SOCIAL COLLABORATION MODEL SUPPORT FOR COLLABORATIVE 3D GIS ENVIRONMENT BASED ON MULTI-AGENT METHOD

Z. E. Chang, S. Li

Dept. of Civil Engineering, Ryerson University, 350 Victoria Street, Toronto, ON, M5B 2K3, Canada – (czheng, snli)@ryerson.ca

KEY WORDS: Social collaboration model, Application-specific ontology, Multi-agent System, 3D GIS

ABSTRACT

The existing 3D Geographical Information Systems (GIS) are confronting complex requirements when Internet-based technology is arising: the users need to share not only 3D data but also the same understanding of the work contexts and environments when they are geographically dispersed, so that they can collaboratively work together for a common goal. These kinds of requirements are usually seen in urban planning, emergency management, group spatial decision support system, etc. The difficulties of meeting these requirements relate to not only the technological design and implementation in computer-supported cooperative work (CSCW), but also the investigation to the social factors for a given collaborative environments. In this paper, a social collaboration model for group decision making process based on a case study is developed in the form of ontology-based presentation. Through applying this model to *GeoLink3D*, a synchronous collaborative 3D GIS, and related multi-agent systems, geographically dispersed users could collaboratively work together to carry out a common task under a real-time collaborative 3D GIS environment.

1. INTRODUCTION

The existing 3D GIS are facing challenges when confronting complex requirements: the users need to share not only 3D GIS data but also the understanding of the work contexts and 3D working environments when they are geographically dispersed, so that they can collaboratively work together for a common goal. In order to support these requirements, 3D GIS software should be adapted to not only the spatial decision making styles, a kind of spatial decision support system, but also remote and real-time collaboration styles.

Some general requirements of such a software systems can be summarized as: 1) geographically dispersed users， the distributed system and shared data sources with Internet-based access and connection, 2) shared visualization and understanding of the work context, common goals and behaviours, shared control of functions and even applications, and 3) synchronous cooperation, communications and multiple negotiations, etc. among users and systems. These kinds of requirements are usually seen in urban planning, emergency management, group spatial decision support system, etc. In responding to such requirements, a new generation 3D GIS therefore arises, which shifts towards the distributed and collaborative environments and is termed as synchronous collaborative 3D GIS (SC3DGIS) in this paper.

These requirements reflect both technical and social aspects. The technical aspect focuses on the system design and development issues such as the system architecture, collaborative interface design and multicast protocol, etc. Users have fundamental collaborative capabilities such as share 3D views, awareness of other users' exists and peer-to-peer or peer-to-many communications. For the social aspect, the core issues relate to the shared understanding (the work contexts, common goals and behaviours), well organized collaborative 3D environment and the related social model support to the environment. The collaborative 3D environment should allow users to be well organized to carry out some common tasks utilizing the basic collaborative capabilities. The users can work on planned tasks, negotiate deals, and approve proposals with respect to related rules and roles. This kind of environment is called structured environment in which the related social model schematically describes the profiles of main elements such as users, resources, systems (services) and their behaviours in a virtual environment (also termed as virtual organization or social networking community) with structured language such as XML-based ontology. This model therefore provides an information exchange platform to formulate the common understanding for the distributed users and services, etc. In order to differentiate this model to other social models, this model is termed as social collaboration model (SCM) in this paper.

There are lots of related prototypes and systems developed with collaborative capabilities. For example, collaborative virtual environments (CVE), such as DIVE, MASSAGE-3 (MASSAGE3 2007) and collaborative manufacturing and construction design, such as SIMNET, CollabCAD and Alibre Design (Fuh and Li 2005), and Skyline (Skyline 2006), provide not only web-based access but also synchronous collaboration ability. But most of these systems just meet the first aspect of the requirements. Few have been found in using the structured environments to support these collaborative capabilities, nor is SCM to support SC3DGIS environments. In Chang and Li (2008), a prototype *GeoLink3D* is reported to support SC3DGIS requirements, which allows geographically dispersed users to share the 3DGIS view, communicate with each other, and be aware of other's activities. However, the social aspect mentioned above is still absent.

This paper aims at bridging the gap between the above two aspects through design and implementation of a SCM based on our previous prototype, *GeoLink3D*. First, the SCM, which is used to describe the group meeting in a typical distributed group decision making process, is described according to a case study in urban planning area. Second, the SCM is implemented with multi-agent approach. In this approach, the application-specific ontology as well as the rule identification and task specification are designed to match the social collaboration model. A multi-agent based prototyping system will be designed and developed thereafter.

2. BACKGROUND

Social model is borrowed from social science to solve socially-related problems such as social programs for disability (Abberley 1996). Virtual organization (VO) and social networking service (SNS) are the two main applied areas. A virtual organisation (VO) is defined as a geographically-distributed organisation whose members are bound by a long-term common interest or goal, and who communicate and coordinate their work through information technology (Ahuja, 1998). All kinds of social models appeared and focused on different aspects of VO. Tjortjis et al. (2002) reviewed the social models such as “models of virtuality”, “VO life cycle model” and proposed their own one for Distributed Software Maintenance Teams (DSMT). These models tried to describe specific type of social organization through limited variables such as structure, communication, processes and lifespan, etc. However, they usually are limited in email-based communication structure. These models are too generic and lack of technical details so that they are not empirical to the design of a useful SCM.

Recently, social network sites (SNS) such as Friendster, Facebook, Orkut, LinkedIn, Bebo, and MySpace, as well as content-sharing sites that also offer social networking functionality (including YouTube, Flickr, Upcoming, del.icio.us, Last.fm, and 43 Things) have captured the attention of millions of users. Social network site is also termed as social networking service or virtual community in which individuals can: (1) construct a public or semi-public profile within a bounded system, (2) articulate a list of other users with whom they share a connection, and (3) view and traverse their list of connections and those made by others within the system (Boyd and Ellison, 2007). SNSs usually offer following basic functionalities: network of friends listings (showing a person’s “inner circle”), person surfing, private messaging, discussion forums or communities, events management, blogging, commenting (sometimes as endorsements on people’s profiles), and media uploading (Breslin and Decker, 2007).

There are also some abstract social models found to describe the social networking community. For example, Mika (2005) partitioned the social network model into three disjoint sets corresponding the set of actors (users), the set of concepts (tags, keywords) and the set of objects annotated (bookmarks, photos etc.) with a tripartite graph. Some ontology-based models describe users such as VCard and FOAF, and resources (document and photos) such as RSS. SNS provides users chance to know each other and to set up relations. While the further collaboration is not provided after the relations are setup. Although these models are simple, they provide clues to solve problems such as shared understanding. For example, ontology and semantics technology are used to solve shared understanding and boundary breaking through among SNSs. Multi-agent approach is used to implement these solutions to change SNS into semantics web service (SWS) (Bryson et al. 2003).

3. SOCIAL COLLABORATION MODELING AND ONTOLOGY

The SCM in this research is a schematic description of a set of elements and behaviours amongst users, systems and data in a group meeting scenario. In this section, first, the case study for a group meeting is investigated; second, the SCM is identified and presented as an application-specific ontology.

3.1 Case study: Group decision making process

The group decision making process involves a series of data collection and evaluation activities that become more specific in each subsequent step of the process. The process, for example in a site selection process, usually involve following steps: 1) confirm readiness, 2) develop the work plan, 3) conduct search for sites, 4) evaluate long list, and 5) evaluate short list/recommend site(s) (GAS, 2007). Group meetings are often held in nearly every step when some decisions need to be made such as setting up site selection criteria (step 2), commencing discussions with customer agency and community (step 3), selecting short list (step 4), and conducting detailed site evaluation (step 5), etc. In these meetings, the chair will first provide the agenda for approval. The agenda could be the proposal of the alternatives and related criteria of the site selection. Related materials such as reports, pictures, and proposals will be sent to all the participants. The previous minutes will be approved if it exists. The issues listed in the agenda will be discussed one by one. During these meetings, the participants can present his/her opinions and demonstrate their ideas through tools such as PowerPoint or GIS tools. Some scoring process may be proceeded to screen the criteria and alternatives. The decision could be made after the screening process.

Based on the process of group meeting, a mock-up group meeting is simulated under a collaborative and distributed 3D GIS environment. In this mock-up meeting, the participants will discuss the alternatives and criteria, and screen the criteria through voting method. These participants are geographically dispersed interested parties such as experts in specific fields, stakeholders, government agency, etc. These participants can be aware of others’ activities and work on the same goal through accessing the collaborative 3D GIS environment. Through this mock-up process, we try to investigate questions, such as 1) how do the distributed participants work on the same goal? 2) What are the main elements for social collaboration model under the mock-up? 3) What is the GIS and 3D factors in this model?

The above mock-up group meeting process seems to be very simple and straightforward; however, the related simulating system may be different from the traditional systems such as client-server system in following aspects:

- Participants and Chair are geographically dispersed. Participants’ finding and registration to common interesting topics are required.
- Participants and Chair need to share the common context to the meeting. Multiple users’ awareness in goal, tasks and behaviours are required. Users can share not only the data, but also the operations and 3D GIS views supporting what-you-see-is-what-I-see (WYSIWIS) or relaxed WYSIWIS.
- Participants and Chair need instant information transmission. Multicast-based message transportation routines are required. For example, in the agenda approval step, or issues discussion step, the clients need a real-time message exchange process. The agenda needs to be transported to all the clients and the clients’ revision about the agenda need to be transported to Chair and other clients. It is a multicast transportation routine which differs from routine between client and server.

- Participants and Chair need some kind of negotiation process when discussing issues. Negotiation mechanism is therefore required.

3.2 Social collaborative model and ontology

The social networking model describes the static contents such as "what are the elements". Whereas the SCM helps the distributed users share a common understanding about not only "who are they" but also "what are they doing" and "how to work together". There are five main elements in SCM: Topic, Participant, Data Source, Systems Container and Task (see Figure 1). Every element is presented in two aspects: Profiles (Attributes) and Behaviours.

- **Topic** identifies the topic that the participants are discussing in a group meeting. Participants can search the topic and join a group meeting session through the topic identification. All the activities will relate to the topic.
- **Participant** presents the people who find an interesting topic and attend the group meeting. Participants will play different roles and therefore have different privileges to operate a shared systems/service container.
- **System Container** presents a place where a system platform or service is contained. In this container, participants can share the same operations and rendered models, even the whole system platform. The system platform, for example, could be a 3DGIS environment, web-based GIS service or a GIS application.
- **Task** describes the tasks performed by the participants. These tasks could be a simple operation or a set of operations to the system platform.
- **Data Source** describes the data sources and the data that are loaded in the system platform. For example, the data format, data source, database connection and web service, etc.

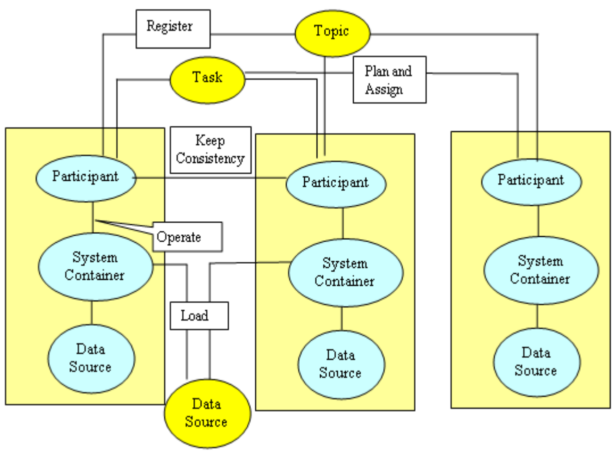

Figure 1 SCM elements and their relationships

Ontology is an explicit specification of a conceptualization (Gruber 1993). Specifically, ontology is a formal explicit description of concepts in a domain of discourse (concepts or classes), properties (slots or roles) and restrictions on properties. According to different purposes, ontology is also classified at difference levels such as top-level, domain-level, task-level and application-level (Guarino 1997). Because the purpose of using ontology to present SCM is to share the common understanding of the group meeting in a SC3DGIS environment among distributed people and software agents. The SCM ontology can be seen as application-level ontology. While the top-level ontology or domain ontology can be refereed in this application-specific ontology. The main work to develop the required ontology is to define the main elements such as discourses (classes), properties and constrains of properties. Figure 2 shows the ontology classes graph for SCM. The main elements of SCM are involved in it.

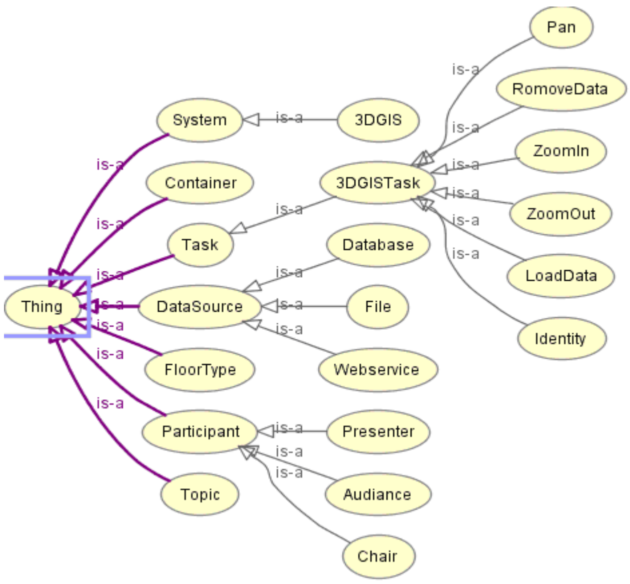

Figure 2 Ontology classes graph for SCM

4. INTEGRATE SCM IN SC3DGIS WITH AGENT-BASED METHOD

Before introducing agent method into SC3DGIS, we have proposed a hybrid architecture and event multicasting processes (Chang and Li 2008). The related prototyping, *GeoLink3D*, was also implemented to evaluate this architecture. In *GeoLink3D*, collaboration component embedded in every client is designed to handle basic collaboration-related functions such as communications among clients and the central servers, floor control, and user management. However, designing the collaboration component faced many difficulties: 1) Peer-to-peer and peer-to-many data transportation, 2) Complicated interaction protocols such as multi-user negotiations, and 3) shared understanding. The multi-agent platform, such as Jade, provides solutions to these challenges:

- Peer-to-peer and peer-to-many data transportation support. Multi-agent platform provides method to transmit all kinds of structured data such as messages, data and operations from one client to other clients directly.
- Complicated interaction protocols such as multi-user negotiation support. Multi-agent method usually follows Foundation for intelligent Physical Agents (FIPA) (2008) interaction protocol. These interaction protocols, such as FIPA-Request, FIPA-query, FIPA-Request-When, FIPA-recruiting, FIPA-brokering, allow the initiator to verify if the

expected rational effect of a single communicative act has been achieved.

- Shared understanding. Multi-agent approach usually provides FIPA-compliant platform and ontology to promote the shared understanding to the working context and environment, topics, tasks and users, etc.

Transducer approach will be adopted to integrate multi-agent part into the SC3DGIS. Transducer approach (Nikraz1a et al., 2006) is used in this prototyping system. Transducer approach provides the interface agent, termed as transducer agent (T-agent), between the legacy system and multi-agents system. According to this method, the whole system is divided into two parts: Multi-agents part and 3D GIS part (see Figure 3). The transducer agent serves as an interface between the 3D GIS and the multi-agents. The distributed 3D GIS is responsible for meeting the basic 3D GIS requirements, while the multi-agents are responsible for handling synchronous collaborative requirements such as multiple communication, structured interaction, etc.

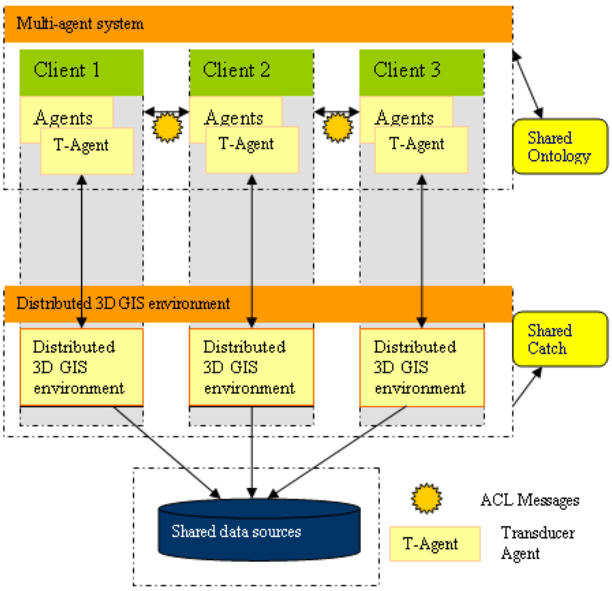

Figure 3 Transducer approach integrates multi-agents to SC3DGIS

The multi-agents will be divided into several agents to implement specific tasks in a distributed pattern. Through Agent Communication Language (ACL), for example in Java Agent Development Framework system (Jade 2008), these agents can communicate and interact; while through ontology, they can share the vocabulary, interaction protocols and achieve common understanding. The 3D GIS part is an independent (legacy) distributed system. The shared catch is a shared virtual memory in which every client can access, update the shared system status and therefore keep the whole system consistent. The detailed requirements, architecture and system design for SC3DGIS can be found in the paper of Chang and Li (2008).

In order to share the same understanding, these agents need to share the same language, vocabulary and protocols. In this prototype, Jade is used to develop the multi-agent system part in which the FIPA communicative acts and Coder/Decoder classes for Semantic languages (SL) are followed. Through defining application-specific ontology, the vocabulary and semantics for the content of the message are shared among agents and the distributed 3D GIS.

Figure 4 shows the detailed messages transportation between agents and 3DGIS environment. First, 1) the agents initiate themselves when they get parameters from shared catch in 3D GIS environment; 2) the agent Chair and agent participant (s), for example, communicate with each other and make a decision; 3) the agent chair transports the decision to the shared catch; and 4) the shared catch notifies the decision results to all the agents who take part in the session. The decision could be a new participant registration, issues approval, etc.

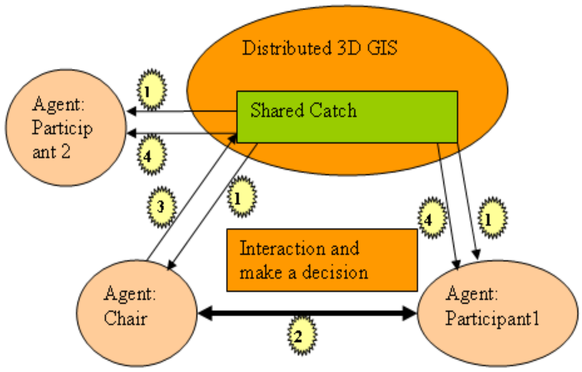

Figure 4 Data transportation between 3DGIS and agents

5. CONCLUSIONS

The SCM is identified according to a case study. This model describes the main elements of the group meeting and their behaviours. These elements and behaviours can be understood among the agents, 3D GIS and users when presented as an application-specific ontology. This ontology will compose the content of ACL messages to facilitate the interaction and communication among multi-agent system and the distributed 3DGIS. In summary, ontology-based, multi-agent SCM benefits collaborative 3DGIS in the following aspects: 1) Formulate the common understanding among users in the SC3DGIS platform; 2) Structure collaborative environments and related communication; and 3) Provide support to complicated interaction protocols such as multi-user negotiation.In the future, a walk-through method will be used to evaluate the model and the prototype, *GeoLink3D*. Some evaluation work will be implemented to compare it to a traditional face-to-face meeting.

ACKNOWLEDGEMENT

This research has been funded by the National Science and Engineering Research Council (NSERC) of Canada (co-author's Discovery Grant) and the GEOIDE Network of Excellence (Project SLM-DFM#15).

REFERENCES

Abberley, P., 1996. Work, utopia and impairment. In L.Barton (Ed.), Disability and Society: emerging issues and insights. Harlow: Longman.

Ahuja, M.K., and Carley, K.M., 1998. Network Structure in Virtual Organizations, JCMC 3(4).

Boyd, D. M., and Ellison, N. B., 2007. Social network sites: Definition, history, and scholarship. Journal of Computer-Mediated Communication, 13(1), article 11

Breslin, J.G., Decker, S., 2007. The Future of Social Networks on the Internet: The Need for Semantics, IEEE Internet Computing, vol. 11, pp. 86-90.

Bryson, J., Martin, D., McIlraith, S., and Stein, L.,A., 2003. Agent-Based Composite Services in DAML-S: The Behavior-Oriented Design of an Intelligent Semantic Web. Web Intelligence, N. Zhong, J. Liu, and Y. Yao, Springer Verlag.

Chang, Z., and Li, S., 2008. Architectural Design and Prototyping of a Web-based Synchronous Collaborative 3D GIS, Cartography and Geographic Information Science, 35(2), pp. 117-132

FIPA Interaction Protocol Specifications, 2008. http://www.fipa.org/repository/ips.php3. (accessed on April 27, 2008)

Fuh, J.Y.H., and Li, W.D., 2005. Advances in collaborative CAD: the-state-of-the art. Computer-Aided Design 37(5): pp. 571-581

GAS 2007. U.S. General Services Administration Site Selection Guide, http://www.gsa.gov/Portal/gsa/ep/channelView.do?pageTypeId=8195&channelPage=%252Fep%252Fchannel%252FgsaOverview.jsp&channelId=-15016 (accessed on November 28, 2007)

Gruber, T. R., 1993. A translation approach to portable ontologies. Knowledge Acquisition, 5(2), pp.199-220,

Guarino, N., 1997. Understanding, building, and using ontologies. International Journal of Human-Computer Studies, 46 pp.293-310

Jade, 2008. http://jade.tilab.com/ (accessed on November 28, 2007)

MASSAGE-3. 2007. MASSAGE-3 website. http://www.crg.cs.nott.ac.uk/research/systems/MASSIVE-3/. (accessed on July 30, 2007)

Mika, P., 2005. Ontologies Are Us: A Unified Model of Social Networks and Semantics. In Proceedings of the 4th International Semantic Web Conference, Springer-Verlag, LNCS 3729, pp. 522-536.

Nikraz1a, M., Caireb, G., and Bahria, P. A., 2006. A Methodology for the Analysis and Design of Multi-Agent Systems using JADE, the International Journal of Computer Systems Science & Engineering, Software Engineering for Multi-Agent Systems

Skyline. 2006. Skyline website. http://www.skylinesoft.com/corporate/corporate_home.asp (last accessed on July 10, 2006)

Tjortjis, C., Dafoulas, G., Layzell, P., and Macaulay, L., 2002. A Model for Selecting CSCW Technologies for Distributed Software Maintenance Teams in Virtual Organisations, Proc. of 26th Annual International Computer Software and Applications Conference.