Supporting knowledge sharing and learning via semantic geographical maps

Publisher:

Association for Computing Machinery, Inc

Published version:

DOI:10.1145/3038535.3038537

(Article begins on next page)

Supporting Knowledge Sharing and Learning via Semantic Geographical Maps

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ABSTRACT

Map-based applications are a good starting point for helping teachers in the preparation of learning material and students in their researches in social sciences. However, they offer basic information filtering support to the generation of dynamic maps. In this paper, we investigate the adoption of semantic knowledge representation and cooperative work approaches for managing thematic maps in group-based learning activities. Moreover, we present a possible solution, based on the OnToMap Participatory GIS, which uses an ontological representation of geographical information to support multi-faceted information retrieval, crowdsourcing, and map creation.

ACM Classification Keywords

H.3.3 Information Search and Retrieval; H.3.5 Online Information Services; H.5.1 Multimedia Information Systems; H.5.3 Group and Organization Interfaces

Author Keywords

Interactive geographical maps for learning; collaborative information sharing; participatory GIS; ontologies.

INTRODUCTION

Interactive geographical maps, traditionally exploited in GIS, are becoming a key user interface component of several applications because they help user orientation thanks to the graphical representation of information. The convergence of GIS and web technologies has made it possible to offer maps outside the scope of complex and technical GIS, and to use them in information retrieval, for displaying the results generated by search engines, travel information applications, and so forth. In the education domain, interactive maps prove to support learning in different topics, including natural science and physical geography, but also social science, e.g., historical geography. The reason seems to be the fact that students can create maps and focus them on a temporal and spatial dimension, instead of only reading them. This helps to analyze and understand the relationships among information items; see [7]. However, even though Web GIS overcome several usability issues of maps (e.g., the lack of usability of professional GIS for non-technical people), further work is needed to "provide an appropriate learning environment based on GIS in which learners have opportunities to interact with geographical information, structure their own learning approach, pursue cross-reference about subject matters, and create and interpret multiple representations of geographic information" [6].

SmartLearn'17, March 13 2017, Limassol, Cyprus

DOI: ---

We view the creation and interpretation of these multiple representations as the capability of synthesizing a personal perspective in terms of (i) information filtering (to select the data relevant for the study), (ii) presentation (to organize data in the maps for improving visualization and analysis) and co-creation (to support the collaborative enrichment of information for individual and group-based learning). For these purposes, interactive maps should not only offer information filtering capabilities, or standard information layers, as commonly done in Web GIS: they should enable teachers and students to co-create personalized layers as they would do on a paper-based map, adding new information items, annotating existing ones, and highlighting data for supporting individual and group-based analysis. Indeed, this approach to mapping is similar to what has been done in Community Mapping, a collaborative practice adopted in user empowerment to enable stakeholders to cooperate at the description of the values and resources of a territory. Community maps integrate information into a unified, map-based representation which synthesizes different perspectives to facilitate data synthesis and interpretation. We thus propose to use the Community Map metaphor in order to enable teachers and students to co-create thematic, custom maps presenting data under different, possibly related, points of view, corresponding to diverse information needs. Moreover, we discuss how OnToMap [8, 1], a Participatory GIS developed for geographical information retrieval and sharing, could help learning activities.

In the following, Section "Background and related work" discusses community maps, collaboration support services, and map-based learning services. Section "OnToMap" describes the main features of the system. Section "Application scenarios" sketches a few scenarios in which OnToMap could support teachers and students in learning tasks. Section "Conclusions and future work" concludes the paper.

BACKGROUND AND RELATED WORK

Community Mapping and Web GIS

Born as paper artifacts, Community Maps are a visual representation of geographical information concerning the values,

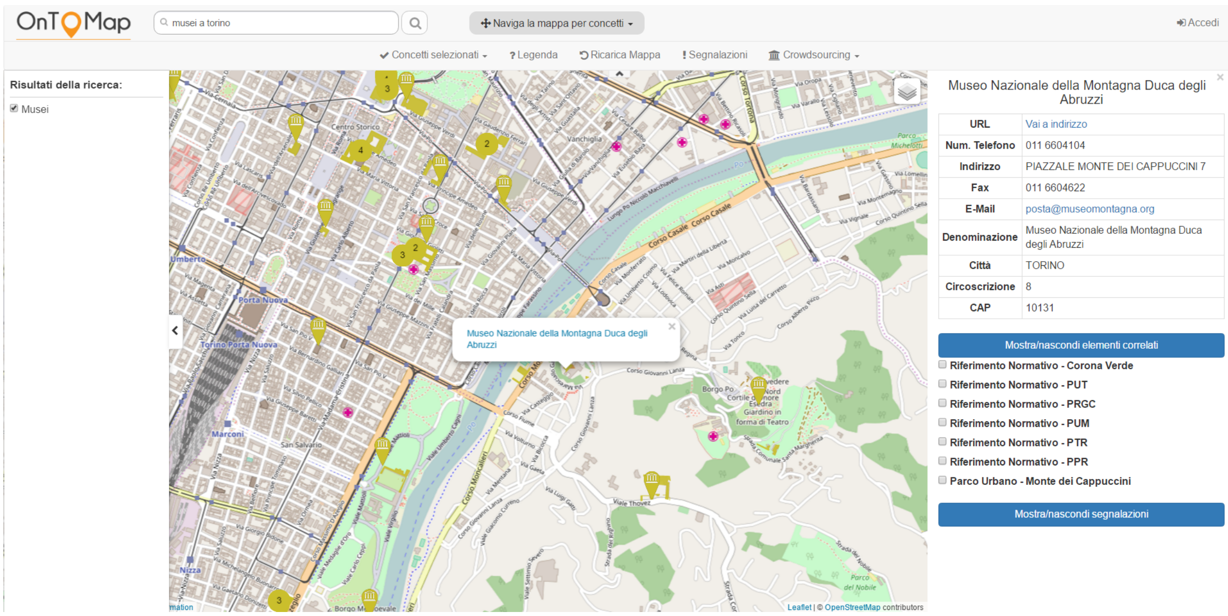

Figure 1. Portion of the User Interface of OnToMap displaying search results on a map. The search query (in Italian), reported in the top-left bar, concerns museums in Torino. The user has clicked on an item to show its details; see sticky note and item description in the right portion of the page.

resources, territorial identity, and they describe different points of view, each one representing a specific lens on the overall situation described. Traditionally, community maps were cartographic representations developed by a community, based on a participatory approach [5]. However, recent Web-based platforms for community mapping have made it possible to develop custom, dynamic maps, which reflect individual, or group information needs, thus providing a valuable option for the creation of customized data-sharing environments.

Web GIS capture a part of the community map concept: they support the sharing of crowdsourced information about geographical areas, offering tags and other classification tools for representing knowledge in a searchable format. E.g., OpenStreetMap (https://www.openstreetmap.org) supports data crowdsourcing based on tags that enable information retrieval and visualization. Moreover, GeoKey (http://geokey.org.uk/) introduces "projects" as the basis for data-classification and retrieval in a map. However, current Web GIS disregard semantics, which is the basis of the GeoSpatial Semantic Web vision [4] and is a key feature for the creation of thematic community maps. For instance, a map representing the "colors" of a town, or its "historical" side, should be generated by selecting the geographic information items related to colors/history, but how can the user identify which attributes of information items are related to those themes, on a keyword basis? Semantics is at the basis of knowledge representation for supporting this type of reasoning.

Collaborative information sharing

Most information sharing environments do not focus on geographical information. For instance, several groupware applications manage shared activity contexts for distributed team coordination; e.g., see Active Collab (activecollab.com). Regarding geographical information sharing, [2] introduce the

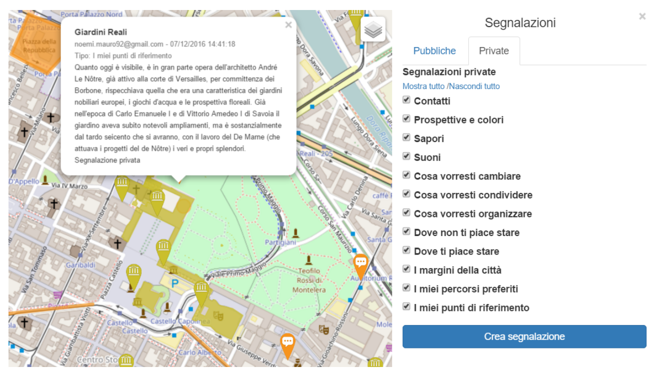

Figure 2. Interactive map with annotations (in orange). In the right portion of the page the user can see the categories of annotations that can be added, and filter the visualization of annotations on their basis.

concept of Personal Information Space (PIS), and applied it to enable tourist guides to create a customized application environment for the presentation of information during a visit to a cultural heritage site. However, the focus is on mashup development, in order to support the integration of documents and SW applications to be used by the tour guide (or, partially, by the tourists). This is different from our objective, i.e., offering flexible information retrieval support for exploring data sets and for organizing heterogeneous information in shared custom maps, which users can personalize to satisfy individual and group information needs.

Mapping support in learning management systems

Various commercial applications support the creation and the editing of maps. These tools contribute to increasing the learning capabilities of the student during class lessons about subjects such as Geography. Most of the tools support map annotation with lines, polygons and text (e.g.: MapFab, https://www.mapfab.com/editor/new) and they typically offer the possibility of focusing on an area, searching the geographical location by means of a search bar. Other applications enable users to select the data layers and show them on the map. For instance, National Geographics's MapMaker Interactive (http://mapmaker.nationalgeographic.org/) offers sets of layers, such as the Climate and Weather ones, to generate thematic maps that users can annotate with text and polygons for highlighting specific areas. The main limitation of these tools is that none of them contains a knowledge base with the elements related to the territory. Thus, users must input all the needed information items. E.g., if a teacher wants to create a thematic map about the monuments of a city, (s)he has to search for the information using external applications and, then, manually annotate the map. This imposes an overhead on teachers, who have to perform extra-work to create every custom map, instead of populating it with the results of a search query.

ONTOMAP

The OnToMap Participatory GIS was developed within project "Mappe di Comunità 3.0" (https://ontomap.ontomap.eu). This application supports the consultation of spatial data and the creation of public and private interactive maps, which reflect individual information needs and can be enriched with crowdsourced content. The key feature of the application is a semantic layer for representing geographical information, which makes it possible to classify heterogeneous data in ontological categories related to each other via semantic relations; see [8, 3].

The ontology underlying OnToMap describes territorial data according to a number of high-level dimensions, such as the natural, artificial and normative points of view, which support multi-faceted data classification and retrieval, allowing the description of the same information item according to different perspectives. The ontology makes it possible to perform queries at different abstraction levels; e.g., to retrieve public, or private, or all the services in a certain area. Moreover, it supports the exploration of the information space by following the semantic links among concepts and Linked Data. Finally, it supports the crowdsourcing of new information items by guiding the user in the specification of structured information items directly usable for information retrieval purposes. Specifically:

- The application supports information retrieval by means of semantic category selection (by browsing the ontology graph) or by textual search queries, which can refer to ontology concepts in a flexible way, using synonyms and other types of linguistic information [1]. On the one hand, search queries can be restricted by specifying attributes of the relevant information items (e.g., searching for mountain museums, instead of considering all the museums in a geographical area). On the other hand, the application can suggest semantically related topics to be explored, trying to guide the user towards types of information that can satisfy her needs in a more comprehensive way [1].

  For instance, the query in Figure 1 is aimed at retrieving the museums in the area around Torino. OnToMap displays results on a map focused on the geographical area delimited by the query. The semantic knowledge representation helps the exploration of the information space in several ways. For instance, the user can inspect the details of a geographical object by clicking on its icon; see the sticky note. In that case, a table reporting the main information about the item is displayed in the right portion of the page (e.g., Museo Nazionale della Montagna "Duca degli Abruzzi" CAI), including a reference to its official web page (URL). Moreover, by clicking on button "Mostra/Nascondi elementi correlati" (*show/hide related items*), the user can visualize other information, related to the item in focus via semantic and geographic relations: in fact, information items are represented as linked data. E.g., the right portion of Figure 1 provides links to some official documents on land usage relevant for the area of the museum ("Riferimento normativo - . . . "), and to Parco Urbano "Monte dei Cappuccini", a park adjacent to the museum.

- The application supports two forms of crowdsourcing: (i) the introduction of new geographical objects, in order to add missing content, and (ii) the decoration of information items, and of geographical areas, with textual annotations that store comments and information for personal and group activities. Figure 2 shows a portion of an annotated map: the annotations, in orange, can be associated to geographical objects, or to zones that the user draws on the map using an embedded editor. At the right the map, a toolbar shows the categories of annotations that can be added (e.g., contatti - *contacts*, prospettive e colori - *perspectives and colors*, sapori - *tastes*, etc.). Those categories can be used to create annotations, or to filter those to be visualized.

OnToMap was designed to support participatory decision-making processes but it has supported other activities in a satisfactory way. For instance, we recently used it to support a group of secondary level students in the creation of projects for the organization of a sport event in Torino. The students used the application to retrieve data about sport facilities, recreation and transportation services, parking areas, etc., and they planned the details of the events by creating personalized maps on which they visualized the relevant data and annotations. A post-test questionnaire showed that, compared to OpenStreetMap, OnToMap supported the students in a more effective way, thanks to (i) the semantic information retrieval support (in comparison to keyword-based search offered by OpenStreetMap), and (ii) the generation of annotated custom maps.

APPLICATION SCENARIOS

We now describe how the semantic exploration features provided by OnToMap could be used in a learning environment by considering two scenarios.

In the first one, the teacher creates an interactive map supporting a virtual tour of a geographical area to bring the students' attention to specific elements of the selected area. The teacher populates the map with the relevant data by selecting the key concepts to be presented to the students. Thanks to the structured representation of information, the students will be able to explore geographical objects by analyzing their properties and by following the links to their official web pages for further documentation. Starting from this personalized layer, which can be quickly generated, the teacher can enrich the map by drawing points, lines and polygons and adding textual annotations for explaining and highlighting particular points/areas of interest. At this point, the map can be used as an interactive table by the students, as well as by the teacher, in order to annotate areas and items with comments and notes. Figure 2 shows a map concerning the museums in Torino. The teacher added annotations to insert specific elements (e.g., Giardini Reali - *Royal Gardens*) with textual descriptions, and to extend the explanation of the museums located in the city.

In the second scenario, the students create the maps themselves. This methodology allows the gathering of proposals related to a particular theme located in a geographical area in order to facilitate the brainstorming activity. The teacher gives students a task to perform; they can explore the available information by querying the application. The inspection of the items allows an indirect learning: the students can retrieve information while exploring the objects in the map, rather than using a static data visualization tool. Moreover, thanks to the semantic representation of information provided by the ontology and by the Linked Data representation of geographical objects, the students can explore semantically related elements in autonomy, without the teacher's intervention. E.g. if a student is visualizing the "Orto Botanico" - *Botanical Garden* of Torino, by browsing the related elements (s)he can visit "Parco del Valentino" and, in a further navigation step, the "Residenza Sabauda - Castello del Valentino", and so forth. They can annotate and draw on the map their own ideas.

The third scenario is derived by combining the previous ones. As the maps can be updated "on the fly", the teacher could create a map template forming a basis for a brainstorming activity, which the students must enrich by collaboratively searching for missing information and annotating relevant data. The creation of the template might facilitate the teacher in the presentation of the task to be performed, offering a starting point for the students' work.

As discussed in [6], the provision of interactive maps improves the students' attention by itself with respect to static maps. However, OnToMap provides more than this: (i) it enables teachers and students to explore large information spaces by exploiting flexible information retrieval functions that take the semantics of data, and semantic relations among data, into account; (ii) it supports the co-creation of custom maps and their annotation, supporting team work. Specifically, students can follow the entire topic created by the teacher using a visual representation of the concepts introduced during the lesson. This increases memorization capabilities, leveraging visual memory. Moreover, the direct manipulation of the map could convey the explained concepts in a more effective way, because the lesson becomes an active method of learning and provides the possibility of doing a brainstorming activity at the end of the task, with the goal of improving the students' criticism skill.

CONCLUSIONS AND FUTURE WORK

We proposed to use Community Maps in education, because of their support to the collaborative management of customizable, geographical visualization of information items, for enhancing student comprehension and memorization of concepts and relations among data. We placed the emphasis on semantic knowledge representation, which is the basis for analyzing data under different points of view. Moreover, we discussed how the OnToMap Participatory GIS could help teachers and students to cooperate at the management of interactive maps that reflect specific information needs. Our future work includes an experiment with students to evaluate the benefits of this approach, both from the objective point of view (learning results) and from the user experience one, in order to assess the usability of this type of tool in a learning environment.

ACKNOWLEDGEMENTS

The authors would like to thank M. Lucenteforte, A. Voghera and L. La Riccia for their work on OnToMap. This work is partially funded by project MIMOSA (MultIModal Ontolgy-driven query system for the heterogeneous data of a SmArtcity, "Progetto di Ateneo Torino_call2014_L2_157", 2015-17).

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