CIVIL: Support Geo-collaboration with Information Visualization

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ABSTRACT

Teams of specialized experts, such as emergency management planning teams, while making decisions need to efficiently pool domain-specific knowledge, synthesize relevant information, and keep track of collaborators activities at a low interaction cost. This requires tools that allow monitoring both low-level information (e.g., individual actions and external events) and higher-order activities (e.g., how members contribute to groupwork). This paper presents design of *CIVIL,* a system prototype developed to support map-based decision-making. We report our empirical evaluation of the effects of visualizations on the decision process and the final product.

Categories and Subject Descriptors

H.5.3. [**Information interfaces and presentation (e.g., HCI)**] Group and Organization Interfaces: *Collaborative computing*

General Terms

Design, Experimentation, Human Factors

Keywords

CSCW, geo-collaboration, multiple-view, decision support

1. INTRODUCTION

Complex decision-making such as emergency management planning requires collecting and analyzing various kinds of information. The decision-making process usually involves a team of specialized experts, who interpret domain-specific information and synthesize it for the team. Consider the following collaborative scenario derived from a field study on emergency management teams [1]:

> *Three experts are planning an emergency management operation: they need to find the best solution available for evacuating a family from a flooded area to a shelter. The three experts, Public Worker, Environmental expert, and Mass Care expert, collaborate through a geo-collaborative system. Each expert has both unique role-specific information and shared information. For example, the Public Works expert is a civil engineer who has information on roads, bridges, and public infrastructures. Interpreting from her specialized map, the Public Works expert informs the other two collaborators that a main road leading to shelter A is under construction for sewage, which makes it unsafe for transporting rescuees. She shares this constraint on their team map. Thus, the other two collaborators can now take into consideration this new key piece of information, which was not available during their initial individual planning. After a full round of sharing on the main issues from each expert, they realize that they have very little time left, thus their group discussion gradually focuses on issues that they now have in common.*

To successfully complete the task presented in this scenario, the three experts need to contribute to the team information and judgments from different perspectives and areas of expertise. To achieve the final goal (i.e., generate a plan), these experts need to overcome challenges such as managing diverse sets of domain knowledge and coordinating a complex task under the constraints of limited time, distributed setting, and tools available. Current social computing tools, such as chat tools, discussion forums, and brainstorming tools provide little support in these conditions.

Communicating about geospatial information, which is critical to many emergency management situations, is often difficult. Although team members can use geography information systems (GIS) (e.g., ArcGIS) and map services (e.g., online digital maps) to share and discuss geospatial information, these applications and services are usually designed for individual users [2]. A gap exists between tools provided by current map-based services and tools required by geo-collaboration [3]. There is a need for combining GIS services and groupware to support distributed teams in sharing, discussing, and synthesizing geospatial information as well as non-geography information in group decision-making.

In this paper we report the evaluation for a web-based prototype system that supports geo-*C*ollaboration through *I*nformation *VI*sua*L*ization (*CIVIL*), implemented for the first time on a web platform. This prototype augments the user interface with novel visualization tools that support the sharing of both content and process information in teams. The target users are small teams of specialized domain experts. The paper reviews related work, describes the prototype and its evaluation, and concludes with discussions, implications, and future work.

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2. RELATED WORK

The cognitive resource involved in group collaboration is not the simple sum of individual intelligence. MacMillian et al. observe that team cognition differs from individual cognition because it requires communication, which is "a process that has no direct analog in individual cognition" [4], except for the individual thinking process itself. The accumulation of team knowledge and protocols (common ground) can be facilitated through communication channels and shared spaces where participants' action relative to task objects are made public and visible [5]. Thus, collaborative visualization, such as the deictic expressions 'this', 'there' and 'it' can be made public and visible through the use of telepointers, pen tools, or annotation tools.

When people work with artifacts in collaborative work, they need tool functions that enable to clearly distinguish between private and public areas in the workspace. Several studies of collaboration have shown that users make active use of such tool functions to determine what should be private and what (or when) should become public. Studies of annotations have suggested that collaborators make different uses of private and public annotations [e.g., 6]. They may benefit from tools for explaining or aggregating subsets of private information while these are transferred from the private spaces to the public space.

For collaborations that involve spatial information, cartographic representation can contribute to collaboration work in three perspectives [6]: a) objects to talk about; b) object to think about; c) objects to coordinate actions. Maps, serving as visual mediation and event context, have been investigated by cartographers on facilitating understanding of the task and thus improve decision making. Argumentation maps, proposed by Rinner [7], provide explicit links between arguments in the discussion and the related geographic objects (see [5] for non map-based task). The argumentation maps support query of both geospatial information and linked discussions. The combinational function helps analysis and summarization of current status in conversation and assist people completing geospatial related planning tasks. However, little research on implementing tools for geo-collaboration draws from existing research on GIS, information visualization, and CSCW [3], and even fewer publicly available tools support synchronous geo-collaboration. For a survey of common features in synchronously collaborative tools see [8].

Maps, as visual tools, externalize geospatial data and help to reduce cognitive workload. Moreover, when used in collaborative decision-making, shared maps help to process both spatial information and the discourse of the group. Maps are not the only kind of medium that employed in geo-collaboration. Information visualizations can be introduced to group decision making in several ways. First, a few studies on bias in groups have shown that collaborative visualization can reduce specific types of bias in decision-making, see a review in [9]. Second, the presence of visualization influences the level of participation of the members [11] and the information sharing process during group decision-making [5]. The research has shown that shared visualizations can allow collocated working groups to communicate more effectively by externalizing communication process and self-regulate it better [10]. Third, studies in military area have shown that visualization techniques help people to rapidly comprehend complexly tangled information in emergency situations [11].

3. DESIGN AND IMPLEMENTATION

The existing visualization techniques used to support group decision-making are primarily focused on promoting the sharing of the group content (see prior section). Little or no support is given for the sharing of the process. But complex, dynamic decision-making requires the team to not only pool content, but also to strategize and monitor the work process. The literature suggests that the more efficient is the sharing about the process, the better is the team performance. We refer here to the shared understanding of the rules, procedures, timing, and manner in which the teamwork will be conducted [13].

In order to better support knowledge sharing about both the content and the process the design rationale that we propose is to make otherwise tacit relevant aspects of individual and group activity explicit, visible, and permanent (e.g., through color-coded annotations). Such tracking and recording of the shared work should promote distributed cognition and transactive memory, by making selected aspects of past activities a tangible resource rather than a burden to short-term memory [13]. High-level visualizations also provide the team with alternative views of its own decision process ([9, 10] see review in [14]).

Motivated by previous fieldwork on the practices for emergency management planning (e.g., tabletop training exercises) [1], we have the following design considerations for a geo-collaboration supporting system in emergency management:

Map-Centric Collaboration Support. Maps have served for century as effective organizers of geospatial data. Map-based collaboration involves the references to common geospatial objects in discussions and planning (i.e. deixis). It is useful to externalize such objects and referencing actions on the maps.

Annotation and Sketching Support. In collaboration, collaborators often need to express their personal perspectives or judgments, which are often referred to objects on maps. Individuals should have tools to annotate ideas as these pop up into their minds, add comments to spatial objects, and draw sketches to illustrate spatial relationships (i.e., spatial reasoning).

Multiple Maps for Private and Public Activities. Distributed collaborators need both private and public space in geo-collaboration. The private space is a place where domain-specific information can be examined and analyzed independently by an individual expert before 'selected' information and analysis results are shared with others. The public space displays shared information and supports team discussions. Thus, collaborators should have a private map and a public map, as well as tools that support information transformer between these two maps.

Visualization to Support Information Aggregation. Our field study shows that geo-collaboration often involves the integration of relevant information from different sources. To have tools that allow the team to aggregate inputs from individuals and examine such inputs is important. Thus, our designs consider visualization tools for information aggregation, review, and analysis.

Based on the above considerations, Figure 1 shows user interface of our prototype, which is dominated by a private (left) and a public map (right). Below, are four tools to support sharing, analysis and discussions: 1) a chat tool, 2) an annotation browser, a table to sort, tag, and review annotations, 3) a chart to aggregate annotations, 4) a timeline to visualize individuals' annotation actions (e.g., add, edit) over time. Due to the limited scope of this paper, refer [15] for a demo of system features.

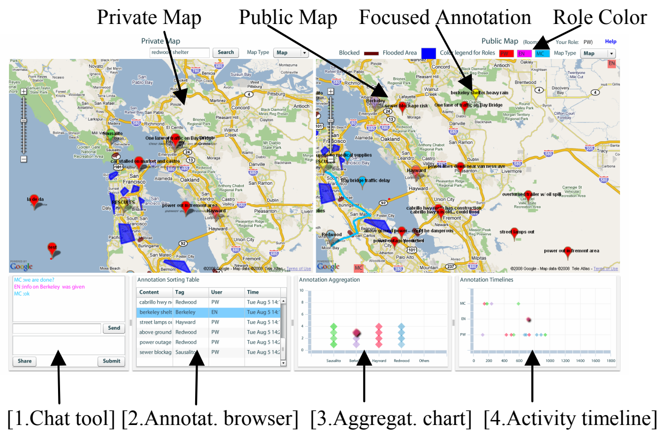

Figure 1. User Interface of Web-based Prototype

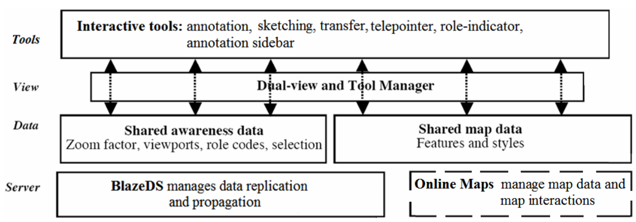

Figure 2. Prototype Architecture

The architecture of the web-based system includes four layers (Figure 2):

Server layer This layer provides basic services for data storage and data communication among client applications. BlazeDS is used to support remoting services, real-time messaging. An online map module (Google Maps API for Flash) processes geospatial data and map interactions.

Data layer This layer has two components: a module for shared awareness data and a module for shared map data.

View layer Above the data layer sits the view layer that connects the high-level interactive tools with low-level data.

Tools We implemented a set of tools to support geo-collaboration, including annotation, sketching, a telepointer to show the cursor locations of other users, role-based indication features to visually associate information added to members' roles, and an annotation sidebar, or browser, for reviewing annotations based on content.

One point worth noting is the benefits of leveraging a preexisting online map service (Google Maps) in our architecture (see Server layer): First, it reduces the costs for developing novel map-based interactive prototypes. The single-user functionalities already provided by online services (e.g., zooming, panning, searching, etc.), can be directly integrated as part of the new prototype. Second, it delegates the burden of geospatial data management to the server side. Our prototype requests and obtains from Google Maps the geography data. These two benefits allowed our design efforts on the CIVIL prototype to focus on the integration of preexisting data or services and the implementation of tools aimed at supporting collaboration.

4. EVALUATION OF CIVIL

4.1 Task

We conducted a lab study to preliminarily evaluate the web-based prototype. The collaborative decision-making scenario presented at the beginning of this paper represents the task scenario used in the study. Three subjects, each assigned to a specific expert role, work as a team. Each team completes two planning tasks. In each task they have to rescue a family in a large metropolitan area, during a flood (map center). Four shelters are available (map periphery) and the team has to choose the best shelter and the route to it. Each member is given a different set of information pieces. The team must integrate and synthesize information to find the best solution. The members work remotely, from three workstations in three adjoining rooms. The communication among the members occurs via a chat tool. The study involved 12 college-student subjects.

We collected both *quantitative* ratings about the usability for the overall prototype and *qualitative* results about specific tools and the overall prototype. We extended the Computer System Usability (CSU) questionnaire [12] by adding open-ended questions focusing on each of the interface components: the two maps and the four tools (Figure 1).

4.2 Evaluation Results

The ratings of the web-based prototype (Table 1) were positive.

Table 1. Usability Ratings for Web-based Prototype (N=12)

CSU Questionnaire Scores	Average	Std. Dev.
Overall Evaluation (items 1-19)	4.9	1.17
System Use (items 1-8)	5.0	1.32
Information Quality (items 9-15)	4.7	1.11
Interface Quality (items 16-18)	5.1	0.91

The average ratings from the CSU questionnaire were overall about 1 point above the neutral value or mid-point (4.0) of the scale. Of the three specific scores obtained from the questionnaire, the highest ratings were about interface quality (5.1). These pertained for example to general learnability, simplicity, comfort of use, task-effectiveness, organization and appeal of the user interface. The lowest ratings were about information quality (4.7). These pertained for example to feedback about error messages, help system, and error recovery. These functions were, in fact, not supported in the prototype.

The participants were asked open-ended questions about the usefulness and ease of use of the interface components: chat, annotation browser, visualization tools, private map and public map. They evaluated as particularly useful and easy of use the aggregation chart tool (7 out of 12 participants) and the annotation browser (6 out of 12 participants). The activity timeline was perceived as the least useful of the tools introduced: only 2 out of 12 participants found it useful. We suspected that the short duration of the collaborative task (lasting about 30-40 minutes) did not provide the condition for the collaborators to experience the benefits of this tool for monitoring the teammates' activities. While the results pointed the need for activity awareness support in collaboration, this result suggests that additional research is required for testing the impact of this tool in longer-lasting tasks.

Additional feedback on the prototype was collected through post-study interviews. In general, subjects liked the overall interface design (i.e., the separation private and public map views) and the visualization tools (i.e., the tools to monitor annotations and the color-coding artifacts. Example comments include: “pleasing, intuitive interface” and “a great tool for work together”.

Two specific design issues raised by the participants suggest useful directions for improvements. First, a participant indicated that synchronizing everyone’s public map led to competition in the team about who should control the public map. A more flexible mechanism for coordinating between the personal (role-specific) and the public (team) map (e.g., radar view) is needed. A second issue was the cluttering or congestion of content on the map due to a large number of annotations in a small but critical area of the map. Advanced visualization techniques are needed to filter out details and improve the map readability (in addition to zooming and panning); e.g. filtering or “text-mining” mechanisms could assist users in searching and managing the annotations.

5. CONCLUSION AND FUTURE WORK

This paper has described a prototype for geo-spatial planning. We developed a series of guidelines for future geo-collaboration supporting systems.

- Integrate map services that people are familiar with.
- Allow users to add personal comments and drawings that overlay on maps.
- Provide both shared maps and private maps and support information transfer between them.
- Provide visualization tools to present information and help information analysis.
- Allow platform-independent, distributed collaboration.
- Develop architectures that allow delegation of non-critical information management tasks to online public services.

The task and the prototype have basic limitations, which we hope to address in our future work. The task consists of planning work in small teams. Thus, our findings apply to synchronous geo-collaboration in this context. As for the prior version of the system [13], the current design does not support map-based collaboration that differs from planning (e.g., emergency management response or plan execution). In fact, different geo-collaboration purposes demand different toolsets [3]. The visualization tools proposed have been presented in the context of a proof-of-concept prototype. They are still an insufficient set of tools (and media types) for the purpose of supporting more complex map-based sensemaking tasks in larger groups: e.g., a community analyzing multi-dimensional data, browsing census data about the region to evacuate, integrating 3D models with maps when searching for a building in a large city, or watching real-time photos or videos when monitoring fast-changing situations.

The future work is targeted toward two objectives: first, construct more complex experimental tasks involving resource planning and deployment, such as presenting a step-by-step plan, and compare findings with those from our current task; second, we aim at improving the design by implementing more visualization tools and user customizable modules in the interfaces.

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