Facilitating Participatory Decision-Making in Local Communities through Map-Based Online Discussion

Bo Yu
College of Information Sciences and Technology
The Pennsylvania State University,
University Park, PA 16802
+1-814-865-6177

byu@ist.psu.edu

Guoray Cai
College of Information Sciences and Technology
The Pennsylvania State University,
University Park, PA 16802
+1-814-865-4448

cai@ist.psu.edu

ABSTRACT

Geographic information systems and online mapping technologies have been widely used for supporting participatory decision-making in local communities. However, limited studies have been conducted to use online maps directly as a communication tool to support community discussion. In this paper, we explore the potential of using geospatial annotation technology to facilitate map-based online discussion among various stakeholders in local communities. In particular, we developed a prototype system, GeoAnnotator, which explicitly links participants' discussion contributions with their geographic references. The features of this system are based on the conceptual understanding of map-based discussion space, which guides the generation of initial system requirements. We demonstrate the utility of such systems by a hypothetical scenario of building a Smoke-Free campus in a university community.

Categories and Subject Descriptors

H.2.8 [**Database Applications**]: Spatial databases and GIS

H.5.3 [**Group and Organization Interfaces**]: Web-based interaction

General Terms

Design, Human Factors

Keywords

Socio-technical systems and design, Communities and e-government, Web 2.0, Map-based discussion, Geospatial annotation

1. INTRODUCTION

It is fairly evident that geographic information systems (GIS) and geospatial technologies has become an important decision-making tool for local communities. For example, geospatial visualization techniques can be used to show the current and future situations of the communities in a more intuitive and realistic way [21]. The spatial analytical capabilities of GIS can assist local committees in understanding the nature of community issues and making better decisions [5,15,26]. However, it has been well recognized that "traditional GIS methodologies often exacerbate the marginalization of community stakeholders who lack access to GIS technologies" [9]. An important recent development in community-based GIS has

been the recognition of the need and the power to enlarge the level of community involvement in spatial decision-making processes [4], since "the complexity of modern society cannot be managed – even at the local level – without the direct involvement of all the components of the society" [8].

The incorporation of community participation into GIS has been discussed extensively in a variety of research areas, such as Public Participatory GIS (PP-GIS) (For reviews, see [7], [27]), Community Information Systems (CIS), or Public Participatory Spatial Decision Support Systems (PP-SDSS) [4]. Although the terms vary, the concept is that geospatial technologies combined with online participatory functionalities can form a new "public square" to augment traditional methods of participation such as community council meetings and consultation documents [28] and to improve the interaction and communication among various stakeholders in local communities where decision-making usually has a spatial connotation.

It has been well documented among scholars that there are various levels of public participation, usually structured in a ladder of increasing participation [3], [32]. Although the detailed level classifications in participation ladders vary in research or practice contexts, the basic structure is the same. On the bottom rung of the ladder, participation can be described as "the public right to know". This stage represents the online delivery of information to the public in the one-way direction. Then the participation moves to a higher level where the citizens can express opinions and provide arguments by engaging in two-way discussion with decision-makers. In the highest stage of the ladder, the public are directly involved in the final decision-making. An example of such decision-making process is voting for the most suitable alternative in community planning issues. The higher levels in the ladder can be reached only by satisfying the requirements of the lower steps in the ladder.

Many researchers have argued that GIS combined with web-based technologies has the potential to assist the communities at all levels of participation [16], [28]. However, the outcomes of many PPGIS projects in literature [1,19,29] reveal that, although GIS and Web technologies have succeeded in many cases broadening the community members' access to spatial information and improving their understanding of public issues, they have limited impact on increasing their involvement in local communities' spatial decision-making processes. In a good number of cases, GIS is only used as a parallel media for broadcasting information to the citizens in a one-way communication process [28]. While these broadcasting activities represent important stages in promoting community participation, as they make the decision-making processes more transparent, they should be only the first of several stages where

geospatial technologies can facilitate the increasing of citizen engagement and participation [13].

In this study, we are interested in using map-based online discussion to facilitate the participatory spatial decision-making processes in local communities. Specifically, we are on the midway of developing an online geospatial annotation system to enable map-based online discussion. The geospatial annotation system, which explicitly links participants' discussion contributions with their geographic references in the map, can provide an effective communication and analysis platform to enrich the dialogues among various stakeholders in spatial decision-making processes. For example, participants can circle an area directly in the map to which they want to draw attention and obviate the need for specialized language in order to orientate the other participants to an object under discussion [12]. It is believed that, such visual discussion support tools can encourage the public to actively participate in community discussion and help the communities climb the participation ladder from the "local government" to the "local governance" [8].
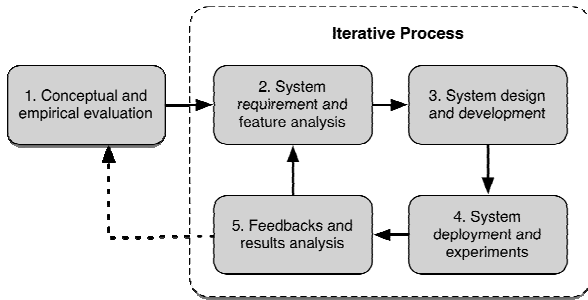

Figure 1. Iterative Development Cycle

To build such a map-based online discussion environment, we adopt an iterative design, development, and deployment cycle [22], since supporting participatory decision-making itself should be seen as an open-ended process in which the system must be developed and adapted to the changing needs of the local communities [10]. The iterative development cycle of our approach is illustrated in Figure 1. In the first step, our conceptual understanding of map-based online discussion is used to provide the inputs for the first iteration of system development. Then the initial feature requirements will be identified, which will be used to guide the system design and development. After the first prototype system is developed, the system will be deployed and tested in experiment settings. The data collected from the experiments and users' feedbacks will then be analyzed to refine our understanding of the system, which leads to a new iteration. In this paper, we will report on the conceptual framework, feature requirements, and the prototype system. We are in the process of validating our design using scenario-based experiments and further, which will be reported in a follow-up paper.

The structure of this article is outlined in the following way. First, we present the framework of map-based online discussion space and explain the major dimensions of it (Section 2). In Section 3, the feature requirement of the system will be identified based on the conceptual analysis. Then, in Section 4, we will discuss the design issues and technical architecture of the prototype system, followed by a scenario-based evaluation of the system. A brief review of related projects is then provided in Section 5. Section 6 draws the conclusion.

2. UNDERSTANDING MAP-BASED DISCUSSIONS: A FRAMEWORK

The distinguished feature of map-based online discussion is that it provides an open and shared *discussion space* that allows all the stakeholders to address a particular *public issue* that is situated in the *geographic space*. On one hand, it goes beyond supporting public participation at the level of spatial information delivery and aims to create the discussion space to encourage all the stakeholders to contribute. On the other hand, the public issues in local communities usually have a geospatial connotation, and the discussion will inevitably include geographic references. Hence, the map-based display and geospatial technologies will play a central role in supporting the discussion space.

In our analysis, the shared discussion space consists of three dimensions: (1) the *information space* that allows the participants to access and share relevant information for the discussion, (2) the *argumentation space* that organizes and structures the participants' debates and arguments, (3) and the *analysis space* where the participants can analyze and make sense of all the individual inputs (see Figure 2). The three dimensions concurring in the creation of the whole discussion space are inspired by the work in [8] that aims to support the deliberative community networks. However, the significant difference here is that we emphasize the roles of map-based display and geospatial functionalities in supporting the discussion space. In the following part of this section, we briefly describe the three dimensions of the discussion space and discuss how maps can play important roles in each of them.
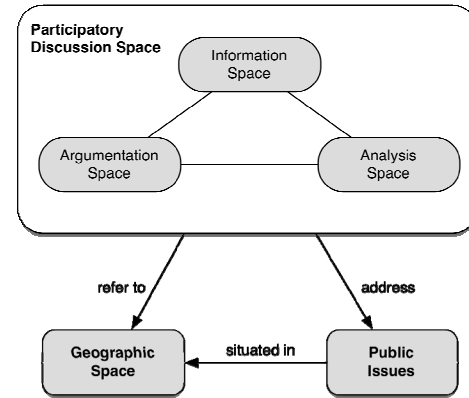

Figure 2. Map-Based Discussion Space

2.1 Information Space

The purpose of the information space is to allow the participants to set up the information background that frames the issue under discussion. Arguments based on a strong information background are more likely to lead to a productive discussion that comes to a rational conclusion [8]. There are two types of information that should be supported in the information space. First, participants should have access to background information about a public issue. Such information sources are commonly produced or published by the local community authorities or other community groups. This resonates the fact that the higher levels in the participation ladder [3], [32] can be reached only if the requirements of the lower steps are satisfied. In order to actively involve citizens in the discussion, they must first be provided with adequate background information. Second, the information space should facilitate the sharing of information contributed by the public. One benefit of involving the

public in the community decision-making processes is that they can contribute with their unique knowledge or interpretation that is likely to lead to a richer deliberation of an issue, promote broader discussion of problems, and enhance the quality of decision-making.

Maps play an important role in the information space. Much of the information provided by the community organizations is geo-referenced, such as the community plans, the population distribution, or the transportation information. The map-based displays provide an intuitive way to present this kind of information to the public.

2.2 Argumentation Space

Argumentation space goes beyond sharing merely factual information and emphasizes the role of discussion space as a place where the participants can freely exchange their personal views on public issues. In the argumentation space, participants can raise questions, express their opinions, and argue with other participants. Participants are more actively engaged in the discussion processes. Therefore, tools to support the discussion should function as facilitators for recording, structuring, and visualizing arguments.

In spatial decision situations, most arguments will contain geographic references [23]. For example, in community planning, arguments in favor or against a new building might contain references to the building's location, and to neighboring buildings. In these cases, the map-based displays can be used to record, structure, and visualize the argumentation, which provides intuitive visual cues to prompt place-based discussion [12]. For instance, anchoring arguments to locations in the map will draw attention to the surrounding places or other arguments referring to the same locations.

2.3 Analysis Space

The analysis space provides the tools for the participants to make sense of the collected information in the Information Space and the Argumentation Space. In order to participate in community decision-making, the participants should be able to create shared awareness and understanding out of different perspectives and varied interests generated in the discussion process. In analysis space, participants search, filter, and browse the information segments and arguments contributed by other participants. Advanced analytic tools, such as the text-mining techniques to discover patterns of interaction during the discussions [11] or the argument mapping to visualize the argumentation structures [30], are relevant to analyzing stakeholder views and reasoning.

Since most of the information and arguments are geo-referenced, the map-based displays can also be used as effective analysis tools. For example, the participants can browse the arguments based on their anchors in the map. Or the arguments can be filtered based on the geographical scopes. Besides, the advanced spatial analytical capabilities of GIS and geo-visualization techniques also have the potential to become meaningful instruments of analysis for group information [12].

3. FEATURE REQUIREMENTS

Based on the understanding of map-based online discussion, we extracted two major categories of requirements: functional requirements and social requirements. Functional requirements concern the functionalities of the system to enable the map-based online discussion space, while social requirements concern the strategies to encourage participation.

3.1 Functional Requirements

The primary function of the system is to enable the map-based discussion space, which allows the participants to access and share information (*information dimension*), to organize and structure the participants' arguments (*argumentation dimension*), and to analyze and make sense of all the individual inputs (*analysis dimension*). Accordingly, we can categorize the functional requirements in these three dimensions:

3.1.1 Informational Requirements
R1: Capability to integrate heterogeneous geospatial information and create customized maps

To support the map-based discussion, the first step is to set up the geospatial information background that frames the issue under discussion. Different public issues usually need different types of geospatial information. For example, the locations of public health care facilities are important for community emergency planning, but have little relevance to a natural resource management issue. This requires the system that can create customized maps for different problem contexts. On the other hand, the geospatial information used for one public issue may come from multiple sources, such as the open data provider, local governments, or other community groups, which usually have their own data types or formats. Therefore, the system should also be able to integrate heterogeneous information and present it in a uniform way.

R2: Support for multi-modal multi-media information sharing

The system should also support multi-modal multi-media information sharing, which provides alternative communication channels other than text, such as drawing, photograph, audio, etc. Each format delivers information of a slightly different qualitative nature. Text provides the opportunity of rich descriptions, while a photograph captures static yet detailed information about scenes. Drawing on the map allows users to share geographic information directly without having to use spatial language and can, in some cases, overcome language barriers [12]. Allowing the information sharing in different modes has the potential to engage the participants in more meaningful discussion.

3.1.2 Argumentational Requirements
R3: Support for explicit linkage between arguments and geographic references

The distinguished feature of map-based discussion is the ability to anchor users' arguments on the map with their geographic references. The system should provide the users a convenient way to create the links. Moreover, the linkage between arguments and geographic objects should be a *many-to-many* relationship. A geographic object may have multiple arguments, for instance, from different users or concerning different aspects, and a single argument may refer to more than one geographic object, e.g. an argument to compare two locations.

R4: Support for structured discussion

Users' arguments are usually related to each other. For example, one user may ask a question that is answered by another. Some participants may support a claim while others may oppose it. The system should be able to maintain the discussion structures that can help the users understand and deliberate other participants' arguments in discussion contexts.

R5: Capability to record contextual information about arguments

Arguments are created in context. Recording the contextual information associated with the arguments can help users make sense of the whole discussion. For example, the creation date of the arguments can be used to reproduce the history of the discourse or detect the trends in discussion. Also, the interpretations of arguments are often context-dependent. For instance, an argument that talks about "the nearby area" cannot be understood without looking at the same map display when the original argument was posted.

3.1.3 Analytical Requirements
R6: Support for combined geo-argumentative query and navigation

One benefit of linking arguments with their geographic references is to allow the combined geo-argumentative analyses that are not possible in an environment, which consists of discussion with mere verbal descriptions of the geographic references. For example, the user can filter the arguments to a specified geographic scope, as well as containing certain keywords. Also, the system should provide the maximal freedom to navigate in the discussion space. Clicking on a geographic object on the map should display all the discussions referring to it, while selecting an argument should also display all its geographic references in the map.

R7: Support for advanced visual analysis

Sophisticated analyses, especially the visual analysis techniques can be integrated into the system in order to help the user understand the problems, detect conflicts or potentials, and deliberate the solutions based on existing arguments. For example, the general progress of a discussion in time can easily be represented by means of a user-controlled map animation, which can help the user discern how the discourse is developed throughout the discussion process, and how the chains of reasoning have been made in order to generate solutions.

3.2 Social Requirements
R8: Easy to access and use

An effective way to encourage the users to participate in discussion is to make the system easy to access and use. One of the reasons why traditional GIS was critiqued for supporting public participation is that the systems were usually difficult to access and use, which actually marginalizes the public from participating [7]. Making the system easy to access and use, for example, by reducing the efforts to install additional software or shortening the learning curve, can reduce the cost to use the system, which in return encourage users to contribute.

R9: Capability to allow the user to control sharing level

Equally important is providing users the opportunity to set the sharing level of their arguments. It is very common that users do not want to share certain information or arguments with the whole community. Allowing users to control the sharing level to a subset of the community can encourage them to contribute ideas. Also, users can keep their inputs only accessible by themselves, which eventually creates a private space, which allows for making ideas explicit yet, initially, only to the individuals. Private spaces preserve a degree of anonymity, which can be used to reduce users' inhibitions to record their ideas and therefore encourage participation [12].

4. GEOANNOTATOR: THE PROTOTYPE SYSTEM

According to the proposed requirements, we have developed the first prototype system – GeoAnnotator (available online: http://130.203.158.62/geoannotator/), which is a Web-based geospatial annotation platform to support map-based discussion. In the following, we will first describe the major design features and technical architecture of the system. Then a hypothetical scenario will be used to demonstrate the utility of our system.

4.1 System Design
4.1.1 Geospatial Annotation

In our approach, we use geospatial annotations to structure map-based discussion. In general, "an annotation is a datum created and added by a third party to the original document, which can be a written note, a symbol, a drawing or a multimedia clip" [20]. Annotations emphasize the reference relationship between the selections of original documents (*context selections*) and the contents of the annotations themselves (*add-on content*). A typical example of annotation is the comment function in most popular word processors, which allows the users to select portions of text in the main document and add notes to them. It is quite common that an annotation can refer to multiple portions of the original document, each of which is called an *atom*. An atom can be a portion of a text document, a freehand selection of a picture, or a contiguous clip of a sound recording. Geospatial annotations distinguish themselves from other annotations in that the atoms of context selections that they are anchored to can be geographic objects or coordinates in a map. As a result, geospatial annotations provide a way to add contents whose interpretation depends at a minimum on spatial context [12].

Geospatial annotations play a central role in our system as the basic unit of map-based discussion. Each of the user's discussion contribution is captured as a geospatial annotation. Typically, a geospatial annotation either provides a piece of factual information or offering an argument, as long as it refers to some geographic objects in a map. The atoms that a geographic annotation links to can be geographic objects in the map or any existing annotations (possibly created by other users). Figure 3 shows an example of the geospatial annotations supported in our system. Jim created an annotation (circled in red) to express his opinion on the location selection of evacuation shelters. This annotation refers to two of the previous annotations (circled in green) and two geographic objects - the two candidate shelter locations - in the map (highlighted in blue).

Geospatial annotations provide the structures for effective organization of map-based discussion. First, it anchors the user's discussion contributions directly to the geographic references on the map, which allows the users to discuss the issues in the specific spatial contexts. Second, users can link their new annotations to previous discussion contributions, which actually fulfills the requirement to support structured discussion (*R4* in Section 3).
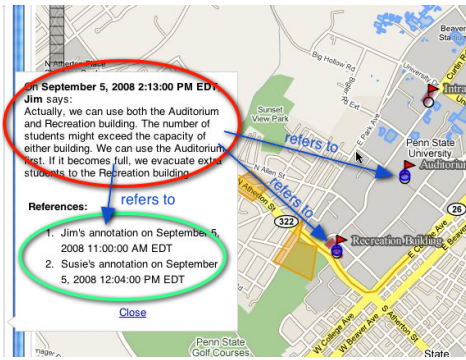
Figure 3. An Example of Geospatial Annotation

Connecting annotations to geographic references and other annotations leads to the *many-to-many* relations. A single annotation may refer to more than one geographic object and multiple other annotations, while one geographic object or annotation may be referenced by multiple annotations. Also, it is possible that no geographic object or annotation is linked to an annotation when it is used to make a general comment. In addition, we support the multi-media annotations whose content includes not only text-based comments, but also media clips. An annotation can have multiple media clips, which may be located in different places. Figure 4 is a portion of the data model in our system that reflects the multiple relations among the annotations, geographic objects, and media clips.
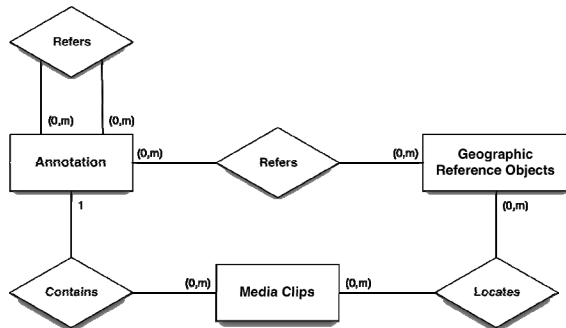

Figure 4. Portion of the Data Model in GeoAnnotator

4.1.2 Software Architecture

GeoAnnotator follows a typical client/server architecture model, with the server storing the annotations and geographic reference objects, and the client handling annotation capture and presentations. Clients communicate with the server to store or retrieve annotations (see Figure 5).

On the client side, a browser instance provides the user with the lightweight HTML + JavaScript user interface, which is implemented by using the Open Source JavaScript libraries: Dojo DHTML toolkit (http://dojotoolkit.org) and the OpenLayers mapping library (http://openlayers.org/). The thin client design allows the user to easily access the system without installing any software or plug-ins.

The client sends HTTP requests to the annotation proxy, which is implemented in ASP.NET, to get, add, modify, or delete annotations from the database. The annotation database is an instance of PostgreSQL (http://www.postgresql.org/), which stores the

information about the users, groups, and the annotations. Besides, the geographic reference objects are also stored in the database through the PostGIS extension. The results of the client's requests will be formulated as an XML file and send back to the client as HTTP response.

When the client receives the response from the server, it will interpret the XML file to display the selected annotation information for the user. The map itself is comprised of multiple layers, which may come from multiple geospatial data sources, such as a local WMS or local files on the annotation server, or some external web services. OpenLayers allows the client to request different sources of geospatial information and overlay them on a single map, as well as to render the geographic reference objects on the map.
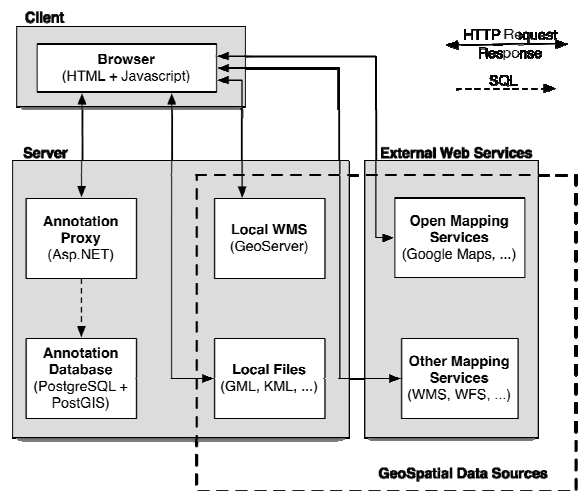

Figure 5. Prototype Architecture

4.2 GeoAnnotator Functionalities

We will use a concrete application scenario to explain the functionalities of GeoAnnotator and to demonstrate its utility.

4.2.1 The Application Scenario: Smoke-Free Campus

A student-led project in a university community starts a grassroots campaign to convince the policy makers to move to a smoke-free campus policy. One of their major activities is to engage all the stakeholders in the community to discuss the current situation and gain their suggestions and support. GeoAnnotator has been deployed as an online map-based discussion space to support the participation and debate on this particular issue. The problem itself is a public issue that can involve all the stakeholders in the community. The web-based architecture of our system allows distributed, and asynchronous discussion across all the participations in the community, so that they do not have to gather together to discuss the issue.

There are two major reasons why our system can help in this issue. First, the discussion of smoke-free campus is tightly geo-referenced. One of the major topics around the issue is to decide the locations of smoke-free zones on campus. For this kind of discussion, a campus map with distributions of major buildings, health care facilities, and other related information is very helpful. Second, to support or oppose a location or an area as smoke-free, the participants are expected to refer to the corresponding geographic objects frequently in their discussion.
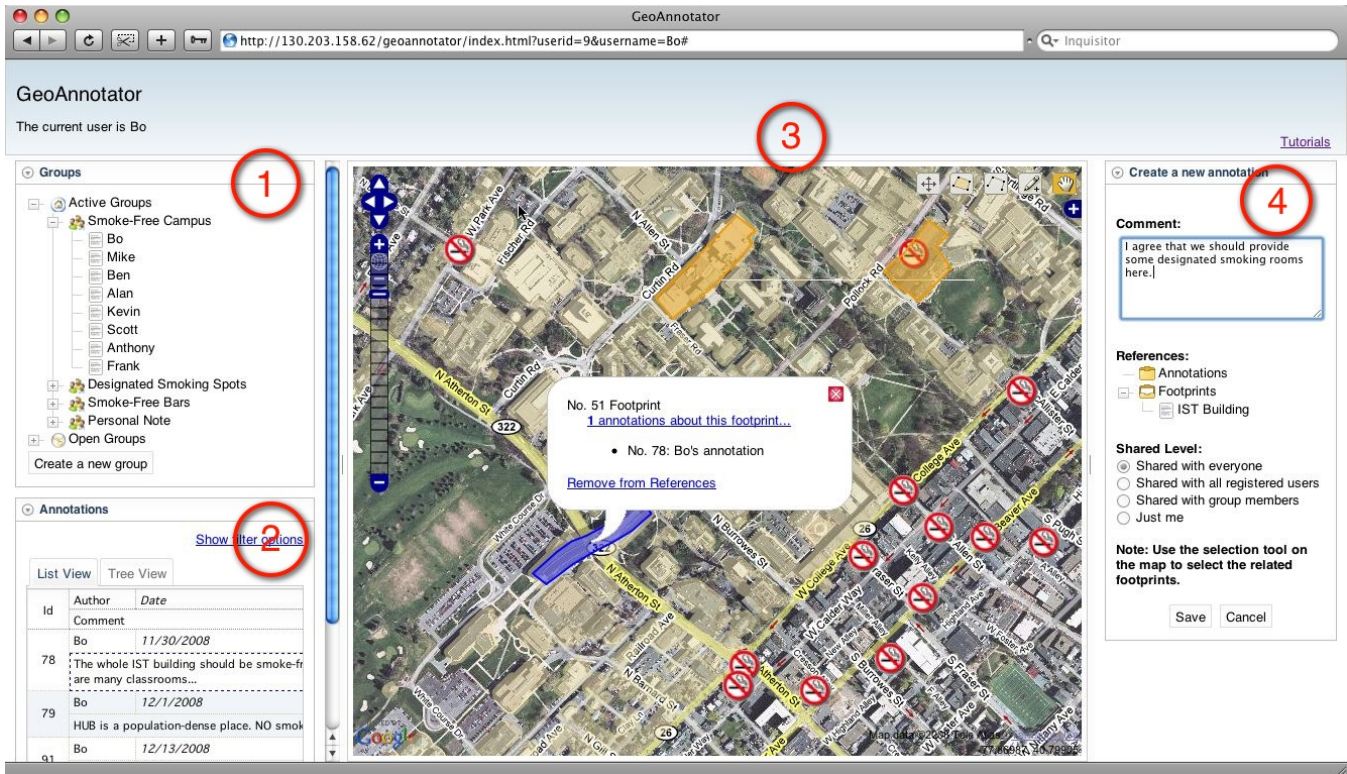
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Figure 6. GeoAnnotator's User Interface:

(1) Group Panel, (2) Annotation Panel, (3) Map Panel, (4) and Annotation/Group Creation Panel

4.2.2 System Functionalities

The user interface of GeoAnnotator is comprised of four components: (1) group panel, (2) annotation panel, (3) map panel, and (4) annotation/group creation panel (see Figure 6). The group panel lists all the discussion groups that the user can join to engage their discussions. The annotation panel organizes the geospatial annotations in each group and allows the user to browse the annotations. The map panel shows the context map of the discussion, as well as the geographic reference objects that the user has mentioned to. The annotation/group creation panel only shows up when the user tries to create a new discussion group/annotation or to edit the existing ones. It contains the web forms to allow the user to input.

Within the system, the user can perform the following major functions:

Managing discussion groups

Discussion groups are used to organize the discussions based on different tasks. Each of the group has a major theme or issue to address. It is possible that a single public issue in a community may include multiple discussion groups. For example, in our scenario (see the group panel in Figure 6), the system includes three public groups: *"Smoke-Free Campus"* allows all the citizens to gather together and discuss the smoke-free issue in general, while *"Designated Smoking Spots"* and *"Smoke-Free Bars"* are relatively small groups that are used for focused discussion of subordinate issues. In addition, users can create groups that are accessible by themselves, which provide the private spaces to encourage contribution.

The user can see the lists of groups in the group panel. The active groups are the discussion groups that the user has already joined, while the open groups are the public groups that the user is able to join. By clicking on each of the group, the user can check the details about the group, and leave or join the group.

Customizing the map for discussion

When the user creates a new group, the user is able to add or remove layers, as well as to change the map scale and extent, to customize the map that is particularly suitable for the new group. The layers in one single map can come from multiple data sources. In the *"Smoke-Free Campus"* group in our scenario, there are four different types of layers in the map (see the map panel in Figure 6): the normal Google Maps, the high-resolution satellite imagery, a vector layer, which shows the major buildings and facilities on campus, and a vector layer showing the locations of existing smoke-free areas. The data of Google Maps is from the external web data source. The satellite imagery is hosted on a local WMS server as a raster layer. The layer of campus buildings is from the same WMS server, but as a vector layer. The current smoke-free areas are stored in a local KML file.

Browsing and searching annotations

The system supports browsing annotations in different ways. On one hand, annotations can be listed in the chronological order in the annotation panel. By clicking on an item of the annotation list, a tooltip will pop up, showing the detailed information about the selected annotation. The map will also be changed to the view when the annotation was created, which allows the user to understand the spatial context of the annotation. If the selected annotation has geographic references, they will be highlighted in the map as well.

On the other hand, the map panel allows annotations to be viewed based on their geographic references in the map. When a geographic object is selected in the map, a tooltip will show up, which lists all the annotations that refer to this geographic object (see the map panel in Figure 6). Clicking on each of them, the annotation will also be selected in the annotation panel.

To narrow down to relevant annotations, the user may filter and search the annotations based on various criteria. Because of the explicit linkage between annotations and their geographic references, the annotations can be retrieved by both the thematic meanings in the comments and the geographic scopes. For example, the user can search for the annotations that are talking about the "health care facility" and have their geographic references contained in a selected scope on the map.

Creating and editing annotations

The user can create a new annotation or edit an existing one in the annotation creation panel. Besides inputting the content of the new annotation, the user is allowed to link any other annotations or geographic references, i.e. footprints, with the new annotation. To link to an existing annotation, the user can browse the annotations in the annotation panel and when the tooltip that shows the detail of the annotation is popped up, the user has the chance to add the current annotation as reference. To refer to any existing geographic object in the map, the user can use the selection tool in the map to choose the related objects and a tooltip will show up and allow the user to add them as reference. Also, the user can create a new geographic object in the map by using the drawing tools, which will be added as reference directly.

In addition, the user is able to set the sharing level of the current annotation, which may be shared with everyone, all registered users, the group members, or just the user her/himself. Besides, the current map view will also be encoded as an XML-based description and associated with the current annotation as its context map.

Analyzing annotations

To enable the user to analyze the annotations, some visual analysis techniques have also been integrated into the system.
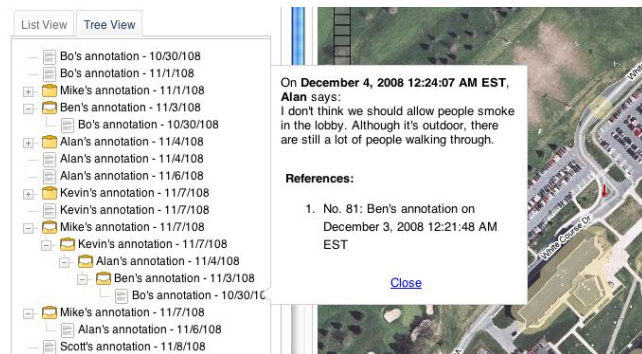

Figure 7. Structured View of Annotations

First, the user is allowed to view annotations based on their reference relationship. By clicking on the "Tree View" tab in the annotation panel, the user can see a tree-like structure that indicates how the annotations refer to each other (see Figure 7). Unlike the threaded structures in Email or online forums where each entity only has one reference, the annotations are allowed to refer to multiple previous annotations.

Also, it is possible to provide specific visual analysis of the annotations in the map in order to help the user discern the spatial distribution patterns in the discussion space. One of the geo-visualization techniques we use in the scenario is to visualize the significant geographic references that achieve the most discussion from the participants by using graduated circles (see Figure 8). At the location of each geographic reference, a circle is displayed whose radius is decided by the number of annotations that have reference to this location. In this way, the user can intuitively check all the hot spots that are under discussion, and see how they are related to each other in the geographic space.
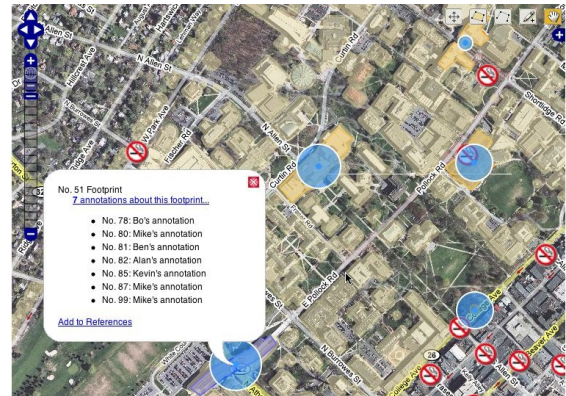

Figure 8. Graduated Circle Map of Annotations

4.3 Discussion

As a summary, Table 1 shows how our prototype system meets the requirements we have defined in Section 3. During the scenario-based evaluation of our system, we have found that the geospatial annotation system offers easy-to-use functions for effective organization of geographically referenced discussions, which have the possibility to encourage users' participation in spatial decision-making processes. Furthermore, although only limited visual analytical tools are currently implemented in the system, the employment of geo-visualization techniques to help the user make sense of the discussion is especially promising. By fully empowering the user in the analysis space, our system may have the potential to further increase the level of participation by allowing them to eventually lead to consensus based on discussions.

Although our system has yet been evaluated within larger communities, such as urban communities, we do involve some design concerns in the system about how it would scale in such environments where intensive inputs can be expected. First, all the annotations along with geographic reference objects are stored in a spatial database, which provides extensible and efficient storage, access, and retrieval of large volume of spatial data. Second, from the interaction perspective, the system provides utilities, such as the graduated circle map, tree view of annotations, and spatial filters, to allow the user to easily navigate and search information from a large number of user contributions. However, we believe that the scalability of the system is still an open issue that can only be fully addressed through practical field tests. The system will be continuously adapted throughout the iterative development cycle to ensure it could really work in practice.

Table 1. How GeoAnnotator meets the requirements

Requirements	Our Solutions
R1: Capability to integrate heterogeneous geospatial information and create customized maps	• Various formats of geographic information can be added as individual layers and overlaid to comprise a map. • The moderator can change the map extent and add/remove layers to customize the map for each discussion group.
R2: Support for multi-modal multi-media information sharing	• The user can draw points, lines, and polygons directly in the map. • The users can create annotations that include text, hyperlinks, pictures, and even audio/video clips. The media files can be uploaded by the user or linked from external web resources.
R3: Support for explicit linkage between arguments and geographic references	• When creating an annotation, the user is allowed to add any existing geographic objects as references or drawing new geographic object directly in the map. • Each annotation can have multiple geographic references and each geographic reference can be referenced by multiple annotations.
R4: Support for structured arguments	• When creating an annotation, the user is allowed to add any existing annotations as references. • Each annotation can have multiple existing annotations as references.
R5: Capability to record contextual information about arguments	• When creating an annotation, the timestamp, the author, and other contextual information will also be recorded. Besides, the current map view will be encoded as an XML-based description and stored in the database. • When the user reads an annotation, the stored map description will be interpreted and used to change the map display to the context when the annotation was created.
R6: Support for combined geo-argumentative query and navigation	• The user can filter annotations based on keywords, author, dates, as well as a geographic scope that is specified in the map. • When the user clicks on an annotation, all the geographic references will be highlighted in the map. • When the user clicks on a geographic object in the map, all the annotations talking about the object will be listed.
R7: Support for advanced visual analysis	• The visual analysis of the annotations in the map can help the users discern the spatial distribution patterns in the decision space. • The User is allowed to view annotations based on their reference relationship.
R8: Easy to access and use	• The system client is implemented using HTML + JavaScript, which can be accessed by any modern web browsers. No extra software or plug-in need to be installed. • The map component is designed similar to popular web mapping or GIS applications, so that new users can quickly familiarize themselves with the tool.
R9: Capability to allow users to control sharing level	• The user can create private groups that only invited users can access, which allows small-group discussions. • When creating an annotation, the user is allowed to specify the share level of the annotation.

5. RELATED PROJECTS

There are a limited number of projects in the area of PPGIS that have made use of maps to support online discussions in local communities. In the following of this section, we will briefly describe some representative applications that have brought insights into our study.

Virtual Slaithwaite was introduced by Kingston et al. [17] to support the discussion of local planning issues. Their online application provided users with a village map and allowed users to select a geographic object to write a comment. This application can be considered as one of the earliest efforts to provide map-based access to discussion contributions. However, the comments were only sent back to the system for future analysis, which are invisible to other participants. Therefore, the map-based discussion space is very limited. In addition, their system only allowed the user to link comments to the existing features in the map. But in our system, the user can draw the geographic reference objects directly on the map.

Research by Al-Kodmany [2] has applied the use of collaborative annotation tools for neighborhood revitalization efforts. The system provided access to an online map and each grid tile of the map could be selected and commented by users. Similar to Virtual Slaithwaite, the comments were collected by a server for later evaluation and not incorporated into the map. Such a system is characterized by collaboration between user and planners and communications among users do not take place.

The cooperative web maps designed by Kolbe and colleagues [18] allowed to comment or change internet maps within the web browsers on the client computers and distributed the comments to other users over the internet using the URL. It allowed any user at anytime to initiate spontaneous communication about the map with other users. However, since the discussion items were not persisted on any servers, it had limitations to support long-term, multi-user discussions.

Urban Mediator [25] is a web-based framework that provides a way for communities to obtain and share information about a city/neighborhood or any other place represented in the map. UM

uses both a topic list and a map-portrayal service as means for organizing and representing location-based information. As the developers describe, "UM does not, in its present form, encourage discussions: it is rather a place to link many discussions together" [25]. Therefore, its functions mainly focus on supporting the information space by connecting the expert knowledge from the city administration and the local knowledge from the citizens. However, it has limited support on encouraging argumentation among users or performing location-based analyses.

Voss et al. [31] described an integration of the GIS functionality and structured discourse. Their prototype implementation that combined two of their existing tools – thematic mapping tool CommonGIS and the Dito discussion forum – was designed to support many-to-many relations between user comments and geographic objects. In addition, their solution provided sophisticated analysis tools on the different annotation layers, including temporal analysis. As the prototype was made up of two separate applications, users had to familiarize themselves with the complex functions of both applications to benefit from it. In our system, we adopt a single user interface, which integrates both the map and the discussion. The integrated interface allows users to access both components seamlessly, without having to switch between two separate applications.

Based on the argumentation map model developed by Rinner [23], [24], which make explicit linkages between arguments and geographic objects in maps, Keßler et al. [14] developed a prototype to support decision-making in spatial planning. The prototype was designed to support the multiple-way discussion among participants in a discussion and planning agencies. The GIS component and the argumentation component were integrated in a single window. Unlike the previous systems, their prototype allowed the user to draw geographic objects directly in the map and to link comments with them. In term of query and analysis of the geo-referenced discussions, users were able to highlight arguments by clicking on related geographic objects, and highlight geographic objects by clicking on discussion messages. Combined geo-argumentative queries were also supported. Their system has the most similarity to ours. However, no advanced spatial analytical functionality was provided in their system. Besides, the system only supported text-based arguments.

Along with the academic research and projects, some of the commercial online mapping tools, such as Google Maps, also provide the functionality to share comments and collaborate with others. The annotations associated with geographic objects on the map can include not only the text, but also pictures and video clips. However, one comment can only refer to one geographic object in the map. Because the annotations on Google Maps are mainly used to share information, it does not support the structured (threaded) discussion and lacks the analysis functionalities.

6. CONCLUSION

In this paper, we have explored the potential of a particular geospatial technology, the geospatial annotations, to facilitate the participatory discussion in local communities. The presented prototype system allows the participants to use maps directly as a communication tool by linking their discussions directly to geographic reference objects. We plan to conduct a large-scale user studies, based on the Smoke-Free Campus scenario, to understand community use of geospatial annotation technologies and real

discussion behaviors. Limited feedbacks so far from the scenario-based evaluation with small groups have shown that the geospatial annotation system offers easy-to-use functions for effective organization of geographically referenced discussions, which have the potential to increase community participation.

Furthermore, we understand that the participatory processes in communities and the supporting technologies affect each other and form a socio-technical system. For successful support of collaborative spatial decision-making processes in local communities, a deep knowledge on the underlying elements, such as the discussion patterns among the stakeholders, is needed. Therefore, our work aims not only at developing useful geospatial tools and platforms, but also at increasing understandings of these map-based participatory processes.

We believe that the iterative prototyping approach combined with participatory research will benefit our research most. Future work will concentrate on the evaluation process in order to gain in-depth insights of the map-based online discussion processes. The evaluation results combined with user feedbacks will be used to develop the next prototype system. Then the new system will again be applied in real application settings, which will presumably lead to further improvements. Also, we will explore the full power of using geographic visualization tools to support the analysis of geospatial annotations.

8. REFERENCES

[1] Al-Kodmany, K. "Extending Geographic Information Systems to Meet Neighborhood Planning Needs: The Case of Three Chicago Communities." *URISA Journal* 12, no. 3 (2000): 19-37.

[2] Al-Kodmany, K. "Using Web-Based Technologies and Geographic Information Systems in Community Planning." *Journal of Urban Technology* 7, no. 1 (2000): 1-30.

[3] Arnstein, SR. "A Ladder Of Citizen Participation." *Journal of the American Planning Association* 35, no. 4 (1969): 216-224.

[4] Barton, J, J Plume, And B Parolin. "Public participation in a spatial decision support system for public housing: Urban data management system, Chioggia, Italy." *Computers, Environment and Urban Systems* 29, no. 6 (2005): 630-652.

[5] Cova, TJ, and RL Church. "Modelling community evacuation vulnerability using GIS." *International Journal of Geographical Information Science* 11, no. 8 (1997): 763-784.

[6] Craig, WJ, and S Elwood. "How and why community groups use maps and geographic information." *Cartography and Geographic Information Systems* 25, no. 2 (1998): 95-104.

[7] Craig, WJ, TM Harris, and D Weiner. *Community Participation and Geographic Information Systems.* CRC Press. 2002.

[8] De Cindio, F, A De Marco, and LA Ripamonti. "Enriching Community Networks by Supporting Deliberation." *Proc. of the 3rd International Conference Communities and Technologies, 2007*. 28-30.

[9] Evans, A, R Kingston, S Carver, and I Turton. "Web-based GIS used to enhance public democratic involvement." *Proceedings of Geocomp 99', Mary Washington College, Virginia, USA*. 1999. 99-1.

[10] Haklay, M, and C Tobon. "Usability evaluation and PPGIS: towards a user-centred design approach." *International Journal of Geographical Information Science* 17, no. 6 (2003): 577-592.

[11] Haythornthwaite, C, and A Gruzd. "A Noun Phrase Analysis Tool for Mining Online Community Conversations." *Proc. of the 3rd International Conference Communities and Technologies*, 2007.

[12] Hopfer, S, and AM Maceachren. "Leveraging the potential of geospatial annotations for collaboration: a communication theory perspective." *International Journal of Geographical Information Science* 21, no. 8 (2007): 921-934.

[13] Kavanaugh, AL, PL Isenhour, M Cooper, JM Carroll, MB Rosson, and J Schmitz. "Information Technology in Support of Public Deliberation." *Proc. of the 2nd International Conference Communities and Technologies,* 2005. 19-40.

[14] Keßler, C, C Rinner, and M Raubal. "An Argumentation Map Prototype to Support Decision-Making in Spatial Planning." Proceedings of AGILE 05', 2005. 26-28.

[15] Kellogg, W. "From the Field: Observations on Using GIS to Develop a Neighborhood Environmental Information System for Community-Based Organizations." *URISA Journal* 11, no. 1 (1999): 15-32.

[16] Kingston, R. "The role of e-government and public participation in the planning process." *XVI Aesop Congress Volos, available at: http://www. ccg. leeds. ac. uk/democracy/presentations/AESOP_kingston. pdf*, 2002.

[17] Kingston, R, S Carver, A Evans, and I Turton. "A GIS for the public: enhancing participation in local decision making." *GIS Research UK (GISRUK'99). Available online at http://www. geog. leeds. ac. uk/papers/99-7*, 1999.

[18] Kolbe, TH, J Steinrücken, and L Plümer. "Cooperative Public Web Maps.", *Proceedings of the International Cartographic Congress (ICC)*, 2003.

[19] McCall, MK, and PA Minang. "Assessing participatory GIS for community-based natural resource management: claiming community forests in Cameroon." *Geographical Journal* 171, no. 4 (2005): 340-356.

[20] Ovsiannikov, IA, MA Arbib, and TH McNeill. "Annotation technology." *International Journal of Human-Computer Studies* 50, no. 4 (1999): 329-362.

[21] Pleizier, I, R van Lammeren, HJ Scholten, and R van de Velde. "Using virtual reality as information tool in spatial planning." *Proceed. EuroConference on methods to support interaction in geovisualisation environments*, 2004.

[22] Preece, J, and D Benyon. *A Guide to Usability: Human Factors in Computing.* Addison-Wesley Longman Publishing Co., Inc. Boston, MA, USA, 1993.

[23] Rinner, C. "Argumentation Mapping in Collaborative Spatial Decision Making." *Collaborative GIS, S. Dragicevic and S. Balram (Eds)*, 2006: 85-102.

[24] Rinner, C. "Argumentation maps: GIS-based discussion support for on-line planning." *Environment and Planning B: Planning and Design* 28, no. 6 (2001): 847-864.

[25] Saad-Sulonen, J, and A Botero. "The Guide to Urban Mediator." *University of Art and Design Helsinki - Media Lab, available at: http://mlab.taik.fi/urbanmediator/documents/GuideToUM_030 22009.pdf*, 2009.

[26] Sawicki, DS, and P Burke. "The Atlanta Project: Reflections on PPGIS practice." *Community participation and Geographic Information Systems*, 2002: 89-100.

[27] Sieber, R. "Public Participation Geographic Information Systems: A Literature Review and Framework." *Annals of the Association of American Geographers* 96, no. 3 (2006): 491-507.

[28] Steinmann, R, A Krek, and T Blaschke. "Can Online Map-Based Applications Improve Citizen Participation.", *TED Conference on e-Government, Electronic democracy: The challenge ahead, Bozen, Italy* 2005.

[29] Talen, E. "Constructing neighborhoods from the bottom up: the case for resident-generated GIS." *Environment and Planning B: Planning and Design* 26 (1999): 533-554.

[30] van Gelder, T. "Enhancing Deliberation Through Computer Supported Argument Mapping." *Visualizing Argumentation: Software Tools for Collaborative and Educational Sense-Making*, 2003: 97-115.

[31] Voss, A, et al. "Evolution of a participatory GIS." *Computers, Environment and Urban Systems* 28, no. 6 (2004): 635-651.

[32] Wiedemann, PM, and S Femers. "Public participation in waste management decision making: Analysis and management of conflicts." *Journal of Hazardous Materials* 33, no. 3 (1993): 355-368