GPS-enabled mobile phones.

An interesting, emerging approach is to utilize knowledge from this large amount of people called "the Wisdom of Crowds" (Surowiecki, 2005). Linking all this collectively gathered knowledge to the rich knowledge offered by professional cultural heritage organizations will create new possibilities. Moreover, social bookmarking and shared experiences about attractions can be analyzed further to create new knowledge. For example, data mining together with ontologies can be used to find out what kind of cultural heritage connections (Kauppinen et al., 2009) there are between places in a cultural heritage knowledge base—e.g. between the home town of a tourist and different possible places for vacation.

These rich sets of cultural objects and layers on maps make the amount of data huge. This calls for personalized and context-aware applications. For example, if a tourist is mostly interested in hiking and nature sites, routing between POIs will be done based on her profile, and topographic layers will be preferred. In case of heavy rain, this context can be taken into account and our tourist can be guided to the (temporally) nearest museum.

Conclusions

In this chapter we examined how ontological knowledge can be used to represent and visualize different kinds of georeferenced data, and to enable spatio-temporal searches. We proposed and demonstrated explication of complex spatio-temporal relations between geographical objects, a search based on spatio-temporal ontologies, visualization of historical contents on a mixture of old and contemporary maps, and spatial and temporal distance-based nearby searches.

Acknowledgments

The research described in this chapter was done in the National Semantic Web Ontology Project in Finland [17] (FinnONTO) 2003–2007, 2008–2010 funded mainly by the Finnish Funding Agency for Technology and Innovation (Tekes) and in the EU project SmartMuseum[18], supported within the IST priority of the Seventh Framework Programme for Research and Technological Development.

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