A Distributed Spatiotemporal Cognition Approach to Visualization in Support of Coordinated Group Activity

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ABSTRACT

Technological advances in both distributed cooperative work and web-map services have the potential to support distributed and collaborative time-critical decision-making for crisis response. We address this potential through the theoretical perspective of distributed cognition and apply this perspective to development of a geocollaboration-enabled web application that supports coordinated crisis management activities. An underlying goal of our overall research program is to understand how distributed cognition operates across groups working to develop both awareness of the geographic situation within which events unfold, and insights about the processes that have lead to that geographic situation over time. In this paper, we present our preliminary research on a web application that addresses these issues. Specifically, the application (key parts of which are implemented) enables online, asynchronous, map-based interaction between actors, thus supporting distributed spatial and temporal cognition, and, more specifically, situational awareness and subsequent action in the context of humanitarian disaster relief efforts.

Keywords

Distributed Cognition, Spatiotemporal Cognition, GeoCollaboration, GeoVisualization, Geographic Information Systems (GIS), Web-Map Services, International Relief

INTRODUCTION

Distributed cognition theory examines the cognitive processes that are dispersed among actors and between actors and artifacts in the external environment with and through which they interact (MacEachren, 2005; Hollan, Hutchins, Kirsh, 2000). Simple examples of visual representations being used as external artifacts to support cognition include individual use of a sketch map to off-load memory for an unfamiliar route or group use of diagrams by sports teams to help team members understand their individual and joint roles in a play as it evolves.

Here, we build on past research to propose a distributed *spatiotemporal* cognition perspective to support group work on geospatial tasks within humanitarian disaster relief. The challenges of this effort are two-fold. First, is the conceptual question of how to create effective abstract and intuitive visual geospatial (and other) representations that (a) help group members maintain awareness of key information and actions about an evolving crisis situation in geographic space over time and (b) help maintain awareness of actions taken by collaborators who may be at locations disconnected from the geographic space of the crisis (e.g., in a command center through which distributed action is coordinated or a remote operations center charged with managing local field teams). Second, is the empirical question of how specific visual representations and tools can be used to achieve this awareness and support coordinated group activities. We address these questions through the development of a web application (early stages of which are implemented) that supports group members' individual and coordinated work through temporally and logically structured visual, geospatial artifacts that are conceptually grounded in a distributed group cognition perspective of environment, actor, and external artifact interrelation. Our particular focus is on the development and use of dynamic, user-manipulable web-based artifacts through which collaborators within teams and across agencies can build shared situation awareness and undertake shared decision making.

The web application introduced here is being developed to enable international humanitarian disaster relief efforts. Typical cross-organization, team tasks that the planned collaborative, map-based, web workspace can support include: shared understanding of the geographic site and situation characteristics of an event, group decisions about the location of relief distribution sites and refuge camps, or cross-organization coordination in planning and tracking the resources and personnel needed to implement response and recovery efforts.

BACKGROUND

The effectiveness of group interaction inherently relies on constructing and accessing knowledge of past activity. Many collaborative systems depict only the present situation (Garbis, 2002), and lack methods for representing individual and group activity chronologically; thus, they do not support understanding of the context within which action(s) took place. By effectively distributing the effects of cognitive processes over time, "the products of earlier events can transform the nature of later events" (Hollan et al., 2000:176).

Geographic maps are key artifacts in coordinated cognitive activities related to disaster relief through their ability to provide focal points for discussion and mediation of perspective, extensions to group memory, and a framework for structuring and tracking progress of coordinated action across geographic space (from neighborhood to global scale). Although crucial in group work, traditional geographic maps also have inherent problems as vehicles for collaboration in time critical situations. These include the potential for displaying outdated or irrelevant information, and a lack of support for a group perspective. Furthermore, when abstracting geographic maps to the notion of external artifacts used in group work, caution must be made to avoid having maps fall into the trap that Garbis and Artman (1998:3) call "artifact fallacy", that the only important component of an artifact is what it contains – rather than how it is used to support collaboration. Crisis management, of course, involves much more than an understanding of the place where a crisis is occurring. To be most effective, geographic maps must also be conceptually linked to the social and organizational networks that underlie management activities, to the rules of engagement and broader knowledge that guides decision and action, and to the information and resources that support that action.

Little attention has been paid by the commercial Geographic Information System (GIS) industry to the issues outlined above and how to address them. The one major exception, Toucan Navigate (http://www.infopatterns.net/Products/ToucanNavigate.html), does support spatial group collaboration, but is marketed primarily as a real-time interaction tool, with place-based discussion threads being the only asynchronous temporal element of the system. We fully acknowledge the importance of real-time interaction systems, however, most international humanitarian relief efforts are carried out over days or weeks, thus collaborative GISs also need to provide users with a sense of time and change over varying scales and an understanding of precedent activity.

THE ORGANIZATION PLACE APPLICATION

Our research team is in the preliminary stages of developing a web-portal application, the Organization Place (OP) that can effectively capture and visually represent geospatial artifacts derived from asynchronous group interaction in an online environment and support distributed spatiotemporal cognition. As outlined by Scaife and Rogers (1996), visual representations can support at least three aspects of distributed cognition. These include (a) computational offloading, or using the spatial characteristics of the display to directly signify distance, direction and relative position, (b) problem structuring or restructuring (for example, dynamic space-time views that make clear that the impediment to relief supply distribution is not a lack of supplies being shipped but rather, bottlenecks at transshipment points, and (c) graphical constraining (for example making un-trafficable terrain explicit so that attention can be directed to supply route options that are potentially most viable).

The primary empirical goal of the OP is to facilitate coordinated work through mechanisms to support (a) externalization of ideas that are visually rendered as map annotations, (b) off-load and retrieving memory, (c) support group situational awareness and shared insight, and (d) enable collective decision making.

The OP is conceptualized as a virtual place within which multiple organizations (institutions) can organize (coordinate) responses to real world events, with responses carried out from and in distributed geographic, activity locations (real-world places).

In the OP, individual and group memory of activities is held in external artifacts that can be easily accessed by the entire group. A key organizing unit for these artifacts is the *activity session*. The activity session represents a high-level, logical assemblage of related group task activities for a given application or problem domain, similar to a project workspace. Examples of how activity sessions can be defined for Emergency Support Functions and Operation Conditions (OpCons) include episodes and the events that define them (e.g., the break of a levee), and tasks such as the delivery of a particular group of supplies. Activity sessions can span hours or days and participants can join and leave the session multiple times. Overall group cognitive work is then reordered and enhanced through mechanisms to encode and retrieve individual and collective actions in semantically-meaningful manner beyond just replaying what other people did. Through this cataloging and retrieval of map-action histories within the context of the problem domain defined for the activity session, users can explain and understand the sequence of activities conducted by other users.

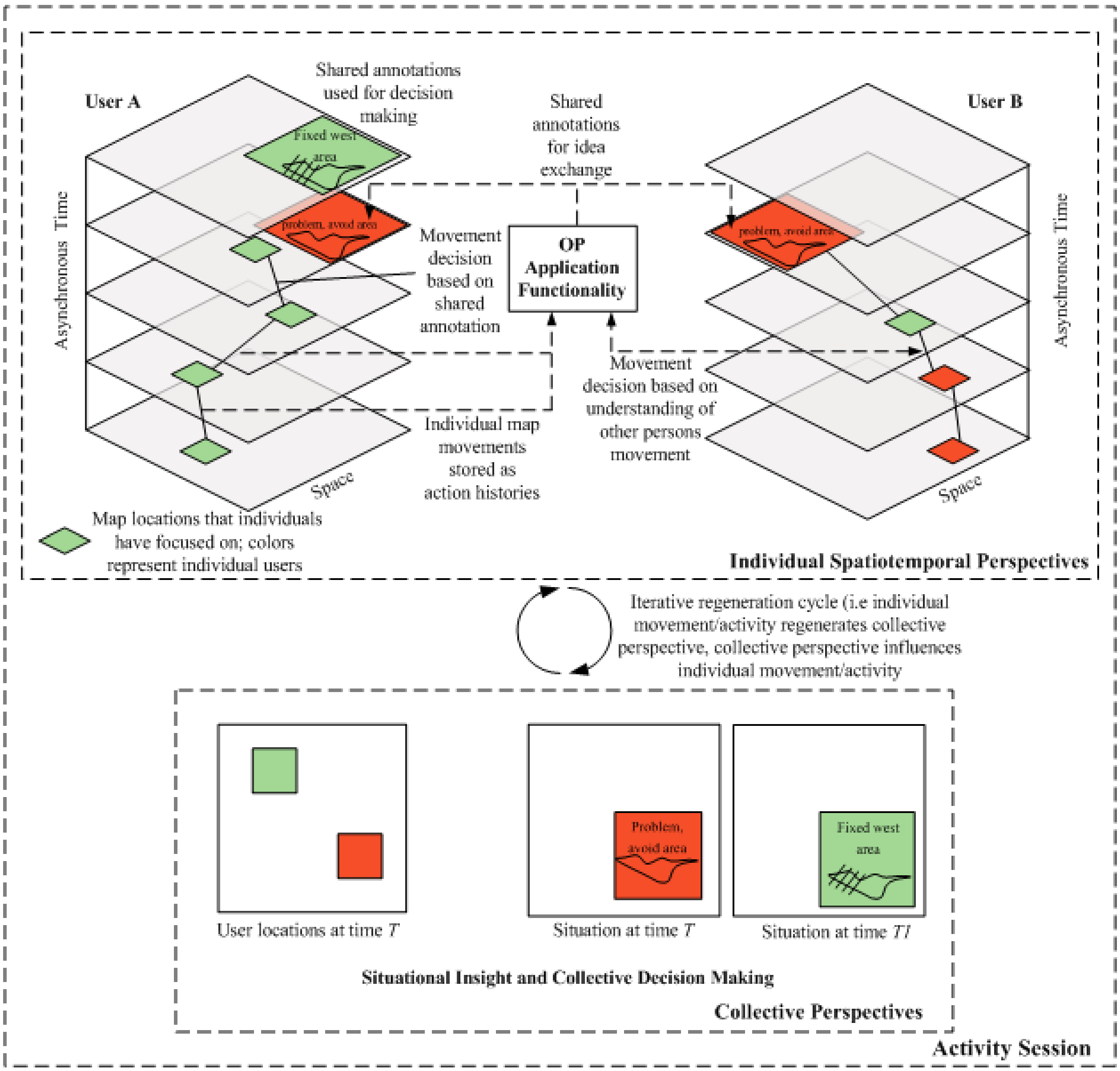

Figure 1: Shared Annotations individual users can add to the map and be seen by others and used in collective Decision Making

A graphical representation of the OP goals and our conceptual perspectives of group interaction is seen in Figure 1. This figure shows individual spatiotemporal perspectives of two hypothetical users (A and B) in an activity session. The OP application records where each user has moved in map and real-world space. In the 4^{th} space-time level from the bottom, user B off-loads memory and perspectives about a problem region to be avoided. This is done using OP annotation tools to mark the area on the collective map. User A sees this information and decides to avoid the area. Later, user A communicates to the entire team through shared annotations that they have partly resolved the issue initially identified by user B. This combined information stored in the OP system allows the entire team to review the sequence of events, and make collective decisions.

Developing Group Awareness, Visualizing Coordinated Activity and Distributed Cognition

Users in any online collaboration system need to maintain an individual perspective and a social consciousness. Our intent is to move beyond the tracking of basic individual map movements (pan, zoom etc.) within a group interaction to maintain these perspectives and focus on supporting the collaborative creation of maps.

Collaborative map creation entails multiple individuals adding their knowledge to a shared map and annotating knowledge added by others. These map building and annotation activities can connect and support multiple users in a distributed cognitive process focused on planning and decision-making. They also serve as communication vehicles that can explain decisions, guide action of field personnel who carry out decisions, and provide a history of actions taken.

Group interaction is a highly dynamic process. Maps, when used in an exploratory mode are critical to finding and exploiting information that is important to overall group performance in relief activities. Users need to be able to take their knowledge acquired through exploration of a map, preserve it through a snapshot of system state, and then share this information with other users so that the next person viewing the information can understand the ideas and perspective of the previous person (Denisovich, 2004). To achieve this, we emphasize the tracking of additions and annotations to the map and of who made what changes when.

The core components of OP annotations are primitive geometries (points, lines, polygons) and textual supplements users can add to the map. As a starting point, we are supporting three features for graphic annotation that allow users to understand the contextual meaning of annotations added by other users and how the annotation relates to situational insight. These features include: (1) categorization – users assign their annotation to one of several predefined categories that are context-dependent such as individual user name, time added, or approach used to add the annotation, such as drawn interactively, or automatically rendered from GPS tracks; (2) labeling, where users assign a meaningful label to each annotation; and (3) text "annotation" used to describe the graphic annotation.

Our graphical tools also include automated annotation methods for distinguishing among collaborators, and tracking actions over time. This includes using point symbols to represent previous map centers, and polygons (rectangles) to show various map extents, allowing collaborators to see where other team members have changed their focus of attention on the map, and location in the real world. We extend these simple renderings to use a time-decay function that visually displays how old a previous map object is relative to current time. The individual user can determine the decay scale in order to achieve a meaningful understanding of past activity.

Anticipated Issues, Problems, and Challenges

We foresee several issues that will need to be addressed in order to fulfill our research objectives.

A primary challenge relates to the interplay between database and real world time, and how this affects map displays. The OP application is capable of displaying four kinds of temporal information: (1) real-time updates on changing real-world situations, using information streamed from sensors or field personnel, (2) recorded real-world events, (3) real-time updates of collaborators' interaction with the display, and (4) recorded collaborator interaction. Users must, therefore, be provided with cues alerting them to the category of temporal information they are viewing and, in the case of recorded events, with tools to manipulate the mapping from recorded time to display time.

CONCLUSION

A distributed cognition perspective provides the structure for understanding the role of maps as visual mediators for joint analytical reasoning and decision making as well as coordination of joint action and as the objects of group work directed to the world through the lens of the map. Our goal is to understand how cognitive processes operate through the interrelation of actors, environment, and artifacts and to use this understanding to develop map-based tools to support group work in crisis management activities. By refining this perspective to distributed *spatiotemporal* cognition, non-collocated, asynchronous work activity can utilize history-enriched geospatial digital objects that can inform, supplement and direct cognitive processes of group members.

The OP is initially being developed and applied to the context of humanitarian relief operations. It represents a first step in a scientific investigation of how distributed spatiotemporal cognition can be enhanced by collaborative annotation, individual and group perspective sharing, and collective map creation. Ultimately, the goal is to provide a foundation for comprehensive information systems that save lives when a disaster occurs.

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