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Research Article

Spatial Annotation Technology for Public Deliberation

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Abstract
Many public policies and decisions deal with geospatially expressed problems that are complex and controversial in nature. Broad participation of all interested parties in the form of deliberative dialogues is crucial to making trustworthy decisions. However, supporting deliberative dialogues on spatial problems places unique requirements for technology mediation that go beyond the current state of research on public participation geographical information systems (PPGIS) and related technologies. In this article, we analyze the challenges of facilitating effective deliberation processes and highlight the progress needed to support spatially-enabled public deliberation technologies. Then, we present our *GeoDeliberative Annotation Technology* (GeoDAT) as a framework for addressing the above challenges. GeoDAT uses spatial annotation objects as models for deliberative artifacts, and manages annotations by a spatial data model that reflects the ecological relationships among annotations, visual contexts, discussion threads, spatial referents, and the cognitive states of their holders. As a proof of the concept, we have implemented GeoDeliberator based on the GeoDAT framework. GeoDeliberator is based on Web 2.0 technology and implemented in AJAX technology, and it offers some unique spatial annotation capture, retrieval and visualization capabilities, such as context memory, reference to multiple geo-objects in one annotation, inferring and visualizing new relations using spatial-temporal and thread-based reasoning, and user-controlled annotation sharing. We demonstrate the utility of GeoDeliberator through a simulated scenario where a community in a university campus deliberates on the alternative courses of actions available for building a smoke-free campus.

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1 Introduction

One of the grant challenges for geographical information science and technology is to advance public engagement in policy decisions and community actions in order to address socially complex problems such as health, planning, and environment (National Center for Geographic Information and Analysis 1996, Kyem 2001). The field of participatory GIS has been historically shaped by two forces. At one end, GIS is perceived by some as technological solutions to a range of social agendas such as promoting democracy, empowering disadvantageous individuals or communities, and building capacity for social changes (Kyem 2001, Harris and Weiner 2002). Geographical information and associated visualization and analytical tools can bring policy-related information to all the relevant stakeholders of an issue, convey ideas in a more persuasive fashion, and convince people of the relative importance and differences among alternative ideas (Wood 1992). Recent advances in Web-based and mobile GIS technologies and services opened new possibilities for scaling up public involvement over large and diverse populations as well as moving beyond traditional public meeting models into virtual town-hall meetings (Kingston et al. 2000, Al-Kodmany 2001, Peng 2001, Haklay and Tobon 2003). On the other end, GIS has been constantly criticized because the use of GIS in public decisions tends to create new forms of exclusion and biases due to the concerns that GIS tends to favor quantifiable data and analytic views over other localized and informal knowledge (Schuurman 2001) and that GIS may further amplify the uneven power relations among participants (Pickles 1995; Ramsey 2008, 2009).

Despite ongoing controversy and skepticism on the effect of using GIS in public engagement practices, much progress has been made in understanding the values, structures, and processes of participatory spatial decision-making (Arnstein 1969, Nyerges and Jankowski 1997, Craig et al. 1999, Jankowski and Nyerges 2001, Harris and Weiner 2002, Balram et al. 2009) and colaborative use of GIS (Balram and Dragicevic 2006, Balram et al. 2009). Some of this understanding has been translated into design ideas for participatory GIS (Kingston et al. 2000, Al-Kodmany 2001, Peng 2001, Haklay and Tobon 2003, Nyerges et al. 2006). Recent reflections on the status of participatory GIS reveals that there remains a large social-technical gap between the true complexity of (geographical) knowledge-intensive public engagement processes and what can be supported by the current GIS and related participatory tools (Elwood 2006, Sieber 2006). It is evident that GIS alone (with traditional data management, visualization and analytical functions) cannot guarantee sound decisions. Knowledge presented in GIS, although often portrayed as scientifically correct, may be not only partial and biased, but also politically inspired. If participatory GIS are to find success in the next stage of development, a radically different conception of democratic politics is needed. Ramsey (2008) suggested Mouffe's notion of 'agonistic pluralism' (Mouffe 1999) as an alternative perspective to democratic processes. This theory calls for the importance of having an explicit stage of deliberation where biases, exclusions, and politics are made explicit and are open to question and debate. This view coincides nicely with the *analytic-deliberative* process view of public decision-making (National Research Council 1996) which characterizes analysis and deliberation as two complementary and interleaving components (with feedback relations) of a larger process leading to better informed decisions.

Nyerges and colleagues (Nyerges et al. 2006a, b) first introduced this Analytic-Deliberative framework to provide a new theoretical perspective on public participation GIS. According to this perspective, geographical information systems contribute to the

analytical component of the participatory decision-making process by providing technical information that represents the state of understanding about the problem, the concerns of stakeholders, possible decision scenarios, and options to address the problem. The *deliberative component*, on the other hand, uses reflection, discussion, logical reasoning, and knowledge sharing to bring new insights, questions and problem formation. It emphasizes the role of deliberation in the early stages of problem formulation, building understanding and reaching consensus. Meaningful public engagement requires explicit incorporation of the process of collective deliberation among all affected and interested parties. GIS has been used to support both the analytic and deliberative components of the participatory decision process. However, deliberation is a relatively less understood process, and even fewer systems are designed to support deliberation. Recently, Rinner et al. (2008) mentioned deliberation as a goal of their work on argumentation maps, where the term 'deliberation' is used in the sense of argumentation. Our research uses the notion of 'deliberation' in a slightly broader and different sense, and emphasizes the cooperative and logical thinking aspects of public discourses. We believe that deliberation presents unique challenges as well as opportunities for geographical information science and it deserves to be another subject of study in participatory GIS. It is deliberative component of public participation GIS that is the focus of this work.

In this article, we extend the work of Nyerges et al. (2006a, b) in two ways. First, we address the very nature of deliberation with geographical information by providing a more elaborated framework of deliberative discourse or deliberative dialogue (section 2). Second, we present the *GeoDeliberative Annotation Technology* (GeoDAT) that documents our findings on the key capabilities and architecture solutions that are needed to make deliberation with GIS possible (section 3). GeoDeliberative Annotation Technology refers to a systematic set of design recommendations for capturing, managing, and visualizing deliberative spatial annotations. We use annotation objects as models for deliberative artifacts, and manage annotations by a spatial data model that reflects the ecological relationships among annotations, visual contexts, discussion threads, spatial referents, and cognitive states of their holders. GeoDAT is grounded on understanding of the group deliberation process (see section 2.2) and an analysis of those existing systems with some sorts of deliberative functions (see section 2.4).

To validate the design recommendations for GeoDeliberative annotation technology, we have implemented *GeoDeliberator* based on the GeoDAT framework. GeoDeliberator offers some unique functionality for capturing, managing and visualizing deliberative annotations, such as context memory, reference to multiple geo-objects in one annotation, inferring and visualizing new relations using spatial-temporal and thread-based reasoning, and user-controlled annotation sharing. GeoDeliberator is a Web 2.0 application implemented in AJAX technology. We will demonstrate the utility of GeoDeliberator through a simulated scenario where a community on a university campus deliberates on the alternative courses of actions available for building a smoke-free campus.

2 Understanding Deliberation

2.1 Nature of Deliberation

Deliberation as a phenomenon of human thinking and communication has been studied in many contexts. Philosophers (Aristotle's book Nicomachean Ethics) make distinctions

between two kinds of deliberation: "cognitive deliberation" and "practical deliberation." *Cognitive deliberation* is deliberation over whether something is true or false, while practical deliberation is over what to do. According to Aristotle, people deliberate about means not ends. We deliberate about things that are in our power and can be done. In this sense, effective deliberation requires proper information input as resources and constraints. Deliberation assumes a certain quality of conversation that supports people learning or reasonably shifting their perspectives as they proceed. Public deliberation implies, in addition, a certain amount of shared concern for the common good and usually a growing appreciation for the complexity of the situation, as people learn more about it and take more into account.

In the context of participatory decision-making, deliberation refers to a form of public discourse where all interested and affected parties that have some stake on a public decision communicate to identify goals and intent, explore different solutions before settling on a specific course of action (National Research Council 1996). The purpose of public deliberation is to think together to gain deeper understanding and collective insight. Thinking together involves listening deeply to other points of view, exploring new ideas and perspectives, searching for points of agreement and connections among ideas, and bringing unexamined assumptions into the open. Through deliberation, people's private ideas and interests are gradually linked and meshed together and form something more closely resembling public values.

Although there are many interpretations and definitions of deliberation, our survey of the literature seems to suggest the following characteristics (Gastil 1993, Harwood et al. 1996, Mathews and McAfee 2000, McCoy and Scully 2002, London 2007).

1. *Thinking abroad.* Deliberation means that a full range of relevant facts, factors, perspectives, options and consequences are being considered in a way that generates new understandings and possibilities.
2. *Thinking together.* By questioning and probing each other, carefully dissecting and analyzing ideas, finding the inconsistencies, never attacking or insulting but always searching for what they could accept between them, they could gradually attain deeper understanding and insight.
3. *Thinking logically.* Deliberation is a form of communication that emphasizes the use of logic and reasoning (as opposed to power, coercion or emotion) to achieve insight and convince others. In this sense, deliberation is different from other forms of public discourse such as debate (which is often dominated by emotion). In a debate, one searches for differences and weakness of other's position, while deliberation involves concerns for what others think and the search for the strength of other's position. Debate is oppositional and seeks to prove the other wrong, while deliberation is collaborative and seeks common understanding.

We consider the type of deliberation that is *decision-driven*. Such deliberation is characterized by the goal of sketching out alternative courses of action and their relative advantages and disadvantages.

2.2 Deliberative Dialogues

Before we can develop technology support to deliberation, we must address one fundamental question: *what kind of deliberative process is most likely to expand civic engagement and make it meaningful to affected and interested parties?* McCoy and Scully

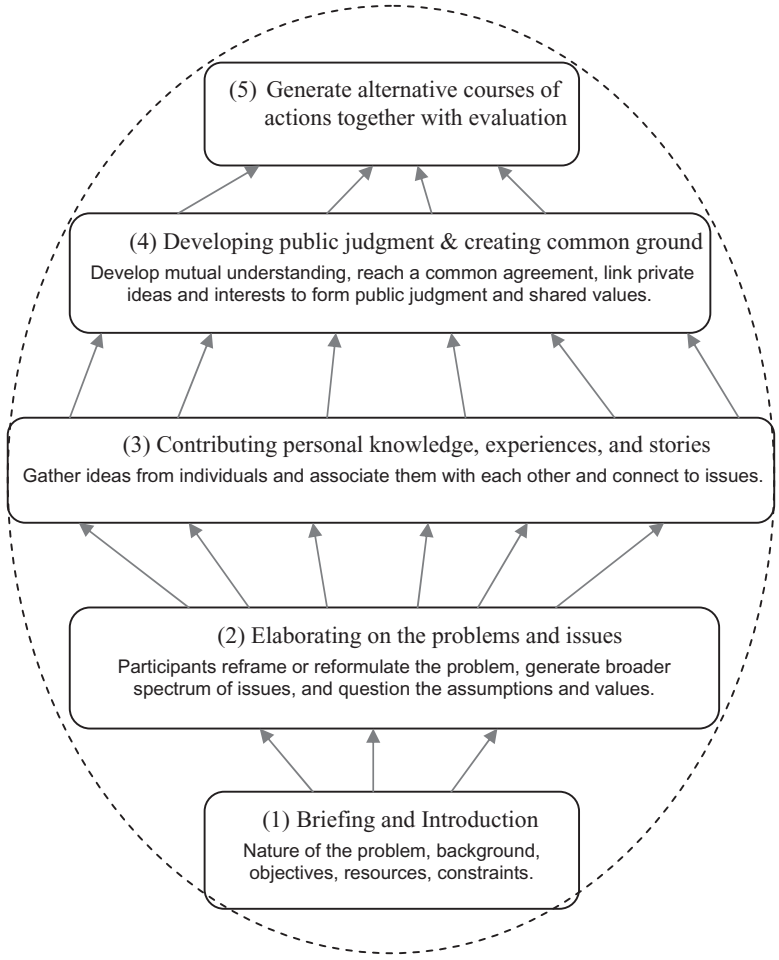

Figure 1 Different forms of deliberation and their natural progression

(2002) answered this question by invoking the idea of *deliberative dialogue*. This concept has its origin from social studies, particularly in the field of deliberative democracy (Gastil 1993, Mathews and McAfee 2000, McCoy and Scully 2002, London 2007). According to this literature, deliberative dialogue tends to unfold in a fairly predictable sequence: making sense of what is going on; sharing concerns and personal experiences; connecting and sharing issues and concerns with others; constructing larger pictures, common grounds and shared value; and formulating possible actions. Inspired by the above work and by Arnstein's ladder of increasing participation (Arnstein 1969), we have developed a conceptual model of deliberative dialogues as depicted in Figure 1. This model recognizes five identifiable phases of any deliberative activity. A typical deliberative discourse begins with a briefing and introduction phase (shown as the first rung in Figure 1), followed by a number of advanced phases showing a natural progression from basic to more advanced forms of deliberation. The balloon-shaped ladder depiction of the model in Figure 1 was intended to show the idea of diverging/converging thoughts in a deliberative process. Next, we discuss the five phases in more detail.

1. *Briefing and introduction to the problem*. When people come to the public deliberation, they need to quickly catch up with what is going on. Understanding what and why it is happening is crucial to people's ability to develop a sense of ownership of public issues. This component is usually very information intensive, and involves the introduction to the nature, background, objectives, known constraints, and what are known to be possible scientifically or practically. The goal is to provide everyone with the baseline information to start their deliberation.
2. *Elaborating on the nature of the problems and issues*. John Gastil (Gastil 1993) believes that the ability to reframe or reformulate an issue is essential if people are to have real power to set the public agenda. To have this type of deliberative dialogue, participants should use discussion materials that help them explore representative points of view, including those that may be unpopular with members of the group. Moreover, it is difficult for people to take responsibility for an issue unless the process allows and encourages them to challenge and amend the point of view presented in the materials. Deliberation about an issue can be encouraged by asking such questions as: (a) how is this issue affecting our community? and (b) what are the root causes of the problem? The process often takes groups in new and unanticipated directions, particularly if they find that the issue they thought they had come to discuss is merely the symptom, or perhaps a part, of a deeper and more complex issue.
3. *Contributing personal stories, experiences, concerns, and preferences*. Public engagement processes depend heavily on the ability of the participants to contribute. Common barriers include the limited choices of expression channels (e.g. public speech only), lack of knowledge about the problems and previous discussions, difficulties to express one's ideas, difficulties in associating one's ideas with others. One way to overcome people's initial hesitation is to ask them to share their experiences and talk about how the issue at hand affects their lives. By relating a public issue to personal experiences, people feel easier to make sense of complex and confusing issues. If we hope to engage people, we need to "begin where they are" by helping them to address public concerns in their own language and on their own terms as well as by helping people to explore how others see the issue. This also serves as the process of strengthening their personal relationships within a community.
4. *Develop public judgment and create common ground for action*. At this more mature form of public deliberation, diverse groups of people *think together* on different points of view on public issues, develop the public judgment and create common ground that is integral to achieving workable public policy and sustainable community action. Thinking together involves listening deeply to other points of view, exploring new ideas and perspectives, searching for points of agreement, and bringing unexamined assumptions into the open. Through this phase of deliberation, a common understanding can emerge that opens an acceptable path to action. The process of deliberation helps linking and consolidating people's private ideas and interests to something more closely resembling public values.
5. *Consider a range of possible actions*. A decision-driven deliberation is expected to lead to a set of two or more alternative courses of action (A, *B*, *C*, *D*, . . .) each of which is physically possible for the deliberators to perform or implement. Further deliberation can be accomplished on the list of alternatives. Is the list exhaustive? If not, what other possible courses of actions are available? Each option has its

advantages and disadvantages, which constitute the reasons for choosing or not choosing it. Participants compare their relative strength with the aim of arriving at an overall agreement on choices of actions, together with the conditions for making such choices.

2.3 GeoDeliberative Dialogue

For the purpose of this article, we further focus on a special type of deliberative dialogue, GeoDeliberative Dialogue, which we define as follows:

> *[Definition] GeoDeliberative Dialogue refers to a form of deliberative dialogues in the civic engagement settings that concerns geographical defined problems and involves the use of geographical information and related technologies.*

This type of deliberative interactions shares general properties of any deliberative dialogues, and, at the same time, has added sophistication because of the geographical component involved. In a geodeliberative dialogue, geographical information and associated technologies can play key roles as they provide a vehicle for structuring the input, process, and outcome of a deliberation. First, deliberation requires information and knowledge input to the thinking process, and geographical information technologies make it possible to gather and present a large volume of spatial data (from disparate sources and across themes and scales) that depicts the context, background, and issues related to the problem. Second, digital representation and visualization of spatial information spark thinking together spatially, which is critical to a deliberation process (Goodchild and Janelle 2004). Third, deliberation contributes to the production and reproduction of collective knowledge space which is geographically expressed.

2.4 Projects Related to GeoDeliberation

From the above discussion on the nature of geodeliberation, it is clear that supporting geodeliberation in democratic practices requires the development of a new kind of geographical information system that is fundamentally different from those in support of analytic processes (a similar argument was made in Ramsey (2008)). The conceptual model of deliberative processes as presented in Figure 1 provides us insight on how to develop technologies that plug into the deliberative processes. In fact, each of the five phases of deliberation in Figure 1 imposes somewhat different needs for technology support. So far, there has been no system that can claim to provide the full range of system support for all the five phases of deliberations shown in Figure 1. However, there are a number of highly visible projects in the area of PPGIS that made progress on selected aspects of geodeliberation. Some of these projects are reviewed below.

Work on Bottom-Up GIS (Talen 2000) and volunteered geographic information (Goodchild 2007, Mummidi and Krumm 2008, Seeger 2008) are relevant to deliberation because they allow people to enter their local knowledge and personal observations into the system, which is needed when people voice their concerns on missing or inaccurate knowledge represented in the system. This type of work can be perceived as marginally contributing to the bottom rung of the deliberation ladder in Figure 1; since community volunteered geographic information helps improve the quality of the information used in deliberation processes.

There has been active work in supporting collaborative decision making in environmental planning applications. For example, *Virtual Slaithwaite* (Kingston et al. 2000) is a web-based online application that supports the discussion of local planning issues, and is one of the earliest efforts to provide map-based deliberation. It provided users with a village map and allowed users to select a geographic object while writing a comment. However, user's comments were only sent back to the system for future analysis, and they are invisible to other participants. Therefore, the map-based discussion space in *Virtual Slaithwaite* is limited to textual annotation by individuals. A slightly more advanced tool was the "Urban Likability and Dislikability" project reported by Al-Kodmany (2000), who studied the use of collaborative annotation tools for neighborhood revitalization efforts. This system allows users to select a cell on the high-resolution aerial photograph and add comments to express likability. These comments were collected by a server for later evaluation and they are not incorporated into the map. Such a system is characterized by collaboration between user and planners, but deliberative dialogues among users do not take place.

Voss et al. (2009) described a system that integrates Web-based mapping tools with structured discussion tools to facilitate participatory spatial planning and decision-making. Their tool supports deliberation in two ways: (1) it supports many-to-many relations between user comments and geographic objects; and (2) it provides sophisticated analysis tools for understanding the spatial-temporal connections among user's comments. The disadvantage of their prototype was that it was made up of two separate applications. Users had to familiarize themselves with the complex functions of both applications to benefit from it.

The work by Rinner and colleagues (Rinner 2001, Rinner et al. 2008) on argumentation maps is perhaps the closest research effort to our work. Their Argumentation map model shares similar ideas with our approach, such as explicit linkages between arguments and geographic objects on maps. Based on the work of Argumentation maps, Keßler et al. (2005) developed a prototype to support decision-making in spatial planning. The prototype was designed to support multiple-thread discussions among participants from 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 on the map and to link comments with them. 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. However, 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 text, but also pictures and video clips. However, one comment can only refer to one geographic object on the map. Because the annotations on Google Maps are mainly used to share information, it does not support the structured deliberation and lacks the visual analytic functionalities that are necessary for working with large datasets.

2.5 Discussion

Here we identify a number of directions where progress needs to be made in order to support geodeliberation. One direction is the increasing sophistication of tools for

capturing, representing, and storing spatially-anchored annotations. In order to mediate geodeliberative dialogues among a group of people, we use annotations as models of the cognitive artifact created during deliberation. The review in section 2.4 shows that there has been proliferation of map annotation tools both in academic and commercial contexts. However, it is still difficult to support digital annotations on web-based maps in a way as easy as annotating on a paper map by a group of people. Since users of public deliberation tools are likely to be non-technical, further improvement on the usability of spatial annotation utilities is needed. Our work makes progress in this direction by creative use of Web 2.0 and AJAX technology, coupled with iterative interface design (see section 4.2).

The second direction is to develop systems and tools that scale-up on the number of users and across large temporal spans. This creates the need to provide persistent storage of annotations so that the state of deliberation can be stored and resumed later. Until now, little attention has been paid to this aspect (with the exception of Voss et al. (2009)). Our work uses spatial annotation database technology (Ovsiannikov et al. 1999, Wolfe 2002) to provide both persistent storage and a complex relational schema for deliberative annotations (see section 3.1).

A third direction is to address the need to preserve semantic of user's comments. A user's comment (annotation) is a product of logical thinking and judgment in a specific geospatial and activity context. Early systems often captured only the comments without associated context, which makes it difficult (or even impossible) for others to interpret the meaning of a comment. Annotations created in the process of geodeliberative dialogues are particularly sensitive to the contexts of their creation at the semantic level. Our work advances this agenda by implementing a spatial data model that reflects the ecological relationships among annotations, visual contexts, discussion threads, spatial referents, and the cognitive states of their holders (see section 3.2).

The fourth direction is to develop mechanisms to mediate the process structure of geodeliberation. Simply providing spatial annotation capabilities is not adequate for mediating deliberative dialogues. According to the model of deliberative dialogues we have articulated in section 2.2, there are a complex set of structures and patterns that dictate how a geodeliberative dialogue advances from one phase to another. Our current work does not yet provide a robust mechanism for supervising a deliberative dialogue. However, we provide a temporary solution to the problem by introducing the role of a moderator in issue management (see section 3.5)

3 GeoDeliberative Annotation Technology

Enabling successful geodeliberation in public engagement requires coupling of the appropriate social and technical efforts and solutions. With that understanding, this section focuses on the technical aspect of the larger problem and seeks technology design solutions to support geodeliberative dialogue for mass participation and in a distributed, asynchronous fashion. The idea is to extend web-based geographical information services with a new set of functions which we collectively call *GeoDeliberative Annotation Technology* (GeoDAT). GeoDAT refers to a systematic set of design recommendations for capturing, managing, and visualizing geospatial annotations to support effective geodeliberation. It documents our findings on the key capabilities and architecture solutions that are needed to make geodeliberation possible.

In GeoDAT, we use geospatial annotations to represent and structure the artifacts of geodeliberation. Each of the user's contributions is captured as a geospatial annotation. 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" (Ovsiannikov et al. 1999). Annotations emphasize the reference relationship between two semantic components: the *context selections* and *annotation content*. The context of an annotation can be a contiguous piece of data (in the original document), called an *atom*, or can be a set of semantically related atoms, called a *clump*. It is possible that one atom is linked to many annotations. Hence there is a many-to-many relationship between atoms and annotations.

In the context of this article, we are mainly interested in geodeliberative annotations. Specifically, geodeliberative annotations have the following characteristics:

1. *They are **collaborative** annotations*. Unlike other types of annotations, deliberative annotations are written (created) with the intention that it is to be understood by others and will be helpful to future readers of the same source documents. To be understood by people other than the author, an annotation is usually created in the form of brief notes or commentaries, and is semantically explicit in its textual expression. We assume that a deliberative annotation is created with the best knowledge of the author, and is as accurate representation of the author's mental status as it can be.
2. *They are **spatial** annotations*. Spatial annotation can be considered as a subclass of annotations that has explicit geo-references to maps or images. Space serves as an important context within which deliberation is structured and shaped.
3. *They are **nesting** annotations with reference relationships*. The ability to maintain the deliberative dialogues by linking to other annotations. The ability to enable logical thinking and reasoning by grounding the current comments on the existing ones.

Geospatial annotations provide a way to add contents whose interpretation depends at a minimum on spatial context (Hopfer and MacEachren 2007). Figure 2 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 – on the map (highlighted in blue).

Next, we consider a number of critical design dimensions and functional requirements for effective use of geodeliberative annotations. These include: (1) annotation persistence; (2) annotation contextualization: (3) private vs. public spaces of annotations; (4) visualization for navigation and sense-making; and (5) issue management.

3.1 Annotation Persistence

Geodeliberation is likely to take multiple sessions of user interactions, and may span a few days or even months. Therefore, spatial annotations must be persistently stored. In GeoDAT, annotations and their associated atoms and clumps are stored in a *spatial annotation database* (SADB), which is separate from the source geographical information document. Figure 3 is a portion of the data model that reflects the multiple relations among the annotations, geographic footprints, users, and their activities. SADB is

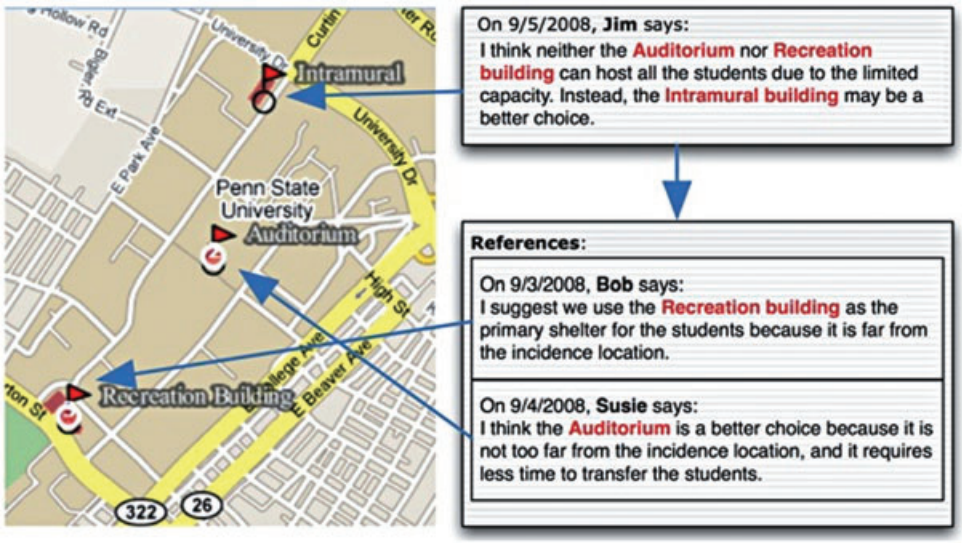

Figure 2 An example of geospatial annotation

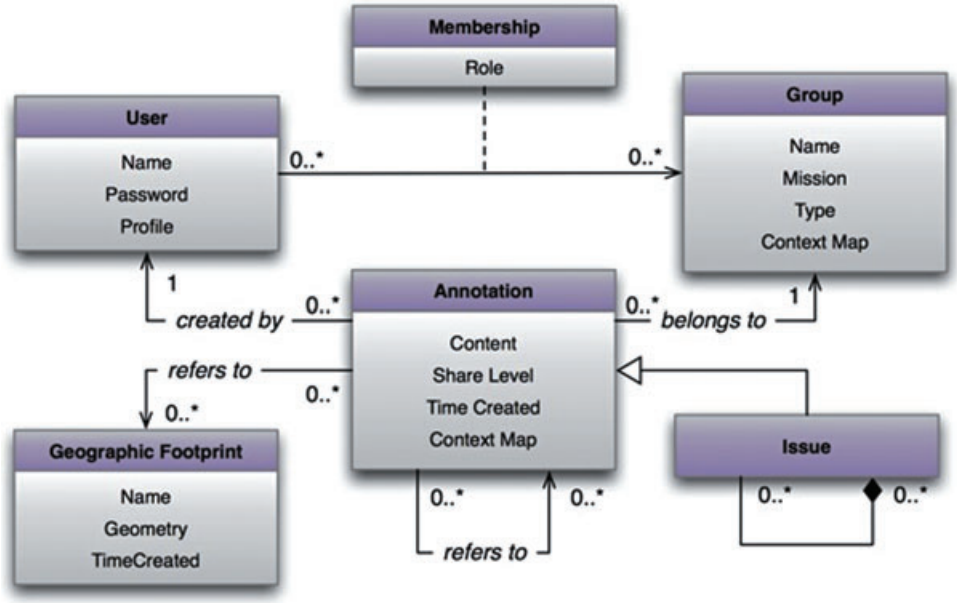

Figure 3 Reference data model of spatial annotation database

designed to deal with the dynamic human communications, and is fully searchable by topics, threads, time, location, topology, and authors. The existence of a SADB opens huge opportunities for annotation-based participation. SADB keeps detailed records of previous contributions so that all the information necessary for future readers to understand and use can be preserved. 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. 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.

3.2 Annotation Contextualization

Each geodeliberative annotation has a very rich set of contexts that are critical for making sense of that annotation. GeoDAT records annotations together with their visual contexts and referential contexts. The visual context of an annotation is the state of the map document (viewed by the user) at the moment when an annotation was authored. We assume that a map document is composed of layered information served from a variety of web-services. We further assume that each of the data sources used by a map document is URL-addressable. Then, the visual context of an annotation can be simply recorded as an XML document with markups defining data sources and specifying the visual appearance of each map layer.

The referential context of an annotation is modeled by the two "refers" relationships in Figure 3, representing that an annotation can refer to other annotations and some geographical footprints (atoms). 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 fulfill the requirement to support advanced forms of deliberation as discussed in section 2.2.

3.3 Private vs. Public Spaces of Annotations

A geodeliberative tool will face the challenge of how to encourage members of the community to contribute the knowledge in their mind to the system as explicitly stored artifacts. Since contributions are voluntary, a system must be designed to accommodate two types of needs from the end-users. On the one hand, a user needs to have a feeling of 'belonging' to a community, which calls for maximizing the sharing of annotations with other members of a community. On the other hand, a user may also want to maintain a degree of individuality and to keep sharing to a comfortable level at any given time. These two contradictory requirements can be accommodated by maintaining two interaction spaces for each user: ***a shared space*** and ***a private space*** (Figure 4). Annotations stored in the shared space are accessible by the whole community, while those in the private space are accessible by the creator only. An annotation can be first drafted in the private space and can later be moved to the shared space. A member of a community has full access to his/her own space (private and shared), plus read access to the shared spaces of all other members of the community. This feature of private/public annotations can be implemented by adding an attribute "*share_level*" to annotation objects in the Spatial Annotation Database schema (Figure 3).

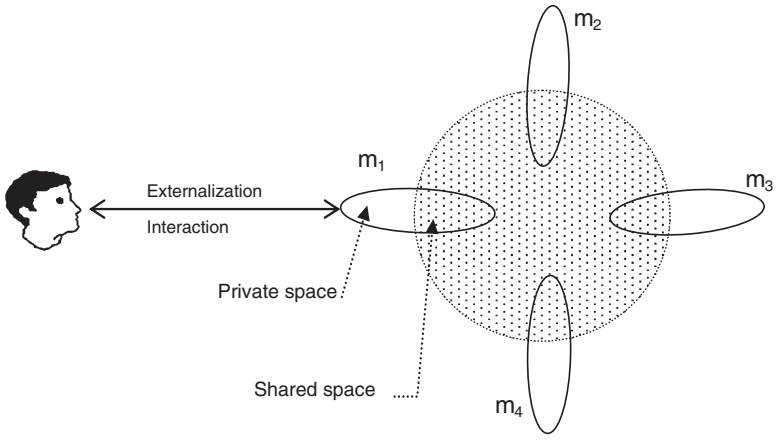

Figure 4 Two spaces of deliberation and interaction

3.4 Visualization for Navigation and Sense-making

One of the prerequisites for enabling quality deliberation is to listen to and understand what others have said about an issue before contributing one's own ideas. As the system accumulates large number of deliberative annotations, reading through every annotation in sequence is no longer a practical option. Geospatial Annotation Technology recommends the use of visualization and visual interaction techniques for exploring large annotation data spaces and aiding the users in understanding what is going on around a problem. With the availability of the spatial annotation database (SADB), various overview plus detail, dynamic filtering, and spatial-temporal visualization techniques (Hill et al. 1992, Keim 2005, Cockburn et al. 2008) can be applied. The linking of annotations through their references naturally form directional trees that can benefit from the use of visual navigation aids such as SpaceTree (Plaisant et al. 2002) to show threads of deliberative dialogues. Geovisualization techniques (Dykes 1998, Keim 2005) can be used to explore the spatial patterns and distributions of annotations. The process of deliberative dialogues fits nicely with Shneiderman's visual information seeking mantra (Shneiderman 1996), and hence can be informed by knowledge of information visualization (Card et al. 1999).

3.5 Issue Management and the Roles of Moderators

Decision-driven deliberative dialogues often make use of issues as conceptual tools to structure deliberative processes and artifacts (London 2007). Issues are relatively stable, manageable, and meaningful units of concerns that are collectively identified by the community. If deliberation can be thought of as exploring a 'space' of concerns, questions, answers, and facts, etc., then issues can be thought of as 'landmarks' in that space. Using this metaphor, we can infer a number of properties about issues and their management. First, an issue should be a cognitively salient concern that is recognizable by most members of the community. Second, we tend to associate related things to an issue in deliberation, just like we associate things to their nearby landmarks. Issues play several roles in the process of deliberation. At the initiation phase of a deliberation, issues may

be imposed by a moderator or some authorities and used as a starting point to stimulate thinking and dialogues. Such issues cannot be too big that they go beyond human comprehension. Instead they should be concrete enough for people to attach personal experiences or observations to them.

Issues can be used by the moderator(s) (if any) of a public deliberation to break up complex problems into smaller, more concrete concepts that make it easier for people to attach personal experiences and form judgments. Issues are used to draw the attention of the public to contribute more ideas.

Due to the above functions of issues, the creation of issues is often controlled by the moderator(s). When deliberation diverges into too many directions, a moderator may opt to create new issues to help aggregate the focal points of deliberation to a manageable number. When deliberation starts to converge, smaller issues can be aggregated into larger issues to form an issue-hierarchy. For newcomers, issues and their hierarchical structures provide efficient paths for navigating around a large deliberation space. A moderator should not delete or modify any entries made by others, but he or she can create/add associations among regular annotations and issues.

Although a regular user cannot create an issue, he or she can propose a concern as a new issue which will be forwarded to a moderator for approval or disapproval.

4 GeoDeliberator

Following the specification of GeoDAT, we have implemented a working prototype – GeoDeliberator (available online at http://130.203.158.62/geodeliberator/), as a proof of concept. GeoDeliberator is a Web-based interactive geospatial annotation environment that supports geodeliberative dialogues. In the following, we will first describe the architecture of the system. Then we demonstrate the utility of our system using a hypothetical scenario.

4.1 System Architecture

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

On the client side, a browser instance provides the user with the lightweight HTML plus JavaScript user interface, which is implemented by using the Open Source JavaScript libraries: Ext JS framework (http://extjs.com/products/extjs/) 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 retrieve, add, modify, or delete annotations from the annotation database. The annotation database is an instance of *PostgreSQL* (http://www.postgresql.org/), which stores the information about the users, groups, the annotations and their visual and referential contexts (for the schema of the annotation database, see Figure 3). Besides, the geographic reference objects are also stored in the database through the PostGIS extension. The server's responses to the client's requests are encoded as XML messages and send back to the client via HTTP.

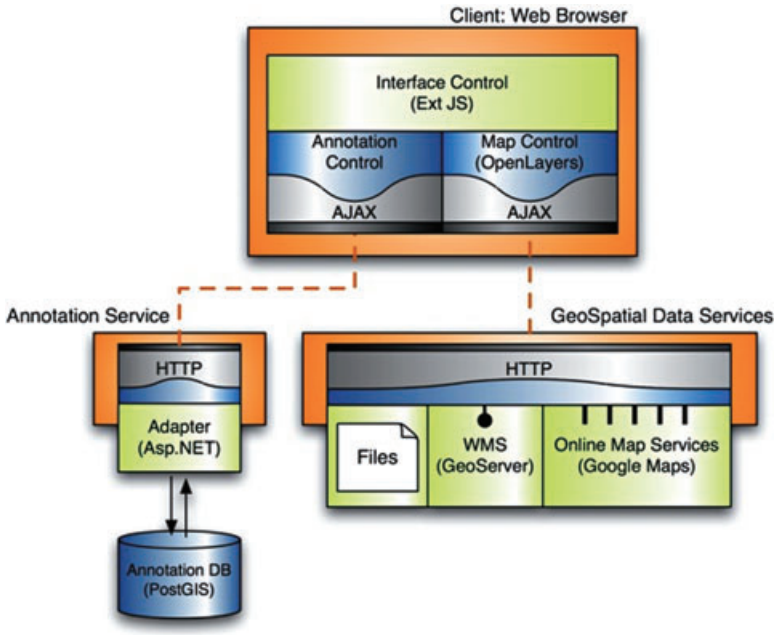

Figure 5 The architecture of GeoDeliberator

When the client receives the response from the server, it will interpret the XML message 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. The web-based architecture of our system allows distributed and asynchronous participation of deliberation across all the participations in the community, so that they can think together and communicate with each other.

4.2 GeoDeliberator Interfaces

Figure 6 shows what a user will see on the screen when she/he begins an interaction session with GeoDeliberator.

The GeoDeliberator interface is comprised of five areas:

1. The *User and Group Panel* provides the functions to login/logout of the system and lists all the active and open groups that the user can enter or join to engage with the group.
2. The *Project Panel* offers four functions. The 'General Info' tab provides an overall mission statement of the project and briefing on the structure of the deliberation process. The "Issues" tab can be clicked to view all the active issues under deliberation. This list of issues can be clicked to see details of the issue on the Annotation Info panel. Users browse through the annotations and issues by navigating between the Annotation Info panel, map panel, and Issues panels. The "Contribute" tab is

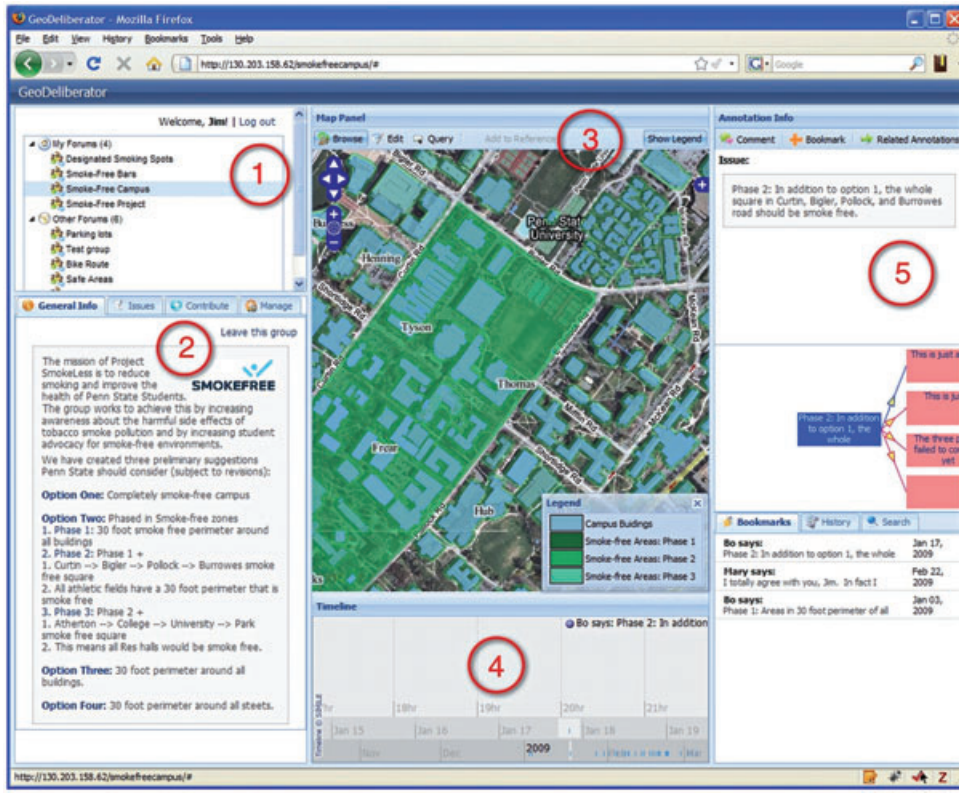

Figure 6 GeoDeliberator's user interface: (1) User and Group Panel, (2) Project Panel, (3) Map Panel, (4) Timeline View, and (5) Annotation Info Panel

where the participants can create a new annotation or propose a new issue. The "Manage" tab provides the functions to allow users to review, edit, and delete their annotations.

3. The *Map Panel* shows the context map (with geographic footprints) of the currently selected annotation. A user is able to add or remove layers on the map, as well as to change the map scale and extent, to customize the map that is particularly suitable for the new group. In the *"Smoke-Free Campus"* group in Figure 6, there are four different types of layers on the map: 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.
4. The *Timeline view* provides a scrollable timeline view of all annotations. It shows individual annotations as dots corresponding to their creation timestamps.
5. The *Annotation info Panel* provides the detailed textual content of the selected annotation, a SpaceTree view (Plaisant et al. 2002) of the deliberative dialogue threads, and a choice of bookmark and history functions. The SpaceTree view

affords navigation on two directions of discussion threads: forward or backward. Items on the bookmark list and on the history list can be dragged and dropped to define references when authoring a new annotation. All these panels are actively linked such that changes/updates on one panel will trigger the update of other panels.

4.3 GeoDeliberator Functionalities

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

Smoke-Free Campus: a scenario

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. The mission of Project SmokeLess is to reduce the risk of secondary smoking. 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 towards a smokeFree campus. Stakeholders of the SmokeFree project in the community include students, faculty, local residents, university administrators, police departments, etc. The project leaders have created three preliminary options for the community to consider:

Option One: Completely smoke-free campus

Option Two: Phased in Smoke-free zones

1. Phase 1: 30 foot smoke free perimeter around all buildings on campus
2. Phase 2: Phase 1 plus all athletic fields have a 30 foot perimeter that is smoke free
3. Phase 3: Phase 2 + all Residence halls would be smoke free.

Option Three: 30 foot perimeter around all buildings.

GeoDeliberator has been deployed as a tool to support geodeliberative dialogue on this particular issue. Deliberation on the project SmokeFree is geographical for two reasons. First, the risk of secondary smoke is geographically expressed and is associated with human activity patterns. One of the major topics around the issue is to decide the locations of smoke-free zones on campus. Second, human experiences, stories, and judgments with regard to smoking risk are likely to be associated with some part of the campus, whether they are buildings, bus stops, or dormitories.

With this scenario, we shall follow the steps of a user to work through a complete round of deliberation and illustrate the functionalities of GeoDeliberator. The discussion below roughly follows the ladder model of deliberative dialogue in Figure 1.

4.3.1 "Briefing and introduction" function

Suppose that Jim has started GeoDeliberator and has chosen to work on the SmokeFree Campus project. If Jim is a first-time user, he will be directed to the "General Info" tab to learn about the baseline information of the SmokeFree project. This information panel mimics the "Briefing and Introduction" phase in the model of Figure 1. The system presents to Jim information about the mission as well as the three options under discussion. Clicking on one of the hyperlinks (Phases 1 through 3) will trigger the map panel to refresh showing the geographical areas of that phase. On the map panel,

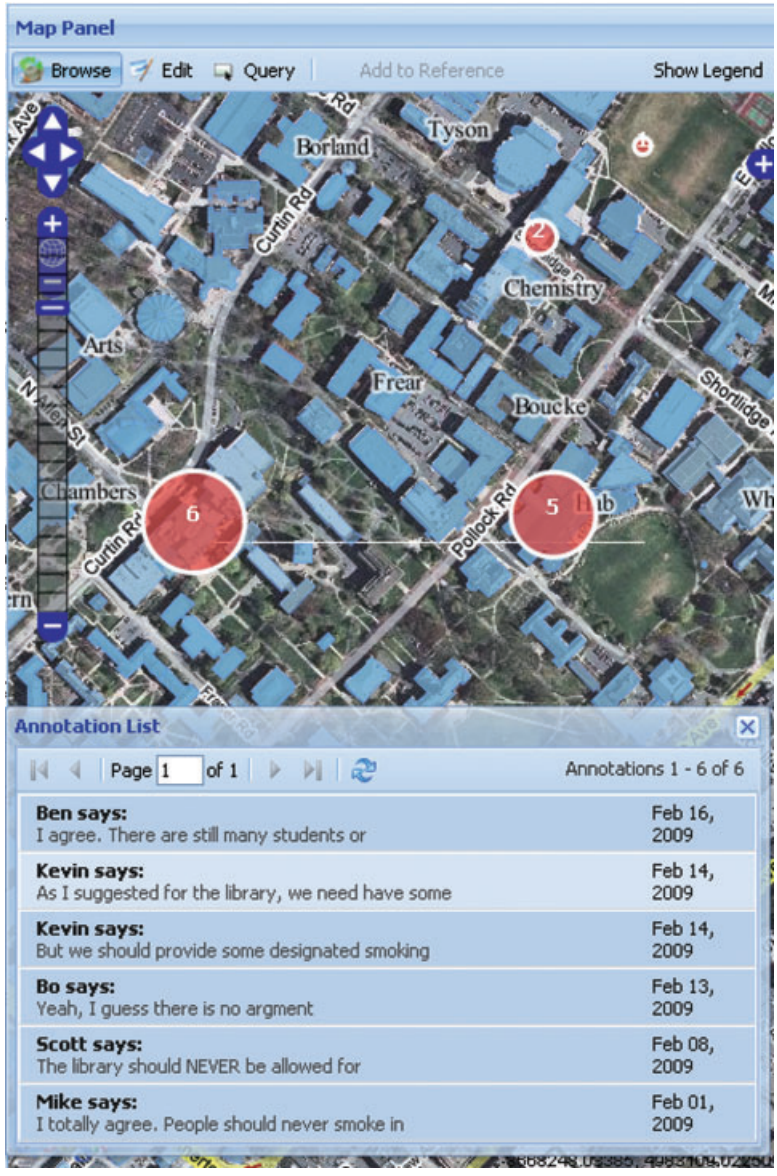

Figure 7 Browsing annotation spatially. Graduated circles showing visual overview while popup list providing details on demand

the system provides the baseline geographical information about the campus, such as the distribution of major buildings, roads, health care facilities, and other related information.

In order to catch up with previous deliberations and figure out what is going on, Jim will also need to spend time making sense of existing annotations. This can be done in multiple ways. On the map panel, a spatial overview of the overall distribution of annotations is presented as graduated circles (Figure 7). The number in the RED circle

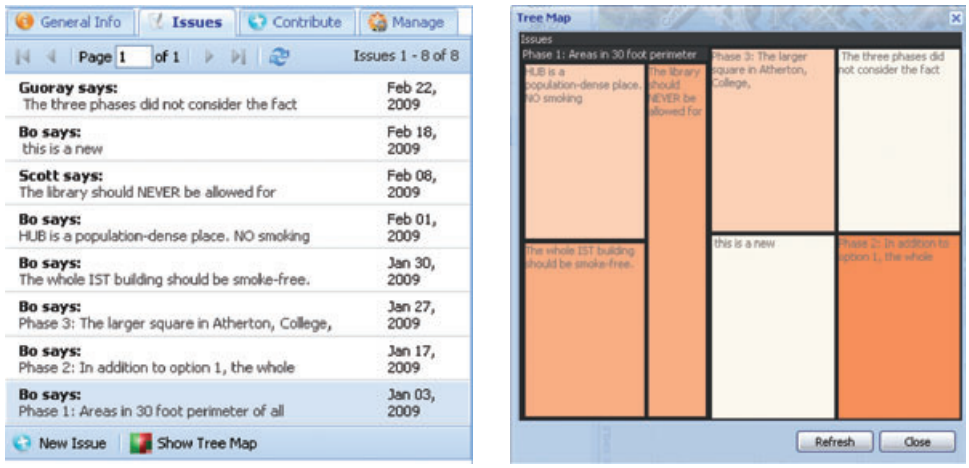

Figure 8 The 'issue-based' browsing function

indicates the number of annotations in that area. Clicking on one of the circles will cause a pop-up window listing individual annotations in that cluster. The detail of each annotation on the list is now accessible by a simple click. Making sense of annotations by browsing spatially is quite natural since we have fully implemented Shneiderman's visual information seeking mantra (Shneiderman 1996).

Alternatively, Jim can start his exploration from the "Issues" tab where active issues are shown as a list or a tree map (Figure 8). Clicking on an issue in the list view brings up details of that issue on the "Annotation Info" panel. The tree map view of issues is best for exploring the hierarchical structure of issues. The SpaceTree view (on the annotation info panel) will show the reference relationships among annotations and can be navigated to follow the threads of discussions. We assume that issues are managed by the moderator and can be generalized or specialized to form hierarchies of issues so that top-level issues are small in number (e.g. 5–10 issues).

4.3.2 "Elaboration on problem and issues" function

After Jim has obtained enough background knowledge about the SmokeFree campus project, he is ready to contribute his own ideas. One way to elaborate on the problem is to deliberate on any other issues that are important but not yet considered. Assuming that Jim would like to raise a new issue that "bus stops around the campus should be smoke-free," he would compose a new annotation like the one shown in Figure 9. This annotation references the three phases and is 'checked' as a proposal for a new issue. The system will alert the moderator who can approve or reject this message as a new issue.

4.3.3 Contributing personal experiences

Contributing personal experiences and stories concerning an issue is a common mode of deliberation. The process is the same as authoring a regular annotation (using the 'Contribute' function), but emphasizes *the connection of the mentioned experience to one or more active issues*. This is done by explicitly adding the related issues to the

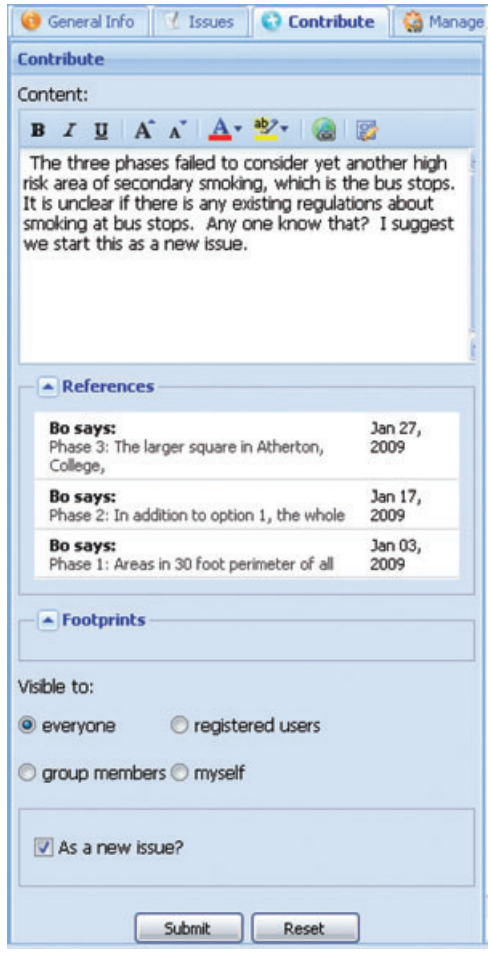

Figure 9 Elaborating on problems and issues

"References" slot of an annotation. Figure 10 shows one example where Jim described his experience at one door entrance to the IST building. The system makes it easy to link an annotation to an issue through drag-and-drop of existing issues and annotations to the 'references' of a new contribution.

4.3.4 Developing common ground and public judgment

At this stage of deliberation, we are likely to see that individual ideas cross-fertilize each other and converge to larger chunks of ideas that can be viewed as public opinions or judgment. In the SmokeFree campus scenario, we did observe this phenomenon even with a small number of participants over a few weeks of deliberation. Our system supports this kind of deliberation by offering functions that allow participants and moderators to create new annotations that serve the role of aggregation or summarization of existing threads or issues. An example would be one contribution made by Jim (shown in Figure 11) where a summary serves as an assessment on how ideas converge.

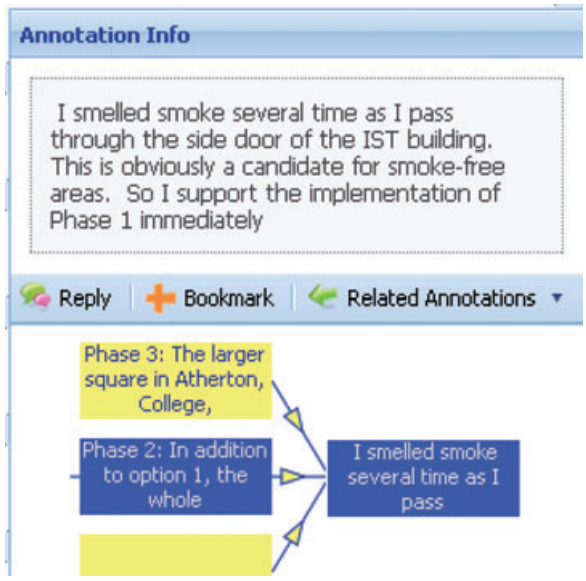

Figure 10 Deliberating through personal experiences

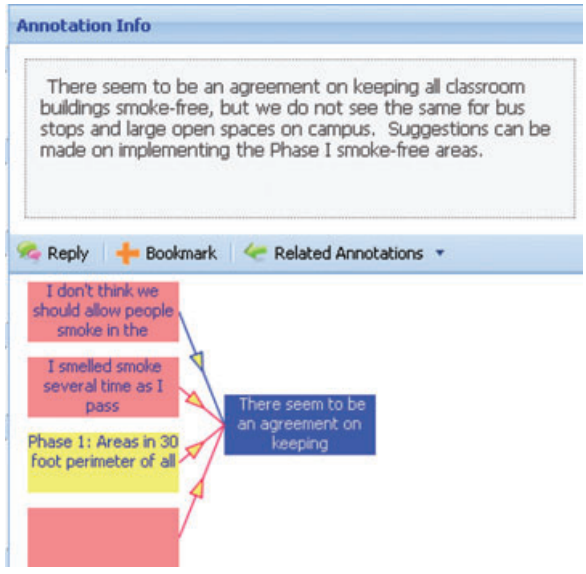

Figure 11 Deliberating through personal experiences

4.3.5 Deliberating alternative courses of actions and their evaluation

This stage of deliberation is heavily dependent on the quality of deliberation from previous stages (although we do not assume a linear sequence of these stages). In the SmokeFree campus scenario, the viable options seem to emerge naturally out of the

quality deliberation, but an explicit summary (in the form of a new annotation) is still necessary for subsequent evaluation.

5 Conclusions

In this article, we have explored the potential of extending Web-based geographical information services with the GeoDeliberative Annotation Technology (GeoDAT) to facilitate public engagement with complex and high impact community decisions and policies. This work extends the analytical-deliberative account of public participation GIS (Nyerges et al. 2006a, b) with an elaborated model of geodeliberation. We articulated a theory of GeoDeliberative Dialogues which guides us in the design and evaluation of the geodeliberative annotation technology. The presented prototype system, GeoDeliberator, is based on our specification of GeoDeliberative Annotation Technology which is informed by work in annotation technology and information visualization. We are in the process of conducting a large-scale user study, based on the Smoke-Free Campus scenario, to understand community use of geodeliberative annotation technologies and real annotating behaviors. Limited feedback so far from the scenario-based evaluation with small groups have shown that the GeoDeliberator offers easy-to-use functions for effective organization of geographically referenced discussions, which have the potential to support deliberative dialogues in communities.

Furthermore, we understand that the participatory deliberation processes in communities and the supporting technologies affect each other and form a socio-technical system. For successful support of spatial deliberation processes, a deep knowledge of 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 understanding of these map-based deliberation processes.

Future work will concentrate on the evaluation process in order to gain insights on geodeliberation processes. The evaluation efforts will help develop and refine the next prototype system. We also plan to explore more fully the power of using geographic visualization tools to support the analysis and sense-making of geospatial annotations.

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References

Al-Kodmany K 2000 Using Web-based technologies and geographic information systems in community planning. *Journal of Urban Technology* 7: 1–30

Al-Kodmany K 2001 Online tools for public participation. *Government Information Quarterly* 18: 329–41

Arnstein S R 1969 A ladder of citizen participation. *Journal of the American Institute of Planners* 8: 216–24

Balram S and Dragicevic S (eds) 2006 *Collaborative Geographic Information Systems* Hershey, PA, Idea Group

Balram S, Dragicevic S, and Feick R 2009 Collaborative GIS for spatial decision support and visualization. *Journal of Environmental Management* 90: 1963–65

Card S K, Mackinlay J D, and Shneidermann B 1999 *Reading in Information Visualization: Using Vision to Think*. San Francisco, CA, Morgan Kaumann

Cockburn A, Karlson A, and Bederson B B 2008 A review of overview + detail, zooming, and focus + context interfaces. *ACM Computing Surveys* 41: 1–31

Craig W, Harris T and Weiner D 1999 *Empowerment, Marginalization and Public Participation GIS*. Santa Barbara, CA, National Center for Geographic Information and Analysis, Varenius Project Report

Dykes J 1998 Cartographic visualization. *The Statistician* 47: 485–97

Elwood S 2006 Critical issues in participatory GIS: Deconstructions, reconstructions, and new research directions. *Transactions in GIS* 10: 693–708

Gastil J 1993 *Democracy in Small Groups: Participation, Decision Making and Communication*. Philadelphia, PA, New Society Press

Goodchild M F 2007 Citizens as voluntary sensors: Spatial data infrastructure in the world of Web 2.0. *International Journal of Spatial Data Infrastructures Research* 2: 24–32

Goodchild M F and Janelle D G 2004 Thinking spatially in the social sciences. In Goodchild M F and Janelle D G (eds) *Spatially Integrated Social Science*. New York, Oxford University Press: 3–17

Haklay M M and Tobon C 2003 Usability evaluation and PPGIS: Towards a user-centred design approach. *International Journal of Geographical Information Science* 17: 577–92

Harris T and Weiner D (eds) 2002 *Community Participation and GIS*. London, Taylor and Francis

Harwood R, Scully P, and Dennis K 1996 *Will Any Kind of Talk Do? Moving from Personal Concerns to Public Life*. Dayton, OH, Kettering Foundation and The Harwood Group

Hill W C, Hollan J D, Wroblewski D, and McCandless T 1992 Edit Wear and Read Wear. In *Proceedings of the International Conference on Human Factors in Computing Systems (CHI'92)*, Monterey, California

Hopfer S and MacEachren A M 2007 Leveraging the potential of geospatial annotations for collaboration: A communication theory perspective. *International Journal of Geographical Information Science* 21: 921–34

Jankowski P and Nyerges T 2001 *Geographic Information Systems for Group Decision Making: Towards a Participatory Geographic Information Science*. New York, Taylor and Francis

Keim D A 2005 Information visualization: Scope, techniques and opportunities for geovisualization. In Dykes J, MacEachren A M, and Kraak M-J (eds) *Exploring Geovisualization*. Oxford, Elsevier: 21–52

Keßler C, Rinner C, and Raubal M 2005 An argumentation map prototype to support decision-making in spatial planning. In *Proceedings of AGILE 05*, Estoril, Portugal: 26–8

Kingston R, Carver S, Evans A, and Turton I 2000 Web-based public participation geographical information systems: An aid to local environmental decision-making. *Computers, Environment and Urban Systems* 24: 109–25

Kyem P A K 2001 Public participation GIS applications and the community empowerment process: A review of concerns and challenges. *Cartographica* 38: 5–17

London S 2007 Thinking Together: The Power of Deliberative Dialogue. WWW document, http://www.scottlondon.com/reports/dialogue.html

Mathews D and McAfee N 2000 *Making Choices Together: The Power of Public Deliberation*. Dayton, OH, Kettering Foundation Press

McCoy M L and Scully P L 2002 Deliberative dialogue to expand civic engagement: What kind of talk does democracy need? *National Civic Review* 91: 117–34

Mouffe C 1999 Deliberative democracy or agonistic plurialism? *Social Research* 66: 745–58

Mummidi L and Krumm J 2008 Discovering points of interest from users' map annotations. *GeoJournal* 72: 215–27

National Center for Geographic Information and Analysis 1996 *Summary Report: Public Participation GIS Workshop*. Orono, ME, National Center for Geographic Information and Analysis, Workshop Summary Report

National Research Council 1996 *Understanding Risk: Informing Decisions in a Democratic Society*. Washington, D.C., National Academy Press

Nyerges T L and Jankowski P 1997 Enhanced adaptive structuration theory: A theory of GIS-supported collaborative decision making. *Geographical Systems* 4: 225–59

Nyerges T L, Jankowski P, Ramsey K, and Tuthill D 2006a Collaborative water resource decision support: Results of a field experiment. *Annals of the Association of American Geographers* 96: 699–725

Nyerges T L, Ramsey K, and Wilson M 2006b Design considerations for an Internet portal public participation in transportation improvement decision making. In Balram S and Dragicevic S (eds) *Collaborative Geographic Information Systems*. Hershey, PA, Idea Group: 207–35

Ovsiannikov I A, Arbib M A, and Mcneill T H 1999 Annotation technology. *International Journal of Human-Computer Studies* 50: 329–62

Peng Z-R 2001 Internet GIS for public participation. *Environment and Planning B* 28: 889–905

Pickles J (ed) 1995 *Ground Truth: The Social Implications of Geographic Information Systems*. New York, Guilford

Plaisant C, Grosjean J, and Bederson B 2002 SpaceTree: Supporting exploration in large node link tree, design evolution and empirical evaluation. In *Proceedings of the IEEE Symposium on Information Visualization (InfoVis)*, Boston, Massachusetts: 57–64

Ramsey K 2008 A call for agonism: GIS and the politics of collaboration. *Environment and Planning A* 40: 2346–63

Ramsey K 2009 GIS, modeling, and politics: On the tensions of collaborative decision support. *Journal of Environmental Management* 90: 1972–80

Rinner C 2001 Argumentation maps: GIS-based discussion support for online planning. *Environment and Planning B* 28: 847–63

Rinner C, Keßler C, and Andrulis S 2008 The use of Web 2.0 concepts to support deliberation in spatial decision-making. *Computers, Environment and Urban Systems* 32: 386–95

Schuurman N 2001 Critical GIS: Theorizing an emerging discipline. *Cartographica* 36: 1–108

Seeger C J 2008 The role of facilitated volunteered geographic information in the landscape planning and site design process. *GeoJournal* 72: 199–213

Shneiderman B 1996 The eyes have it: A task by data type taxonomy for information visualizations. In *Proceedings of the IEEE Symposium on Visual Languages*, Washington, D.C.: 336–43

Sieber R 2006 Public participation geographic information systems: A literature review and framework. *Annals of the Association of American Geographers* 96: 491–507

Talen E 2000 Bottom-up GIS: A new tool for individual and group expression in participatory planning. *Journal of the American Planning Association* 66: 279–94

Voss A, Denisovich I, Gatalsky P, Gavouchidis K, Klotz A, Roeder S, and Voss H 2009 Evolution of a participatory GIS. *Computers, Environment and Urban Systems* 33: in press

Wolfe J 2002 Annotation technologies: A software and research review. *Computers and Composition* 19: 471–97

Wood D 1992 *The Power of Maps*. New York, Guilford