P2P GIS for Collaborative ESDA

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1. Introduction

Collaborative work in GIS has been considered very necessary to solve a variety of spatial problems including urban and environmental affairs (Jankowski and Nyerges, 2001; Medeiros et al., 2001; Manoharan et al., 2002). The existing models of collaborative GIS mainly deal with common workspace (Finley and Coleman, 1999; Li and Coleman, 2002), groupware with electronic meeting system (Faber, 1995; Medeiros et al., 2001) and synchronized visualization among members (Churcher et al., 1997; MacEachren et al., 2001). In the common workspace, multiple users share a workspace to manipulate spatial data. The groupware with electronic meeting system allows group members to watch a broadcasting screen for geovisualization and to exchange information by voting or questionnaire survey. The synchronized visualization among members is used as a visual way of inter-group communication to understand and discuss the characteristics of spatial phenomenon.

While many researches have been performed for the common workspace or groupware with electronic meeting system, a similar amount of work has not been achieved yet for the synchronized visualization. Typical client/server or Web-based environment is enough for the common workspace or groupware with electronic meeting system. However, the synchronized visualization requires more efficient communication architecture where any user can be a server and a client simultaneously. In this sense, the method of P2P (Peer-to-Peer) recently introduced to collaborative computing (Cugola and Picco, 2002; Fox et al., 2003) and GIS area (Tsou and Buttenfield, 2002; Guan et al., 2004) can be an alternative, because the P2P allows every computer to be an equal player. P2P is a communication model in which each party has the same capabilities and either party can initiate a communication session[1]. Particularly, P2P Messaging for instant information exchange can be effectively applied to the applications of synchronized visualization.

The objective of this paper is to develop an application framework for P2P-based collaborative GIS, focusing on the synchronized geovisualization and collaborative spatial analysis for small group brainstorming. For this application framework, we implement and integrate each collaboration agent of P2P Messaging, map processing and spatial analysis. An ESDA (Explorative Spatial Data Analysis) application is prototyped for the synchronized geovisualization and collaborative spatial analysis. ESDA for finding spatial patterns in data can be performed in a collaborative way, providing useful information for the discussion on spatial problems. We can suppose a collaboration scenario like [Figure 1], where the P2P-based synchronized geovisualization and collaborative spatial analysis is required.

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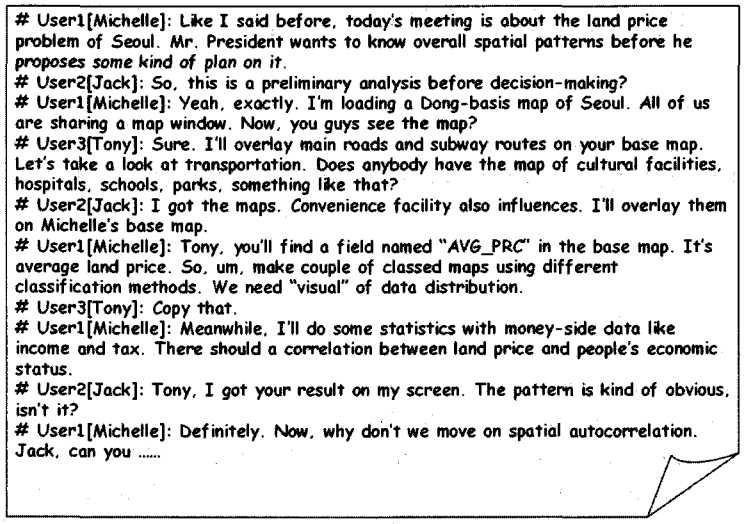


[Figure 1] Collaborative ESDA - A Scenario

2. Collaborative GIS

The existing works of collaborative GIS have established a foundation for (i) common workspace, (ii) groupware with electronic meeting system and (iii) synchronized visualization among members. For the first case, main interest lies in the multi-user support for the GIS workflow of spatial data production and management through a shared workspace. The second case is associated with computer-supported cooperative work (CSCW) and collaborative spatial decision-making (CSDM). Communication among group members is usually conducted by electronic meeting system, which provides a collaborative visualization on broadcasting screen either operator-driven or user-interactive way.

As Wood et al. (1997) addressed, the ideal collaborative visualization systems should support both instructor-driven collaborations and the interaction of multiple independent participants. The interactive collaborative visualization is closely related to the third case, the synchronized visualization among members. In the synchronization environment, any user's geovisualization work can be shared by instant relay to the desktop screen of any other participants. TalkServer (MacEachren et al., 2001) provides a good example of the synchronized visualization for collaborative GIS. Running in the form of thread, it listens to connections from clients in order to receive and request the visualization events.

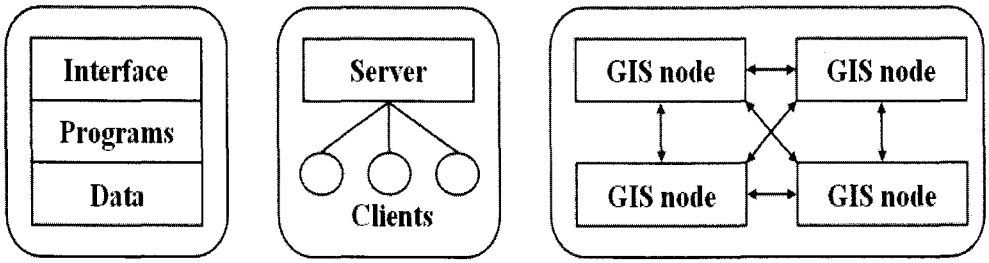
3. P2P Technology in GIS

In the pure P2P system, every node is a "servent" (both a server and a client), and can equally communicate with any other connected nodes. However, most systems described as P2P actually use super-peer (super-node) as a server, and client peers are connected to the super-peer in a star-like fashion[2]. Such a subset of P2P systems is known as hybrid P2P, where some special functionality is still centralized on the super-node, and the elements of both pure P2P and client/server system coexist (Schollmeier, 2001; Yang and Garcia-Molina, 2001). For the collaborative GIS with synchronized visualization and collaborative analysis, the hybrid P2P system is more suitable, because a super

2)http://wikipedia.org

-node needs to provide some shared functionality for map processing and spatial analysis.

Both in pure and hybrid P2P system, communication among nodes is conducted by P2P Messaging which delivers data unit, called message or



[Figure 2] Three Types of GIS Architecture (Tsou and Buttenfield, 2002)

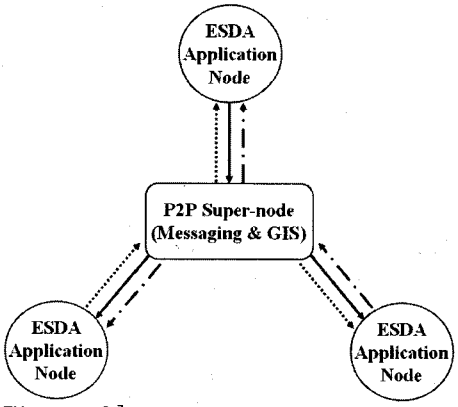
event, and provides the extended communication functionality such as queuing and exactly-once delivery (Junginger, 2003). Point-to-point messaging model is for one-to-one communication and publish/subscribe messaging model is for one-to-many or many-to-many communication[3]. For the collaborative GIS with synchronized visualization and collaborative analysis, the publish/subscribe messaging model is more suitable, because any equal "servent" node needs to communicate with the other peers based on the many-to-many communication.

In the distributed computing environment [Figure 2], P2P GIS can take advantage of wider range of spatial data. In the client/server GIS including Web-based GIS, all the spatial data is provided by server-side databases. However, in the P2P GIS, not only the server-side data but also each user's personal data can be used, because the resources of any GIS node are shared among the connected nodes.

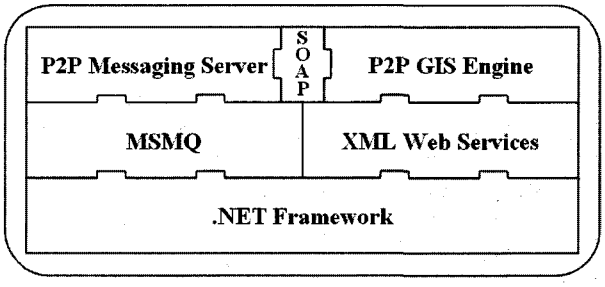
4. Application Development

The characteristics of our P2P-based collaborative GIS are summarized according to (i) collaboration target, (ii) P2P model and (iii) system composition. First, we focus on ESDA as an example of collaborative GIS. Some of the functionality for synchronized geovisualization and collaborative spatial analysis are implemented in the ESDA application. Secondly, we adopt the many-to-many communication under hybrid P2P system. For the equal and interactive information exchange among ESDA-working members, many-to-many communication with publish/subscribe model is required. Also, the functionality of mapping and analysis, which needs to be centralized in the form of service provider, should reside in the super-node of hybrid P2P system [Figure 3]. Thirdly, the whole system is composed of P2P client application, P2P Messaging server and P2P GIS engine. We implement the three components: P2P client application for collaborative ESDA participants, P2P Messaging server for message exchange among application nodes, and P2P GIS engine for map processing and spatial analysis. Our P2P Messaging server and P2P GIS engine are fully integrated by SOAP (Simple Object Access Protocol) within the .NET Framework [Figure 4].

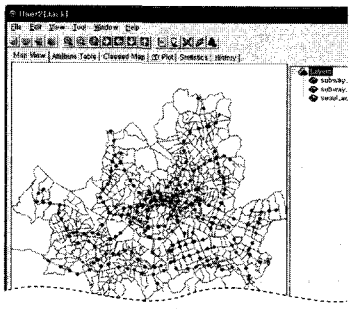
3)On-to-many communication can also be many-to-many communication, if ultiple publishers are involve



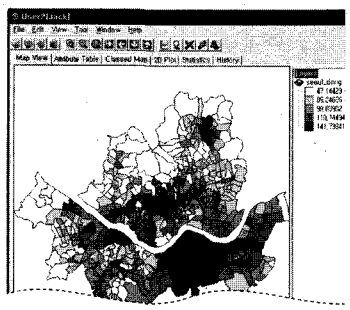
[Figure 3] Communication among Nodes



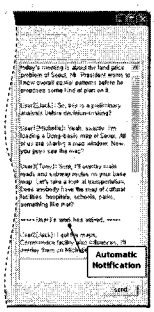
[Figure 4] Composition of P2P Super-node



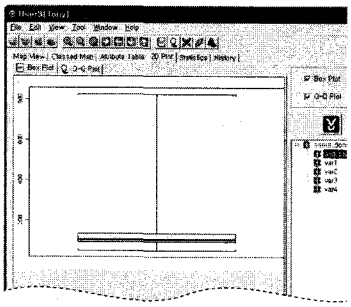
(a) Map Overlay



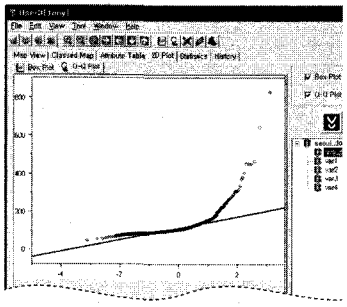
(b) Classed Map



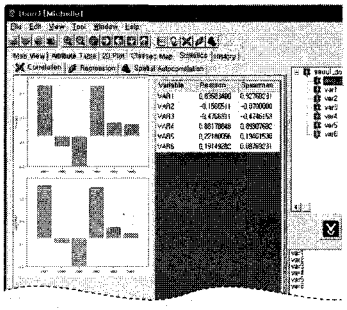
(c) Chatting Window



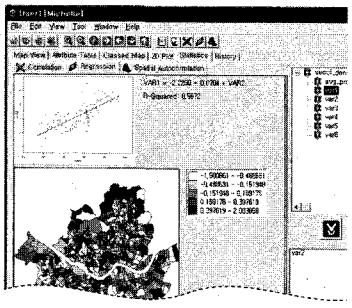
(d) Box Plot



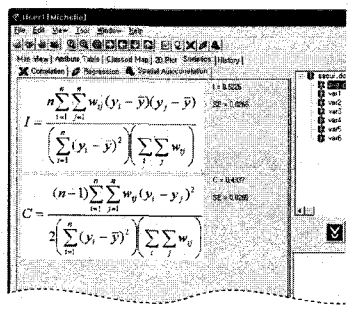
(e) Q-Q Plat



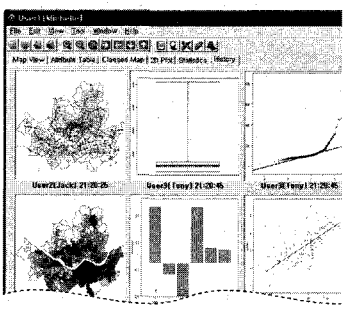
(f) Correlation



(g) Regression and Residual Map



(h) Spatial Autocorrelation



(i) History View

[Figure 5] Demonstration Screenshots

In this P2P-based system, each user's work event is sent instantly to the other participants, so that every member has the same screen at the same time. If the work events of users occur consequently, they are arranged by messaging queue and processed according to the FIFO (First-In-First-Out) structure. In case a user cannot participate for a little while, he/she can catch up with all the work events by referring the History View.

5. Conclusion

We have discussed the possibilities of P2P technology for GIS collaboration and developed an application framework for collaborative ESDA. We implemented application node for ESDA participants and super-node for map processing and spatial analysis. Our P2P framework adopts many-to-many communication under hybrid P2P system in order to support users' share of data, view and analysis. We confirmed that not only visualization but also analysis can be supported in P2P environment. Based on this preliminary effort, more analytic and powerful P2P system for GIS collaboration can be built in the near future.

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