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 enables online, asynchronous, map-based interaction between actors to supplement distributed spatial and temporal cognition and to support both situational awareness and subsequent action. We apply this approach 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 objects in the external environment with and though which they interact (MacEachren, 2005; Hollan, Hutchins, Kirsh, 2000). Simple examples of visual representations being used as external supports for cognition include individual use of a sketch map to off-load memory for an unfamiliar route or group use of diagrams used in sports 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 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. This application is being developed to coordinate international humanitarian disaster relief logistical efforts. The ability for groups to interact and perform effectively has real consequences in disaster response where literal life and death can be determined by the effective and relevant allocation of resources to displaced and effected populations as a result of group activity and coordination.
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 an action(s) took place (Brodaric, 2005). 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 activity 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.

BACKGROUND

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. Ideally, collaborative GISs will provide users with a sense of time and change over varying scales and an understanding of precedent activity. This is especially relevant in international disaster relief efforts that may span multiple weeks or longer and, thus, need to support asynchronous, coordinated activity over extended periods of time.

THE ORGANIZATION PLACE APPLICATION

Our research team is currently investigating how to develop an application that can effectively capture and visually represent geospatial artifacts derived from asynchronous group interaction in an online environment using a distributed spatiotemporal cognitive perspective. The working title for this application is Organization Place (OP) which semantically captures the purpose of the application through the double meanings of the coordination of elements, institutions, and agencies (“organization”) and geographic and activity locations (“place”). These categories take the emphasis off relying solely on maps and allow the application to include other artifacts.

In the OP application, memory of activities conducted by individual group members 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. Overall group cognitive work is then reordered and enhanced through mechanisms to encode and retrieve individual and collective actions. 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.

The activity session user interface (UI) allows multiple users to interact via a common geographic web map space where interactions are recorded, retrieved, and managed by back-end application procedures. This allows users to be online at the same time and interacting in near real time, or provides options for returning to sessions as needed, interacting asynchronously. The OP application allows for an unlimited number of activity sessions and varying numbers of users per session.
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. The OP application addresses these issues by providing standard floor control and attention modes for real-time and asynchronous group interaction. Our intent is to then move beyond the tracking of basic individual map movements (pan, zoom etc.) within a group interaction. Our focus is on supporting collaborative creation of maps as both planning and decision-making devices and communication vehicles to explain decisions and guide action, and visualizing and sharing the record of actions taken by users.

The primary goal is to facilitate the exchange among users of ideas visually rendered as map annotations in order to facilitate distributed spatiotemporal cognition, support group situational insight, and enable collective decision making (Figure 1). 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. 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 be capable of sharing 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 record who made what changes when.
The most basic shared annotation procedures are primitive geometries (points, lines, polygons) users can add to the map. Through back-end processing functions, users can then see what others have added. Each graphical element has the option to be rendered to uniquely identify each user, qualify how the geometry was added (for example, by GPS, or drawn interactively), and when it was added. In addition to graphical annotations, the OP application also provides textual annotations that supplement graphical annotations by providing a forum to add notation for a particular location or situation.

We also use simple color coding schemes 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.
We also include a Viewpoint tool that supports switching between a personal viewpoint and one collaborator’s viewpoint. This tool includes the following options: (a) synchronizing all aspects of the viewpoint, (b) synchronizing selected aspects from a list of: place, time, features (layers), and (c) for either of the above options, applying a local “style” to the display (including text in alternative languages, or symbols from specific organizations).

Also included is the History tool. This allows a user to learn what has transpired through a feedback mechanism that provides an open-ended list of “map transactions” that can be queried by a time range, location, or individual.

**Anticipated Issues, Problems, and Challenges**

We foresee several issues that will need to be addressed in order to fulfill our research objectives. We have identified three key challenges to meeting the overall goal of developing an effective distributed spatiotemporal cognitive perspective and structuring to support group work on geospatial tasks within humanitarian disaster relief.

The first 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.

Second, a semantically-based information retrieval mechanism and visual analytic tool that allows users to understand past events and actions (rather than just view them) will be needed. This could potentially include tools that allow users to focus on events or episodes (rather than predetermined time spans), identify repeating patterns of real-world events or collaborator actions, understand sequence and cause-effect, or understand process.

Lastly are the issues of developing an easy to use, intuitive user interface that supplements rather than hinders group activity. This is particularly important in situations where application usability issues could arise from the interaction of users from multiple countries, speaking different languages and having different cultural perspectives. Also, since many of the users will not be technology or geospatial information specialists, UI usability issues must not interfere with time critical decision-making and action functions.

**Application to Humanitarian Relief Work**

The OP application is being developed as an asynchronous geocollaborative component in an online information system designed to support humanitarian relief logistics operations. Effective and efficient supply chain development and management is at the core of any logistical operation. Efficacy of the supply chain inherently relies on the collaboration of a myriad of individuals and organizations. Through the use of a distributed spatiotemporal cognition approach, our intent will be to apply the OP application and other domain-specific tools to a proof of concept case study focused on collaborative humanitarian relief logistics operations where the interrelationships of actors, and the management and movement of goods, services, value, and information are all maintained at optimal levels.

**CONCLUSION**

A distributed cognition perspective provides the structure for understanding the role of maps as visual mediators for group work and as 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 (Hollan et al., 2000) that can inform, supplement and direct cognitive processes of group members.

The OP application being applied to the context of humanitarian relief logistics represents a first step in a scientific investigation of how distributed spatiotemporal cognition can be enhanced by collaborative annotation, individual and group perspective ordering and control and collective map genesis. Ultimately, our hope is that this research will provide a foundation for comprehensive information systems that save lives when a disaster occurs.
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