A General Framework for Real-Time Geocollaboration: Spatial Behavior Lock Graph

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1. Introduction

Nowadays, an important trend is the mobility for the development in global position system (GPS) which enable the users to pinpoint their position anywhere on earth. According to Neogeography (MTurner 2006), people can create their own maps and convey location information among friends and visitors. In fact, most work with geospatial data is carried out by groups (Maceachren and Brewer 2004). And geographic research, decision-making and education are, more than ever before, the products of group activities (MacEachren 2001,Technology and Council 2003). Popular concepts include collaborative GIS (Neville and Clare 1996, Shivanand Balram 2006), Multiple Criteria Decision Models (MCDM) (Malczewski 1999), Argument Map (Rinner 1999), Collaborative Mapping, Collaborative GIS Data Production (Li and Coleman 2002), collaborative spatial decision-making (CSDM) (Armstrong and Densham 1995,MacEachren 2001), geocollaboration (Maceachren and Brewer 2004) and volunteered geographic information (VGI) (Goodchild 2007). To maintain terminological consistency, we use geocollaboration in this paper. Real-time geocollaboration can be defined as a collaboration that allows geographically dispersed people to view and contribute to the shared geographical knowledge (or spatial decision) over the Internet at same time by referring to the definition of real-time collaborative systems (Greenberg, Roseman, Webster and Bohnet 1992, Greenberg, Hayne and Rada 1995, Kanawati 1997, Sun, Jia, Zhang, Yang and Chen 1998, Sun and Chen 2002, Agustina, Liu, Xia, Shen and Sun 2008,Chang and Li 2012). We are particularly interested in how to build a general framework to support geographically dispersed people work together to achieve various geocollaborative applications with real-time requirement.

2. Related work

According to a book published by the National Academies Press, *IT Roadmap to a Geospatial Future*, most research on human interaction with geospatial data falls into three domains: visualization, human-computer interaction (HCI) and computer-supported cooperative work. In particular, developments in the domain of geocollaboration can be discussed in three aspects: geovisualization, geocollaborative interactivity and geocollaborative conflicts.

2.1 Geovisualization

Up to now, time dimension and participants have not received proper attention in understanding the geovisualization (Challenging problems of geospatial visual analytics). Contributions from participants often take place over large distances and go beyond same time-same place situation (Rinner 1996). For being closely related with the behaviors in geocollaboration, dynamic and consistent visual display of spatial knowledge is required for dispersed participants to work smoothly, especially in time-critical crisis situations.

2.2 Geocollaborative interactivity

In the process of collaboration, the place where collaborators are located and the time dimensions of the collaborative work being under taken constitute the CSCW Matrix (Rein 1991, Ronald Baecker 1995). Similarly, geocollaboration can be described in the two aspects by replacing operational objects by geospatial information. Among the categories of geocollaboration, real-time geocollaboration lies in a high degree of interaction amongst a tighter, more trusted community. As shown in figure 1 is the level of interactivity.

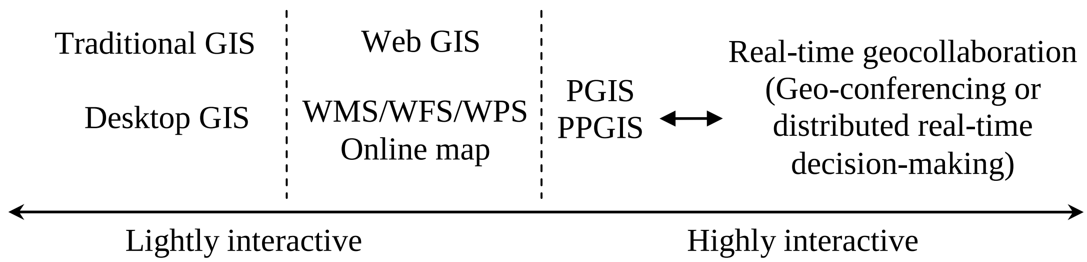

Figure 1 Level or degree of geocollaborative interactivity

2.3 Geocollaborative conflicts

Conflict is a common phenomenon in collaborative systems for the inherent differences in individual participants' experiences, personalities and commitments (S. M. Easterbrook 1993). Existed systems adopt an optimistic strategy which takes the conflicts as events with small possibility and resort to the manual process when uploading data. However, it is far from good when highly collaborative task are going particularly in real-time decision-making for the conflicts.

3. Framework of spatial behavior Lock graph

3.1 Geocollaboration with spatial dependence graph

In the *spatial dependence graph* (*SDG*), geographic facts are expressed as graph vertexes, and the dependence among facts are expressed as graph edges, e.g. spatial topological relation, spatial distance relation, or spatial orientation. Through *SDG*, spatial dependence among facts is modeled and the shortest path is used as the quantitative measurement for representing the reachable distance of the fact-changing influence. Practically, only the relations that affect the interactive process should be chosen to connect vertexes. *SDG* can be formally defined as:

$$SDG = G(V[S, O, I], E)$$

SDG contains a graph vertex set *V* and a graph edge set *E*. Each vertex in *V* is a triple with three elements: ***Status***, ***Owner*** and ***Intensity***. ***Status*** indicates the fact's lock state. ***Owner*** indicates who is occupying the vertex. ***Intensity*** indicates the length of shortest path from the changed vertex. As figure 2 shows is an adjacent relation graph.

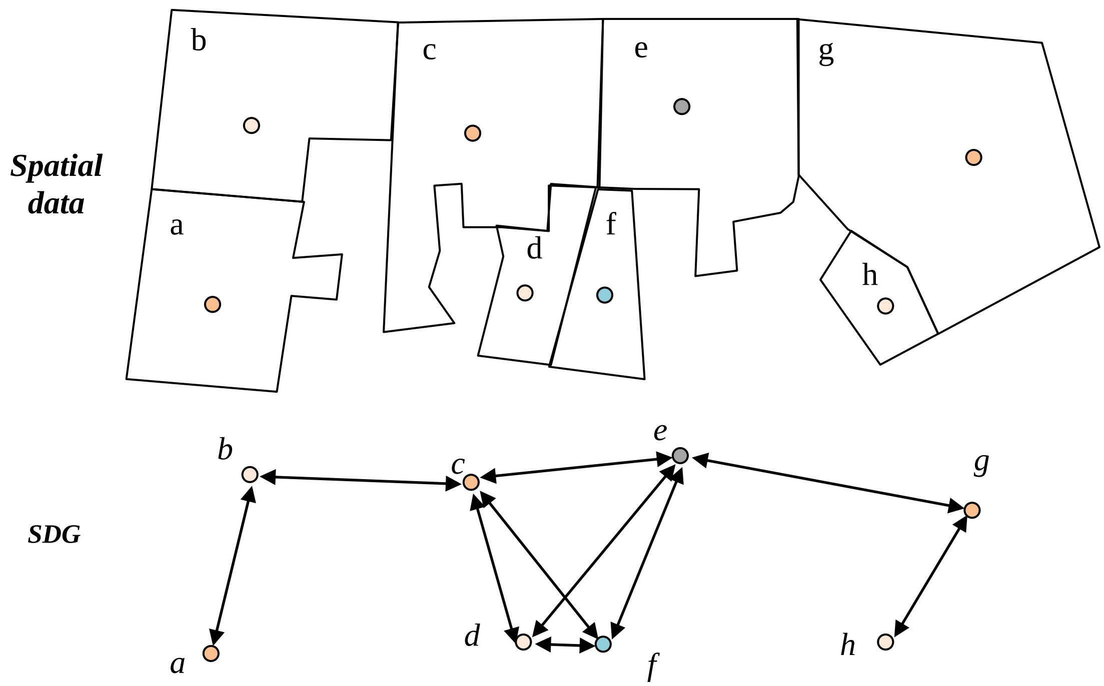

Figure 2 spatial dependence graph model for adjacency

When manipulating a fact (e.g. c in spatial data), corresponding vertex (e.g. c in SDG) will be locked ahead. This mechanism enables the common facts or related facts to be manipulated sequentially, and independent facts to be manipulated concurrently.

3.2 Types of behavior lock

The framework provides a real-time communicative mechanism in client/server architecture composed by participants and one decision center, from which participants can freely exchange messages through the decision center which maintains spatial data and the lock graph. Messages from participants to decision center are called operation requests, conversely, operation responses. A request consists of new node status and owner info that will be added to the lock graph in decision center in server side, a response can be simply described by ‘yes’ or ‘no’. In order to keep a better concurrency, the participants can firstly access the spatial data and lock graph in locally replicated decision center which is proximately consistent with the server side center. Main types of lock in graph node contain vertex-write lock (***VWL***), vertex-separate lock (***VSL***) and vertex-read lock (***VRL***). ***VWL*** is exclusive for the feature or part of the fact being manipulated by one participant can’t be manipulated by another before releasing this lock. Before modifying an existed fact, the vertex representing the fact should be locked firstly. Through ***VWL***, the geocollaborative work continues in a serial mode and no conflicts may emerge. In order to support operations both in level of geometry and points that composite the geometry, ***VWL*** is represented in a function with two parameters like ***VWL*** (*pt_index*, *pt_num*), which indicates the number of *pt_num* from *pt_index* can’t be manipulated currently. Let *pt_size* is the total number of points in the feature geometry, ***VWL*** *(0,pt_size)* means the whole feature can’t be manipulated by others currently. But concurrent manipulated is allowed if the two operations, ***VWL*** *(pt_index1, pt_num1) and* ***VWL*** *(pt_index2, pt_num2)*, are independent.

5. Case study

We developed a prototype system named Real-time Geocollaborative Mapping (RGM) based on Quantum GIS (an open-source, desktop GIS software for single user application). RGM adopted a Client/Server framework composed of a decision center and multiple participant clients. The whole process in decision center can be performed in 3 steps (as shown in figure 3):

(i) Determining which graph vertex to lock through spatial query. Requests that trying to lock the same vertex will be rejected except for the earliest one.

(ii) Locking the node and updating data. This step can be completed in parallel, for different jobs have no dependence on each other.

(iii) Broadcast incremental graph and data to the participants. When participants receive the messages, local information will be modified accordingly.

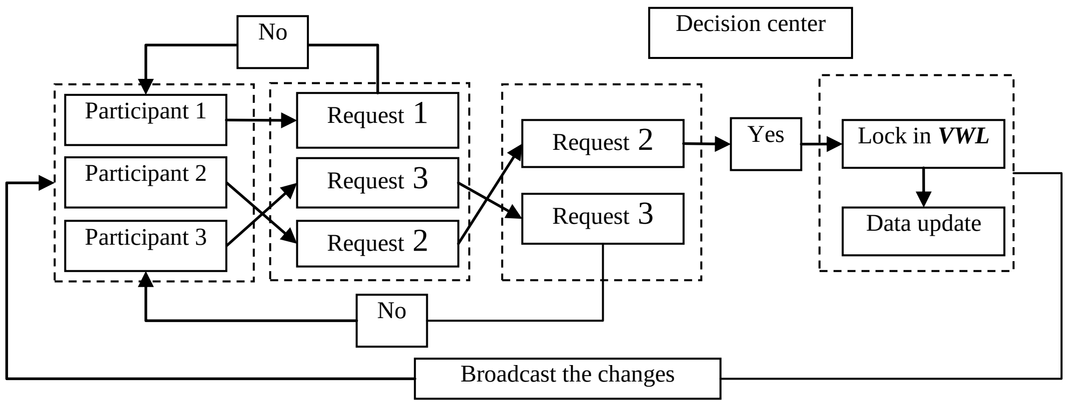

Figure 3 Real-time Geocollaborative Mapping

6. Conclusion

In this paper, we propose a novel framework based on graph which can represent the spatial dependence in mapping data to support the real-time geocollaborative applications. More generally, the spatial relation can be customized by users for more complex situation. The utility of this framework is demonstrated through the development of a real-time collaborative mapping project.

8. References

[1] Turner. Introduction to neogeography. 54, 2006.

[2] Maceachren and Brewer. Developing a conceptual framework for visually-enabled geocollaboration. 1-34, 2004.

[3] MacEachren. Cartography and GIS: extending collaborative tools to support virtual teams. 431-444, 2001.

[4] Technology and Council. IT Roadmap to a Geospatial Future. 2003.

[5] Neville and Clare. GroupARC - A Collaborative Approach to GIS. 1996.

[6] Shivanand Balram. Collaborative Geographic Information Systems: Origins, Boundaries, and Structures. 2006.

[7] Malczewski. GIS and Multicriteria Decision Analysis. 1999.

[8] Rinner. Argumentation Maps: GIS Based Discussion Support for Online Planning. 1999.

[9] Li and Coleman. Results of CSCW Supported Collaborative GIS Data Production: An Internetbased Solution. 2002.
[10] Armstrong and Densham. Cartographic support for collaborative spatial decision-making. 49-58, 1995.
[11] Goodchild. Citizens as sensors: the world of volunteered geography. 211-221, 2007.
[12] Greenberg, Roseman, Webster and Bohnet. Issues and experiences designing and implementing two group drawing tools. 139-150 vol.4, 1992.
[13] Greenberg, Hayne and Rada. Groupware for real-time drawing: a designer's guide. 1995.
[14] Kanawati. LICRA: A replicated-data management algorithm for distributed synchronous groupware applications. 1733-1746, 1997.
[15] Sun, Jia, Zhang, Yang and Chen. Achieving convergence, causality preservation, and intention preservation in real-time cooperative editing systems. 63-108, 1998.
[16] Sun and Chen. Consistency maintenance in real-time collaborative graphics editing systems. 1-41, 2002.
[17] Agustina, Liu, Xia, Shen and Sun. CoMaya: incorporating advanced collaboration capabilities into 3d digital media design tools. 5-8, 2008.
[18] Chang and Li. Geo-Social Model: A Conceptual Framework for Real-time Geocollaboration. n/a-n/a, 2012.
[19] Rinner. Discussing Plans via the World-Wide Web. 1996.
[20] Rein. Groupware: some issues and experiences. 39-58, 1991.
[21] Ronald Baecker. Readings in Human-Computer Interaction: Toward the Year 2000. 1995.
[22] S. M. Easterbrook. A Survey of Empirical Studies of Conflict. 1-68, 1993.