Personalised community maps

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Abstract: With the convergence of geographical information systems (GIS) and internet technology, the public administration is starting to use online maps as a web-based bidirectional communication channel with the population: maps are used: i) in public portals, for publishing and crowdsourcing information about the territory; ii) in policy-making, for defining a community vision of the territory and for involving people in public choices. Both cases raise challenges related to the large amount of data handled in the maps, and to their lack of group collaboration support. We attempted to address these issues by developing an information-sharing model, and a testbed software application, that support group management and the generation of persistent, custom community maps focused on the user's interests. Our model builds on tag-based user profiles and on information filtering. This paper describes our model and the results of an evaluation of the GroupMapping application, based on it.

Keywords: community maps; PGIS; participatory GIS; GIS; geographical information systems; personalisation; information filtering; crowdsourcing.

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1 Introduction

The use of information and communication technologies (ICT) in public administrations (PAs) is increasingly widespread. Moreover, the European Union and the European Smart City model (i.e., the set of strategic actions to make cities intelligent, digital and inclusive) are closely connected to the development of infrastructures devoted to communication and social participation. There are different forms of expression of the Smart City model: from the concept of eGovernment (AOEMA, 2005) aimed at providing services for citizens, to the inclusive models that also refer to learning communities, i.e., communities focused upon the sharing of knowledge (Coe et al., 2001).

In the context of knowledge sharing, community maps are used to represent people's view of an area by gathering and visualising site-specific data (heritage, landscape, knowledge about the area), to understand differences in perception, and to identify the values that people attach to places or elements of their living space. The convergence of geographical information systems (GIS) and internet technology has enabled the management of dynamic, web-based community maps, used by the PA as bidirectional communication channels to interact with the population. These maps enrich public portals with a description of the territory and of its services. Moreover, some of them support crowdsourcing for updating public data, as well as for collecting feedback and checking proposals in public policy-making. The latter aspect is particularly useful to evaluate territorial decisions.

Various participatory GIS (PGIS) support the generation of online maps fed via crowdsourcing. However, they offer limited information filtering and access control services, which are important for collaboration and information sharing. Specifically:

- People and automated sensors can upload heterogeneous data regarding, e.g., the services available in a city, viability, cultural heritage, pollution and energy consumption, as well as the ecological network. While these types of data can be very useful for the fruition and monitoring of an area, they answer rather different information needs. PGIS enable users to select the categories of interest, but the resulting maps cannot be saved for repeated consultation. At the same time, static layers, offered to retrieve data in a 'one size fits all' model, fail to answer individual information needs because they include pre-compiled datasets. These limitations suggest the need for a map generation model enabling people to configure persistent, custom maps by specifying individual information filtering criteria. Notice also that a user might wish to consult maps under different viewpoints; e.g., looking for data relevant to his or her family or to work. Therefore, it might be useful to let users create multiple, personal views of the same information space, reflecting different usage contexts.
- Group-management is a key feature for the organisation of collaboration and communication (created bottom-up and/or top-down) in focus groups and in restricted communities, typically involved in participatory processes. In 'bottom-up' focus groups, social actors can share territorial information and proposals for achieving a common agreed project or plan. Group management is also useful for inviting stakeholders to collaborate with the PA in decision-making processes. In this context, the creation of public or private community maps, focused on specific topics and possibly on small geographical areas, is interesting for information sharing in local communities, as a way to structure data for information retrieval and collaboration. Moreover, the organisation of discussions in subgroups, and their subsequent integration in a general map devoted to the overall participatory process, is strategic to enable the management of focused and structured work. This perspective makes the generation of persistent, custom maps relevant not only for personal use, but also at the group/subgroup level and for PA policies. However, it may require the management of access control to regulate the visibility of data items. To our knowledge, current PGIS fail to offer hierarchical group-management functions and access control policies of this kind.

- On a perspective mainly (but not exclusively) related to participatory processes, a 3D visualisation of the territory facilitates information-seeking tasks concerning geographic information, such as the exploration of an unknown area. Moreover, graphical feedback is important to extend the contributions provided by stakeholders to project proposals integrated in the map of the territory. Currently, most PGIS only support the generation of bi-dimensional community maps and the acquisition of textual feedback or images.

In order to address the above issues, we propose a novel information-sharing model aimed at dynamically generating personalised 2D and 3D community maps for information retrieval and crowdsourcing in public and private groups. As a lightweight and extensible approach to information retrieval, we adopt tag-based data filtering: group members can tag information items to describe their content. Moreover, they can formulate search queries for information visualisation by specifying the tags of interest, or meta-tags representing clusters of tags for filtering information at a more abstract level. Beyond the presentation of ephemeral search results, users (or groups) can define their own persistent maps by specifying/revising the tags for their generation. Furthermore, they can create multiple views on the maps by superimposing additional tag-based filtering criteria. These are represented as Personae, which enable the same user to select information by applying different interest models, possibly associated to specific usage contexts.

As a first testbed for our model, we developed the web-based GroupMapping PGIS, which supports the management of 2D and 3D personalised community maps helping individual users and/or user groups to represent territorial information. This application enables people to share content and collaboratively edit it, as well as to discuss with each other via email, or by adding streams of comments to the elements visualised in the maps. The graphic annotation support offered by our application allows extending the maps by adding comments to delimited geographical regions.

We carried out a preliminary evaluation of GroupMapping with experts in participatory processes, and with generic users in a school scenario. While the latter scenario does not have the complexity of a typical participatory process, it represents a good testbed to evaluate the information sharing and communication capabilities of the application. The test provided encouraging feedback about the efficacy of our model.

This paper extends the work presented in Ardissono et al. (2014) in three aspects:

- While that work models private and public maps associated to 'main' user groups, our model supports the management of subgroups, with associated maps and access control policies, and the selective sharing of results achieved by subgroups in the community map of the main group.
- The present work also introduces tag-based user profiles and Personae supporting the generation of persistent, personalised maps and views on them.
- Moreover, different from Ardissono et al. (2014), it provides experimental results for the validation of the proposed model.

In the rest of this paper, Section 2 provides some background on ICT-supported participation and on spatial information representation. Section 3 presents a sample scenario. Section 4 describes our model and Section 5 presents GroupMapping. Section 6 provides some architectural details about the application. Section 7 positions our work in the related research and Section 8 describes the results of the experiment we carried out. Section 9 discusses the limitations of our work and outlines our future work. Section 10 concludes the paper.

2 Background

Participatory processes are eGovernment models based on an inclusive decision-making approach that promotes the contribution of the population to public policy development by expressing their needs, proposals and feedback. The overall goals are raising the PA's awareness of the priorities to address, focusing on the most useful services and reaching consensus on the actions to carry out.

The use of ICT for sharing geographical knowledge in support of spatial design and urban planning has an important impact on decision-making. In line with institutional geographical knowledge transfer practices, based on digital media via geographic information systems, new possibilities emerge for citizens to construct geographic knowledge voluntarily and spontaneously, using different digital media (Goodchild, 2007, 2009). Indeed, eParticipation tools are evolving with the diffusion of new technologies and software applications supporting participatory processes: e.g., chats, discussion forums, online surveys and web logs (Marzano, 2006). However, social barriers challenge a concrete involvement of the population: even though the diffusion of ICT is increasing, many people perceive online services as complex tools, and they are more comfortable with 'face to face' interactions with the PA. Therefore, online participation, taken by itself, should be considered a model targeted to a subset of the whole population. In order to extend the representativeness of the user base, participatory processes usually include a user involvement phase that could be a traditional one. In that phase, facilitators interact with people (e.g., referents of the main stakeholders) and help them use the services, or they work as intermediaries between people and services, inputting the feedback collected during 'face to face' interactions. Currently, this activity is important to promote online collaboration using ICT and our proposal does not make an exception to this, unless adopted in restricted contexts, in which people have good IT literacy level and the acceptance of an online platform for information sharing, collaboration and communication is possible.

The size and complexity of real-life problems require a true synergy between the power of computational techniques and human capabilities to obtain significant progress in supporting space-related decision-making. Geovisual analytics is a research discipline of visual analytics that emphasises the importance of visualisation and interactive visual interfaces for spatial decision support (Andrienko et al., 2007).

One of the challenges for geographical information sharing, and for processes related to territorial policies, is how to represent space and its inherent relations in a way that is both informative and involving for lay people. As in most urban studies data is found in map format, visualisation capacity (by employing mapping services) and the possibility of describing and representing values that people attach to places (Brown and Raymond, 2007) are critical. PGIS, which support various forms of community participation, are thus emerging as promising tools to overcome traditional barriers to public involvement in decision-making processes and policy-making with a spatial dimension (Bugs, 2012; Brown and Weber, 2012).

PGIS also offer great opportunities to enhance traditional forms of community planning, such as drawing community maps. Historically, these maps consisted of cartographic representations developed by the community, based on a participatory approach; they were created with the support of an artist who summarises the collected data. Usually developed at the scale of small or medium-sized people groups, they offered a clear representation of common values for non-technical users. Recent experiences show that using GIS and other ICT tools can significantly add value to community mapping, allowing to uncover individual and collective neighbourhood definitions (Coulton et al., 2011) and to highlight local issues, planning priorities and needs, or identify development sites. In this way, people add information to the map and act as sensors in their local environment, highlighting both negative and positive factors and producing interesting outcomes for local policy makers and governments (Ellul et al., 2012).

3 A testbed scenario

We introduce the testbed scenario used in the rest of this paper in order to present and validate our information-sharing model. We abstract from the complexity of a realistic participatory decision-making process, which would include other activities, such as consultation and voting. Our scenario focuses on the collaboration support offered to stakeholders.

Let us suppose that a school in Torino, Scuola Media Dante Alighieri, uses the GroupMapping application to manage a website where stakeholders, i.e., teachers, students and parents, share information in a community map during the school year. The main group is private and people can subscribe to it on an invitation basis. However, as the group could be heterogeneous, with people interested in rather different topics, it includes subgroups, with related sub-maps, in order to support restricted collaboration among stakeholders. For instance, specific maps might be devoted to communication and information sharing within individual classes, allowing teachers, parents and students to collaborate, and enabling the students to develop their own joint projects. In our scenario, a subgroup is devoted to the music classes, which represent a particular curriculum, and another one is devoted to information sharing among teachers.

All the stakeholders use the main map to publish data relevant for everybody. For instance, the administrator could publish general information about the school calendar and selected books for the current year, the meal service and so forth. Moreover, he or she could ask people to upload and discuss proposals for activities to be carried out (e.g., projects which the school might apply for, or places to visit), or to share information about events of interests in the city.

Each group member can add comments to information items. Moreover, he or she can upload textual, 2D and 3D content (e.g., proposals for the installation of some equipment in the garden of the school), as well as documents to be collaboratively edited with other group members (e.g., a draft letter to the Dean), and he or she can tag items to describe their content. Furthermore, each group member can create public and private subgroups devoted to specific collaborations.

Even though the overall information space is structured in community maps created for the subgroups, the content presented in a map could exceed the information needs of an individual user. In that case, he or she could define one or more interest profiles for generating the corresponding views on the maps. Each interest model would include a list of tags relevant to his or her interests. For instance, a parent might not be interested in the events and attractions published by the students. In that case, he or she might define a personalised map that filters out that information. Moreover, he or she might create a set of focused maps to access data and discussions about the school projects, or the services offered to students. The views that a user defines represent shortcuts to information for a quick retrieval in different usage contexts.

4 Information-sharing model

This section describes the main features of our information-sharing model.

4.1 Management of user groups

Our model supports communication and information sharing in public and private groups. A group has the following features: name, URL, type (public or private) and geolocation. Moreover, it has an owner, one or more administrators and a possibly empty member list of registered users, who can work in the group with limited access control rights. Groups enable the sharing of two main types of data:

- the information items created or uploaded by the group administrators and members
- the set of tags defined within the group for information classification and retrieval purposes (see Section 4.3).

Within a group, members can create subgroups to support restricted information sharing and collaboration. A group is therefore associated to a possibly empty list of subgroups and it can refer to its parent group. A main group is the root of a hierarchy and has no parents.

Subgroups have the same structure as main groups and they retain separate information spaces to support restricted collaboration and access control on data items. The idea is that not all the information produced in a subgroup might be relevant to the main group or sharable with it. Thus, subgroups support a selective publication of content in order to share it with the whole community in a controlled way.

While a subgroup inherits the geolocation of its parent group, it can override it to focus on a different geographical area. This is relevant for discussions in participatory processes concerning large areas, such as river and lake contracts, because their focus subgroups might be geographically distributed.

4.2 Representation of information items

The information items shared in a group, or subgroup, are objects having different nature: e.g., they can be documents (texts, images, spreadsheets, etc.), 2D elements (objects, lines, regions, etc.) and 3D elements (e.g., KMZ models[1] and 3D models created by means of the graphical editor embedded in the application). All the information items have the following metadata:

- An identifier, represented as an URL, which makes it possible to unambiguously refer to the item from different groups or subgroups.
- The title of the item.
- An optional description field.
- The date in which the item was added to the information space and the identity of the user who added it.
- Geographical coordinates: these are optional because not every information item is geo-localised.
- The list of tags associated to the item.
- A reference to the stream of comments associated to the item. Each comment has an owner, a title and some textual content.

Moreover, 2D and 3D items have features that specify their shape, position and orientation. Furthermore, editable documents such as textual documents, spreadsheets, etc., have their own descriptors, generated by their source applications.

4.3 Content classification

We classify content by exploiting user-defined tags; moreover, we base information filtering on the selection of content tagged with keywords corresponding to search queries.

Tags are keywords that users can freely define and associate to objects in order to represent their meaning, or to refer to related concepts; e.g., see Mathes (2004). The association of tags to items supports information filtering by exploiting knowledge spontaneously produced by people. The tag system can adapt to the dynamics of information seeking needs because it incrementally evolves with the definition of new tags.

In our model each user can visualise the tags defined in his or her groups and associate them to information items; moreover, he or she can create new tags. As different main groups may work on diverse topics, the user-defined tags are local to a group; however, in order to limit the redundancy in the definition of relevant terms, they are shared among a group and its subgroups. The tag system consists of a two-level hierarchy that supports the organisation of tags according to the broad topics to which they refer:

- tag categories represent general topics addressed by the group and each of them includes one or more tags
- tags are keywords for classifying information items.

The management of a user-defined tag system has pros and cons with respect to the conceptual representation of information applied in semantic knowledge representation, where formal ontologies explicitly describe the domain entities and the relations among them; e.g., see Gruber (1995), Lowe (2005) and Fonseca et al. (2000). On the one hand, tag systems are easy to use because they do not require any technical skills for their management and people can directly update them by adding new tags. On the other hand, they offer limited flexibility in information search because they lack semantic inference capabilities. For our model, we selected a tag-based information filtering approach because our priority was the development of an application supporting simple group collaboration. In that context, the specification and maintenance of a domain ontology, which requires knowledge representation expertise, would be too complex.

4.4 User profiling

In our model, the personalisation of community maps to the individual user builds on the management of an explicit user profile storing preferences, which are expressed as a set of tags. For transparency and control purposes, we adopted a *scrutable* approach to user modelling (Kay, 2006): the user can inspect and modify his or her profile at any time, in order to revise the specification of his or her interests and to correct any existing mistakes or obsolete information. For instance, the user can remove the tags that have become irrelevant.

As previously stated, we aim at supporting the management of multiple views on the information space to help the user interact with his or her personalised maps in different contexts, which might determine diverse information interests. These contexts might be driven by the roles played by the user (e.g., family vs. work) or simply by the need to quickly access different sub-maps of a map. For this purpose, we structured the user profile in multiple 'Personae', each one representing an interest profile for the generation of a personalised map. The user can select the Persona to be applied when browsing the information space. The user profile has the following structure:

- *General model*: It maintains general information about the user and is valid across all the groups to which he or she belongs. The general model stores:
  - *Personal information*: First name, family name and user account.
  - *General preferences*: This is a list of < *feature, value* > pairs storing preferences that can be applied to any map generated for the user. Currently, it only stores the properties of the font for the visualisation of information; however, in the future it might include the preferred language for the user interface, and other similar data.
  - List of groups to which the user is subscribed and, for each group, a non-empty list of Personae defined within the group. For each group, the user model includes a default Persona, used to store the tags selected by the user. If the user wants to manage multiple customised maps, he or she can create more than one Personae.

In turn, a Persona includes:

- Identifier of the Persona.
- *Tags*: this is a possibly empty list of tags and specifies the information filtering criteria to be applied when the Persona is used.

- *Items*: This is a possibly empty list of references to information items that the user wants to visualise in the map. This is important in community mapping and in participatory decision-making processes because it enables people to force the inclusion of information items that they need to visualise, regardless of any specific filtering criteria.

4.5 Information filtering and personalisation

Our model supports the projection of a community map on a restricted set of information items by exploiting tag-based data filtering. Given a set of shared items $I = \{i_1, \ldots, i_n\}$ and a set of selected tags $T = \{t_1, \ldots, t_m\}$, the projection of I on T is a map M that only includes the items tagged with at least one of the tags in T. That is, the intersection between T and the list of tags associated to the items of M is not empty.

The tags defined within a group are thus the key tool for managing both personalisation and information retrieval. The idea is that a custom map should only include the information items whose tags correspond to the user's interests. Moreover, given a map and a search query expressed as a list of tags, the results of the query will be a further filtered map:

- A personalised community map corresponding to a Persona P (or to the default Persona) is derived by visualising the information items whose tags are included in P, together with the information items explicitly referred by P.
- Any community map can be projected on specific types of information by applying the corresponding tags. For this purpose, the user must select the set of tags (or complete tag categories as a shortcut) relevant for filtering data.

5 The GroupMapping application

GroupMapping is based on the previously described information-sharing model. We designed its user interface and functions in a user-centred way, involving domain experts, who were mainly urban and regional planners.

The experts highlighted the importance of enabling users to crowdsource different types of information (written, graphical, photos) in the maps. Specifically, in order to develop a socially shared map, on which a community of people expresses the requirements in the management of a part of a city, an ICT application should support the development of simple 2D or 3D objects, describing territorial needs.

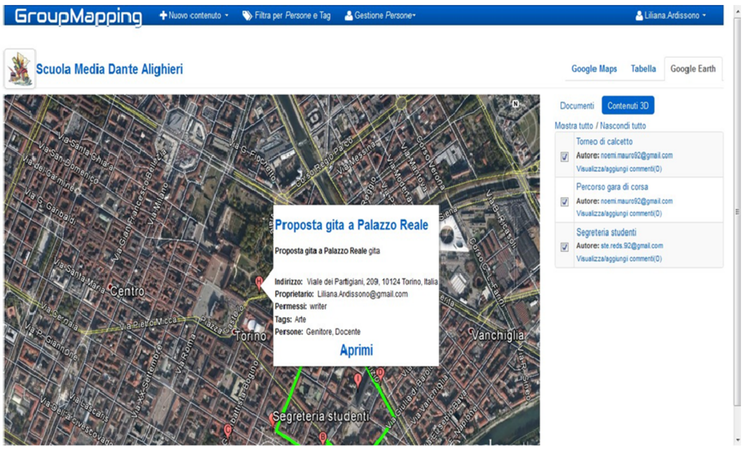
In the following, we focus on the functions offered by the maps, leaving the details about group subscriptions and other similar information apart.

5.1 User interface and functions

The main page of a (sub)group enables the user to view its main community map. The page supports the management of his or her user profile and it offers the communication services to interact with the other group members.

Figure 1 shows a portion of the 3D map for the Dante Alighieri group, personalised for a specific user. The map displays one graphical item, drawn in green: this is the path of a running competition ('Percorso gara di corsa'). Moreover, it shows a few markers associated to documents. Each marker or 3D model can be clicked to view features, tags and Personae of the information item, or to open it for reading/editing purposes, depending on the user's access rights ('Aprimi' link – open me). In Figure 1, the user has expanded the 'H' marker, associated to a document describing a proposal for a trip to Palazzo Reale in Torino.

Figure 1 A personalised community map for the Dante Alighieri group (see online version for colours)



The right portion of the page displays the items available in the map in two tabs, one for 2D/3D content ('Contenuti 3D') and one for the other geo-referenced items ('Documenti'), including the editable documents. These lists enable the user to interact with information items: e.g., to open documents, zoom the map on 2D/3D objects (by clicking on the title), or to visualise comments and add new ones. The 'Documenti' list also includes the items that are not geo-referenced.

The map enables users to share and collaboratively edit various types of items, including documents and drawings. The '+Nuovo contenuto' (+new content) link at the top left of the page makes it possible to:

- create or upload a document
- upload a 3D model from a repository, e.g., a KMZ model
- create a 3D item by means of an editor that allows sketching broken lines and polygons, selecting colour and height of items, moving, orientating and resizing them.

Figure 2 shows the editor for drawing polygons ('Nuovo poligono' – new polygon): at the top, there are the instructions for drawing lines and shapes, and the fields for adding the item name ('Nome del poligono') and an optional description ('Descrizione del poligono'). Below, there are the tools for selecting colour and height. The lower part of the editor includes the menu showing the main tag categories for associating tags to the item, and two buttons to save the item or discard it.

Figure 2 Form for sketching polygons and 3D models in a community map (see online version for colours)

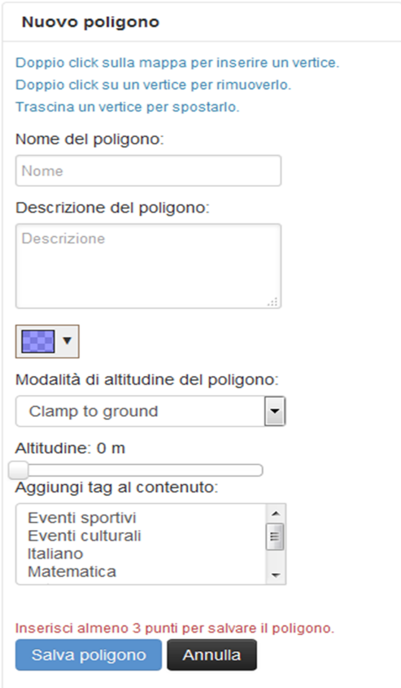
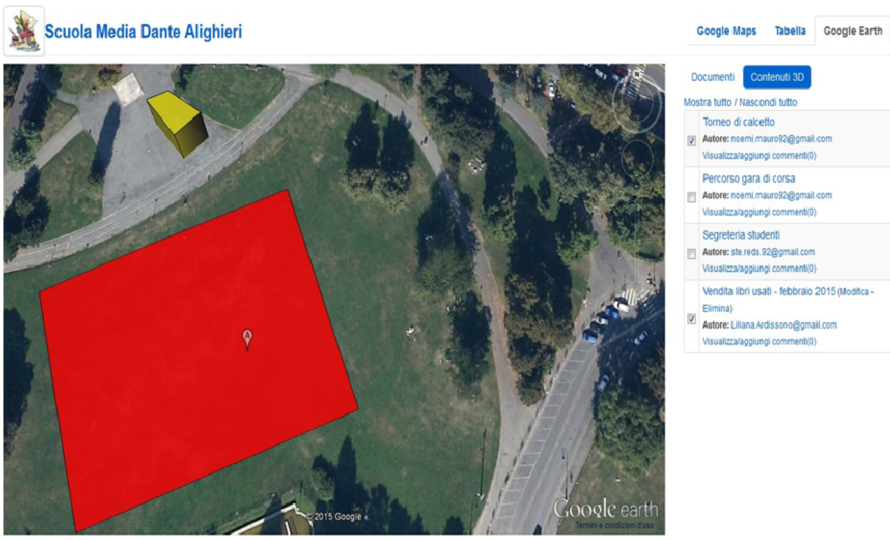


Figure 3 shows a zoom of the map in the area of Torino. It displays the proposal of a soccer competition (‘Torneo di calcetto’) and a free book market (‘Vendita libri usati’). The area selected for the competition has been drawn as a red rectangle in a park. Above it, a yellow 3D object represents the tent for the market.

Figure 3 Zoom of the 3D personalised community map (see online version for colours)



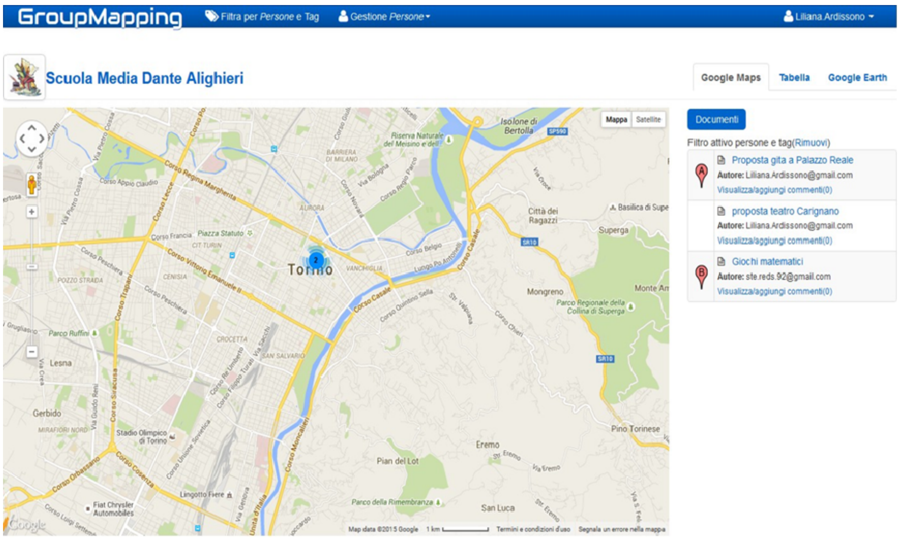
The ‘Google Maps’ and ‘Tabella’ tabs at the top right of the page make it possible to visualise the map in 2D or as a table. The latter format does not render the geographical location of items but it is accessible from any end-user device and browser.

5.2 *Information search and filtering support*

The ‘Filtra per Persona e Tag’ (filter by Persona and by tag) link above the map of Figure 1 supports information filtering. It enables the user to select a Persona for the generation of a custom map, and/or to select tags for further filtering items. The map presents the results showing the information that satisfies the current search criterion. For the user’s convenience, GroupMapping also enables users to search for textual documents by content (i.e., included words) and by document name. We skip the description of these functions for brevity.

Figure 4 shows the results of searching for information items related with tag ‘eventi culturali’ (cultural events) on the map of Figure 1, but it is visualised in 2D. The search query returns three items, one of which is not geo-located and thus only appears in the table at the right side of page.

Figure 4 2D visualisation of cultural events from the map of Figure 1 (see online version for colours)



5.3 *Adding notes and comments to the maps*

In order to support discussion and information sharing, users can add comments to any data items shared in a group. The comments associated to an item can be visualised by clicking on the ‘Visualizza/aggiungi commenti’ (show/add comments) link in the tabular list of items displayed at the right side of the map; e.g., see Figure 1.

Drawing models and adding comments to information items are powerful tools for discussion and collaboration support because they enable people to enrich the maps with proposals and feedback, and to associate notes and streams of comments to specific regions of a territory.

6 Technical details

We developed GroupMapping in Java, using JavaScript and HTML5 for the development of its user interface.

The application uses some cloud services: for instance, the management of documents (textual, spreadsheets, etc.) exploits the Google Drive repository (google.com/intl/it_it/drive/), which supports the sharing and collaborative editing of documents under defined access control rights. Moreover, the user authentication is based on the Google Identity Platform (developers.google.com/identity/), and on the OAuth 2.0 protocol (oauth.net/2/).

For the generation of the maps, we initially considered open-source technologies, and in particular, the usage of graphical 3D libraries related to the WebGL project (MDN, 2015) on an OpenLayers map (http://openlayers.org/). However, the available libraries were not mature enough for developing a user-friendly interface supporting an efficient visualisation and interaction in 3D environments. Therefore, for the current version of the application we selected Google Maps (https://www.google.it/maps) and Google Earth (https://www.google.com/earth/), which provide highly usable interaction tools for browsing and editing the virtual environment of 3D maps from standard browsers. Unfortunately, the Google Earth plug-in is only partially supported. As the WebGL technology has meanwhile largely improved, we will use it in our future work for replacing the implementation of the 2D/3D interactive functions offered by GroupMapping.

7 Related work

Several GIS support information filtering but they restrict the selection of content to fixed categories representing pre-defined layers; e.g., see MyLondonMap (mylondonmap.com). Our work aims at providing flexible information filtering tools for the generation of maps satisfying individual user interests, expressed by means of tag-based filters.

The basic tag-based filters provided by CrowdMapping are similar to those offered by PGIS such as OpenStreetMap (openstreetmap.org/) and location-based social networks such as TripAdvisor (tripadvisor.it) and FourSquare (https://it.foursquare.com/). However, our model enables users to define Personae for a quick retrieval of information. Moreover, it offers tag categories that group sets of related tags and can be used to retrieve clusters of information items associated to broad information categories. Furthermore, it supports the visualisation of results in persistent maps, useful for incremental project development. For instance, leaving group collaboration apart, let us suppose that the user is organising a trip and he or she wants to select hotel, restaurants, points of interest, etc., possibly revising his or her itinerary later on. Our application makes it possible to visualise all the relevant types of information together, in a unified view that the user can update as needed.

Most PGIS enable the collection of textual feedback using standard bi-dimensional maps; e.g., see CrowdMap (https://crowdmap.com) and GeoKey (http://geokey.org.uk/). Other projects offer a virtual representation of the territory for an immersive navigation, but their maps cannot be enriched with user-generated content. Some PGIS enhance communication with 3D information in virtual reality (VR) or augmented reality (AR) environments describing proposed re-development scenarios. For instance, the LIVE +

GOV project combines AR and VR with social networks for enabling internet users to upload and receive geo-localised information about buildings and locations in a city, as well as to participate in polls and discussions. Moreover, Min Stad (2015) (a portal for the City of Goteborg) and partially PlanYourPlace by Hunter et al. (2012), integrate GIS with social networks enabling users to upload 3D contents and to publish comments.

With respect to these works, GroupMapping offers a richer type of crowdsourcing where users can share and collaboratively edit heterogeneous content, including 3D models and drawings directly created on the maps. Furthermore, it supports information sharing in groups and subgroups with access control management. Finally, it handles multi-faceted, personalised maps filtered according to individual user interests.

The Ushahidi PGIS (ushahidi.com) supports crowdsourcing by enabling people to upload geo-localised textual information, pictures and videos, lines or regions directly drafted in the maps. However, it does not manage groups, nor does it model the users' interests. Therefore, it can only visualise 'one size fits all' maps, filtered according to pre-defined content categories.

The research on Computer Supported Collaborative Work developed frameworks for the management of shared information spaces for team-based collaboration. Ardito et al. (2013, 2016) introduce 'Personal Information Spaces' to enable people to share, annotate and manipulate documents in a customised Web-based repository. Moreover, several groupware applications manage shared activity contexts for distributed team coordination; e.g., see Project View IM by Scupelli et al. (2005), and Active Collab (activecollab.com). Introne and Alterman (2006) introduced the concept of coordinating representation of shared activities to support general-purpose collaboration in distributed teams. With respect to these works, we aim at facilitating group collaboration in the management of geographical data, which brings additional issues in the visual representation of information spaces and in information search and filtering.

The work in Hu et al. (2015) presents a collaborative 3D GIS for public participation in multistage decision-making. The application has a dual-subsystem architecture to fit the collaborative 3D GIS objectives for an iterative decision-making process. The first subsystem supports problem definition and analysis, alternative solution generation, and a preliminary evaluation of solutions. The second one allows interested individuals and groups to review the alternative solutions and opens the evaluation process to a broader public participation. However, the effectiveness of the collaborative editing tools in the design system is limited and only the review system is a web browser-based application.

Finally, the recent research on social network analysis for e-Government is complementary to our work because it offers analysis functions that might be useful for the interpretation of crowdsourced data and the extraction of summaries from them, e.g., consider (Villena-Román et al., 2014).

8 Experiments

In order to test our information-sharing model, we carried out a summative evaluation of the GroupMapping application by means of two user studies, described in the following subsections:

- In the former, we organised a focus group with few experts in participatory processes to collect their feedback on GroupMapping and to elicit further user requirements for improving the participation support offered by the application.
- In the latter, we carried out an empirical usability test of the information sharing features offered by the application, in a collaboration scenario, focusing on information retrieval. In this case, we involved a group of non-technical internet users. It is worth noting that we were not interested in evaluating tags *per se*, because they have largely proved to be useful for information filtering; e.g., see Gemmel et al. (2012) and Carmagnola et al. (2008). This experiment focused on assessing whether the combination of tag-based filtering and Personae improve information retrieval in a shared information space with respect to tag filtering alone.

8.1 Focus group with experts in participatory processes

We collected feedback on the functions offered by GroupMapping from experts in participatory processes (urban and regional planners) who are not familiar with Computer Science but who are internet users and regularly use GIS and PGIS for their work. We selected experts from the CED PPN researchers of DIST of Politecnico di Torino. The focus group consisted of an evaluator of city policies, a social inclusion facilitator, a landscape and urban designer, and an urban planner. The experts used GroupMapping to explore the (subgroup) community maps that presented documents and project plans produced for a river contract. We asked them to examine the functions offered by the application while they searched for information. Then, we interviewed each expert asking her or him to provide feedback on the main functions offered by GroupMapping and suggestions for further system development. The following aspects emerged from the interviews:

- The experts confirmed the importance of group-based mapping and information access control for participatory processes, in order to manage local communication and information sharing within focus groups, handling discussions in separate, possibly private interaction threads, and integrating them in later phases of the processes. Moreover, the experts positively evaluated the crowdsourcing functions that support the introduction of shared elements, and the discussion activity on such elements, based on comments. However, they asked to moderate user-generated content. They also strongly appreciated tag-based filtering for the specification of custom maps and for the generation of restricted views, because this helps specialised discussions and easy information access.
- The experts identified the following functions that deserve to be developed:
    - First, they raised the issue of privacy management and anonymous contributions to discussions for dealing with controversial topics.
    - Secondly, they asked for trusted user authentication to support voting; see also Hunter et al. (2012). While the management of ePetitions is important in participatory processes, we believe that extending CrowdMapping in this sense would not be strategic and a better approach might be the integration of a software specialised in this type of activity, such as LiquidFeedback (http://liquidfeedback.org/). Under this assumption, trusted user authentication

would be necessary when people express their votes. Differently, a looser type of authentication, such as the one currently provided by our application, is sufficient for carrying out the other types of activity.

- Thirdly, they asked to extend the user interface of GroupMapping, and the types of data stored in the maps, to multimodal content such as voice comments and videos, in order to enrich the contributions to community mapping accepted by the system and its presentation capabilities.
- Other feedback concerned general aspects of the user interface. For instance, the experts suggested that we extend the editor for drawing 2D/3D content with additional features. They suggested that we offer pre-defined shapes and models, and to develop a drag and drop function in order to add items to the maps. However, we believe that, similar to the case of voting, specialised tools, such as those used by planners, could be employed to develop models which can be imported in the maps by means of a file upload feature as the one currently offered by our application.

8.2 Evaluation in a school domain

In order to assess the efficacy of our model in public services, not related to participatory processes, we conducted an empirical usability test based on the sample scenario outlined in Section 3. We asked participants to perform tasks by using the discussion group of the school; the shared information included newsletters, proposals by parents or teachers and feedback on services. Most documents shared in the group were geo-located and some of them were 2D/3D elements that characterised the areas affected by the described activities; e.g., markets, competitions and so forth.

We asked participants to play the role of parents who had registered their children in school Dante Alighieri, and who wanted to enrol them in a set of services; see below the details of the two tasks. We did not specify the exact steps of the task: we only provided participants with scenario and final goal, and they were free to interact with GroupMapping to reach their goals. However, we limited the functions they could use (tag-based filtering alone, or in combination with Personae) depending on the task they were carrying out. Our main research question was:

> *Does the adoption of interest models for the generation of personalised community maps improve information search with respect to tag-based filtering alone?*

We involved 23 people (16 males and 7 females) who worked for free, without any reward; 16 of them were parents with children in scholar age; the others did not have any children. Participants had different backgrounds (34.78% technical, 47.82% scientific, 17.39% humanities) and their age ranged between 23 and 54 years (average: 34.52).

The experiment had a single-factor, within-subjects design. Two treatments were applied, a base-case control treatment, and an experimental one that included two tasks. Both treatments were conceived as information-seeking tasks for decision-making. Participants had to complete the tasks by browsing the maps managed by GroupMapping and by exploiting its information retrieval functions:

- In the baseline treatment (tag-based filtering alone), participants filtered information 'on the fly' by selecting the tags relevant to their search queries.
- In the experimental one (tag-based filtering + Personae), participants performed the requested tasks by using a pre-defined Persona, and by creating a custom one (in order to generate a personalised community map), and by further refining results through tag-based filtering.

We considered each treatment condition as an independent variable and each person received both treatments; however, we counterbalanced their order to minimise the effect of practice and fatigue.

Before starting the experiment, participants read a document describing the scenario. Then, we presented the GroupMapping application and they used it for 20 min to familiarise with it. One participant at a time performed the test, which lasted ~1 h. While the participants were working, the experimenter wrote down their comments while sitting at some distance from them. Each person performed three tasks:

- *Baseline treatment*: he or she was asked to analyse the services offered by the school for evaluating whether to register his or her child in the normal class, planning morning activity only, or in one of the experimental classes (in particular, a music one), which offered integrative activities during the afternoon hours. In order to do that, the participant had to browse the main map of the school and a sub-map, looking for information about services and opinions expressed by people who used those services before. The participant could use tag-based filtering (but not Personae) for finding data.
- *Experimental treatment*:
    - First, the participant had to search for information about the proposals concerning sport and cultural activities in order to subscribe his or her child to some of them. For that purpose, he or she was asked to generate a map personalised to the interests of a stereotypical parent by using a pre-defined Persona. Given the map, he or she could further filter the content by means of tag-based filtering in order to compare the available proposals.
    - Secondly, the participant had to define a Persona, with associated tags and (possibly) references to documents, in order to generate persistent, personal views on the information shared in the main community map, as well as in the sub-map for the music class. We asked this in order to monitor his or her actions and to check whether he or she encountered any particular difficulties when creating a custom map in the absence of a specific search goal.

At the end of the experiment, we interviewed each participant using a questionnaire aimed at assessing the usability of GroupMapping, the efficacy of its information search support, and at collecting verbal comments about the application. We asked people to rate the following dimensions on a seven-point Likert scale (from 1, the worst value, to 7, the best one):

- the usefulness of the joint usage of Personae and tags when searching for specific types of information in a possibly large dataset
- the ease of use of the application

- the efficacy of the support in completing the experimental task, i.e., in making the requested decision
- the clarity of the user interface.

Table 1 reports the questions we proposed and Table 2 shows the statistics concerning the answers provided by the participants.

Table 1 Post-test questionnaire (translated from the Italian language)

No.	*Dimension*	*Question*
1	Usefulness of Personae + tags	How useful was it to use Personae jointly with tags when you searched for specific types of information?
2	Ease of use of the application	How easy did you find the interaction with the application?
3	Efficacy of the application	To which degree do you think that the application helped you in the execution of the tasks of this experiment?
4	Clarity of the user interface	How easy was it for you to understand the meaning and usage of the functions offered by the application?

Table 2 Evaluation of the user experience with the GroupMapping application

	Personae + tags	*Ease of use*	*Efficacy*	*Clarity*
Avg.	6.087	5.478	5.957	5.652
Median	6	6	6	6
Std. dev.	0.848	1.41	1.107	1.265

Concerning the first task (baseline condition), most participants confirmed that tag-based filtering strongly supports information search, even though the resulting maps contained a few items that were not relevant to their search queries. This means that we should try to improve the precision of the system to achieve more focused results.

Regarding the second task, 17 participants rated the combination of Personae and tag-based filtering very well, providing an evaluation ≥6. Moreover, most participants told us (verbal comments) that, by combining Personae with filters, the resulting maps focused on the information needed to achieve their objectives. However, the remaining participants complained that the joint application of the two techniques produced narrow search results. We believe that this might be caused by the fact that the stereotypical Persona used to generate the map did not accurately represent the interests of these people, and they needed a custom one.

Finally, by observing participants in the third task, we noted that they did not encounter any particular difficulties in the definition of a custom Persona. They were satisfied about the resulting projections of the maps, which met their interests. We also noticed that they learned to use GroupMapping rather quickly. This is coherent with the fact that they positively evaluated the ease of use of the application.

9 Discussion and future work

The results of the evaluation highlighted positive features and limitations of our information-sharing model. It is clear that further collaboration support functions have to be developed: e.g., trusted user authentication, customisable data management, integration with ePetition software, and so forth. In general, however, for a successful exploitation, we should extend our model to address other technical barriers that we have not discussed so far:

- The first ones concern data management: we currently assume that the information items uploaded in a map are visible to all the group members and that only the owner of an item, and the group administrator, can remove them. In order to provide a flexible treatment of shared information, our model should be extended to deal with finer-grained access control policies (e.g., to establish which users can read and modify items), version management, and data provenance. Moreover, it should support policy configuration at the group level; in this way, stakeholders might control data management.
- Another important issue, affecting all crowdsourcing platforms, is the evaluation of the quality of Volunteered Geographic Information, which strongly influences the trust in the data provider service and the usefulness of sharing information; e.g., see Barron et al. (2014).

The experiments we carried out also raised some issues concerning the user interface of our application, which the test participants positively evaluated, but suggested to improve as far as 3D data editing is concerned. Indeed, the management of 3D data models is a critical feature because it employs the Google Earth visualiser, which requires a plug-in that is not available for mobile devices. However, cross-device accessibility is a compulsory requirement of any online application, given the large diffusion of smartphones and tablets with respect to desktop computers. Our future work will address a transition from proprietary software such as the Google Earth plug-in to the usage of an emerging standard for Web-based data visualisation, such as WebGL, increasingly supported by internet browsers. Anyway, it is worth noting that our application also supports standard map visualisation (see Figure 4), which makes it possible to present information cross-device.

In our future work, we will extend the personalisation capabilities offered by our model in order to move from adaptable (Opperman, 1994) community maps, explicitly configured by the user, to user-adaptive ones, which reflect the changes in the user's interests. We will introduce a dynamic user-modelling component for the unobtrusive acquisition of user profiles, given the user's actions during the interaction with the application. GroupMapping already logs the main user actions, e.g., tagging data items, creating new tags, filtering maps by tags, and so forth. However, it does not employ this type of information for automatically updating the Personae. For the extension of the application, we will follow the approaches described in recent research on personalised information filtering and recommendation, which has proposed content-based and collaborative recommendation models based on people's tagging behaviour; e.g., see Agrawal et al. (2009), Gemmel et al. (2012) and Ardissono et al. (2015). In particular, we will monitor the usage of tags, and their frequency, to identify the most interesting ones for the user, taking the temporal dimension into account to keep user profiles coherent with the changes in his or her interests; e.g., see Basile et al. (2015).

10 Conclusions

This paper presented an information-sharing model, and a testbed application, which support the management of personalised community maps for information search and crowdsourcing in public and private collaboration groups. While the overall scope of the project underlying this work concerns participatory decision-making, this paper focused on information sharing and crowdsourcing.

The GroupMapping application, presented in this paper, supports the online management of discussion groups and subgroups. It enables users to share various types of digital content, including 3D objects, and to discuss about it by interacting with 2D/3D community maps that offer tag-based information filtering. Moreover, the application allows the projection of maps on individual interest models in order to generate custom, persistent visualisations of the information space. A preliminary experiment with a restricted number of people provided encouraging results about the efficacy of our model and the usability of GroupMapping. Furthermore, it provided useful feedback for extending the application to support richer interaction with people. The PA is currently interested in collecting data to offer services and to produce participated territorial decisions. River agreement (RA) is an example of the impact of those technological facilities. The model underlying GroupMapping can support many of the current participated design processes. These need to involve different stakeholders in the definition of a representation of the territory, as well as in the design of strategies for the water quality, fruition and valorisation of the natural and cultural landscape in a specific river basin. Anyway, ICT should not replace a direct communication between PA and the population. An application such as GroupMapping can help identify social actors interested in the innovation of these river territories, and involve them in an eParticipation process that could accompany the traditional one in the River Assembly for negotiating decisions.

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Note

[1]Keyhole Markup Language models.