

1-1-2006

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Claus Rinner

*Ryerson University*, [crinner@ryerson.ca](mailto:crinner@ryerson.ca)

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## Recommended Citation

C. Rinner (2006) Argumentation Mapping in Collaborative Spatial Decision Making. In S. Dragicevic, S. Balram (Eds.): Collaborative GIS. Idea Group Publishing, pp. 85-102

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# Argumentation Mapping in Collaborative Spatial Decision Making

Claus Rinner

Department of Geography  
University of Toronto  
100 St. George Street  
Toronto ON M5S 3G3, Canada

rinner(a)geog.utoronto.ca (new: crinner(a)ryerson.ca)

## Abstract

Collaboration and decision-making of humans usually entails logical reasoning that is expressed through discussions and individual arguments. Where collaborative work uses geo-spatial information and where decision-making has a spatial connotation, argumentation will include geographical references. Argumentation maps have been developed to support geographically referenced discussions and provide a visual access to debates in domains such as urban planning. The concept of argumentation maps provides for explicit links between arguments and the geographic objects they refer to. These geo-argumentative relations do not only allow for cartographic representation of arguments, but also support the querying of both, space and discussion. Combinations of spatial queries and retrieval of linked arguments provide a powerful way of analyzing and summarizing the current state of a debate. In this chapter, we provide an overview of the original argumentation model and we discuss related research and application development. We also link argumentation mapping to related concepts in geographic visualization, spatial decision support systems, and public participation GIS under the umbrella of collaborative GIS.

## Keywords

Geographic Information Systems, Public Participation GIS, Collaborative GIS, Spatial Decision Support Systems, Argumentation Maps, Spatial Planning, User Interface

## INTRODUCTION

Collaboration almost imperatively entails argumentation, that is, the exchange of personal views on certain topics, in particular using logical reasoning. Argumentation is often structured into discussions, or debates, with contributions by individual participants responding to each other. In spatial decision situations, most discussion contributions will contain geographic references. For example, in urban planning, arguments in favour or against a new building might contain references to the building's location, and to neighbouring buildings or streets. A common geographic reference in contributions to public debates is the participant's home location.

Argumentation maps were developed by Rinner (1999b, 2001) as a concept for computer support of geographically referenced discussion by cartographic visualization and query functionality. Argumentation maps have since been discussed in the context of “place-based group knowledge building” (MacEachren et al. 2004) and geo-collaboration (MacEachren & Brewer 2004), and the approach has been summarized in a textbook on “Information Systems for Urban Planning” (Laurini 2001). In this book chapter we will review the original concept and related research from a collaborative GIS perspective, and comment on existing argumentation map implementations.

Section 2 describes concepts and techniques for recording, structuring, and visualizing human argumentation. Formal models for debates were developed in the 1950s and 1970s, and have been implemented in graphically oriented software tools in the sequel. In section 3, theoretical considerations for linking discussion contributions to geographic objects are examined. Section 4 discusses the resulting argumentation maps from the perspective of collaborative GIS, while section 5 presents selected implementation examples and describes the functionality of an optimal argumentation map from a user’s and a content provider’s point of view. Section 6 concludes this chapter with an outlook on the development of research and applications of argumentation maps within the field of collaborative GIS.

## ***RECORDING, STRUCTURING, AND VISUALIZING ARGUMENTATION***

In his dissertation on “communication with automata”, computer scientist Carl Adam Petri (1962) addresses two distinct visions of using computers: the computer as intelligent counter-part in human-machine communication, and computers as a medium to facilitate human-human communication. In fact, Petri argues for enhancing communication media in order to extend the limits to human thinking (Rozenberg 1991). Petri was one of the first to work on reliability and security issues of computer networks and on accelerating argumentation and decision processes between persons with conflicting interests using the computer (Rozenberg 1991).

As an early example of computer-based communication, Turoff (1970) describes an implementation of the Delphi method, a group decision-making process in which experts are questioned about future developments in their fields. Today, the most popular study object of computer-mediated communication is the Internet. The World-Wide Web (WWW) as the Internet’s visual layer is based on non-linear, linked text documents – hypertext. Conklin (1987) provides an overview of hypertext systems in the pre-WWW era. The concept of hypertext is envisioned by Bush (1945) when he devises the “memex” as “a device in which an individual stores all his books, records, and communications, and which is mechanized so that it may be consulted with exceeding speed and flexibility”.

Tim Berners-Lee, the inventor of the WWW, imagined the Web as a much more interactive communication medium than it appears today: “Any user should be able to save comments into a document – just like writing in the margin of your book, but in this case, your note could transport you to the electronic version of the place you are musing about” (Holloway 1997). Berners-Lee thus envisioned the Web “as a powerful force for social change and individual creativity” (W3C 1999). While most of the WWW still is used for presenting information for passive reception, quite a few tools have been developed that use the Web as a platform for computer-supported cooperative work.

Groupware tools have been developed to facilitate human interaction in various settings. Applegate (1991) and Ellis et al. (1991) suggest a time-space taxonomy distinguishing same-place (face-to-face) from different-place (distributed), and same-time (real-time) from different-time (asynchronous) communication. The time-space taxonomy of groupware tools has been adopted by Armstrong (1993) and Shiffer (1997) in the context of collaborative spatial decision-making and by Janelle (1995) from the perspective of time geography. In this text, we will focus on asynchronous distributed communication.

Communication processes in cooperative decision-making often include argumentation, and deliberation. When using computers to support these elements of human interaction, tools for recording, structuring, and visualizing argumentation are required. Argumentation is usually recorded in the form of text messages representing the position of their author with respect to an issue under discussion. Toulmin (1958) develops a model of human argumentation that is based on three types of arguments – claims, data, and warrants – which are combined in a way that data support claims based on warrants (propositions).

Another influential argumentation model was put forward by Kunz & Rittel (1970): the issue-based information system (IBIS). Kunz & Rittel use issues, positions, and arguments to guide “the identification, structuring and settling of issues raised by problem-solving groups” in political decision processes. Conklin & Begeman (1988) propose a hypertext tool that implements the IBIS method. Their graphical IBIS (gIBIS) and its successors QuestMap and Compendium (Conklin et al. 2003) provide examples for argumentation visualization through graphical representations of argumentation elements and their relations. For example, question marks would be used for issues or questions, plus and minus icons would represent pro and contra arguments, while arrows show supporting or rejecting relations between such elements.

The book by Kirschner et al. (2003) on visualizing argumentation is a collection of success stories of “software tools for collaborative and educational sense-making”. The authors argue for using visual tools to reify, contrast, critique, and integrate multiple stakeholders’ perspectives and establish a common ground for subsequent decision-making. In particular, Horn’s (2003) argumentation maps provide a graphical overview of both the history and the current status of some of the great debates in science. Horn uses the term “mapping” to refer to the organization and graphical presentation of information rather than to cartographic maps. In this chapter, we deal with argumentation maps in a cartographic sense.

## ***LINKING DISCUSSION CONTRIBUTIONS TO GEOGRAPHIC OBJECTS***

One capacity of a geographic information system is the representation of geographical phenomena through spatial, temporal, and attribute data. For example, a measured temperature can be linked to the location where it occurred by being stored as a numeric value in a grid cell (raster data model). And calculated population density can be linked to the geographic area where it occurred by being stored as a numeric value in a feature attribute table (geo-relational, vector data model). Attribute values – whether metric, ordinal, or nominal (e.g. place names) – are strongly tied to their geographical reference. In object-oriented geographic data models, attribute values would even be completely incorporated with geographic objects. When geographic reference objects or raster data cease to exist, attribute values do also perish. With regards to

argumentation mapping, we are interested in a looser coupling of independent information objects to geographical references.

An early approach to linking information objects to space was introduced by Laurini & Milleret-Raffort (1990) as the concept of hypermaps. Hypermaps are defined as “multimedia hyperdocuments with a coordinate-based access” (Laurini & Milleret-Raffort 1990, p.643). In this case, the geographically referenced information objects are “hyperdocuments” defined by Laurini & Milleret-Raffort as short semantic units that are inter-connected to each other by reference links. Their definition refers back to Conklin’s (1987) review of hypertext (see above). Ki-Joune & Laurini (1991) discuss the dichotomy of spatial and semantic queries in hypermap systems but only address spatial locality. Kraak & van Driel (1997) re-introduce hypermaps in view of the hyperlinking capacity brought about by the emerging World-Wide Web. These authors define hypermaps as “geo-referenced multimedia”. To access documents through hypermaps, Kraak & van Driel (1997) propose the “geotag” as a reference coordinate or an area. This contrasts with the more restrictive coordinate-only access in Laurini & Milleret-Raffort (1990). In the context of digital libraries, Goodchild (1997) brings forward the notion of “geographic information-bearing object” to describe a library’s “good” that has a geographic footprint, and contains a representation of this place. Goodchild’s examples of such objects include photos taken at known locations and reports on city neighbourhoods.

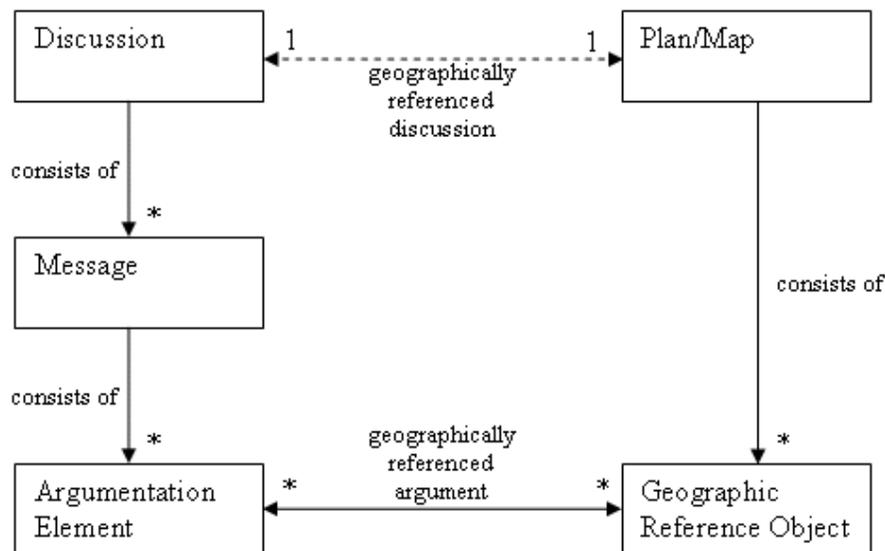


Figure 1: Argumentation map model (modified from Rinner 1999b)

Structured discussions consist of arguments expressed by different stakeholders. We interpret each recorded argument as an individual, independent information object, which has an implicit geographic footprint. One of the principal ideas of argumentation mapping is to let users make the geographic reference for discussion contributions explicit by selecting one or more objects on a map. Rinner (1997a) suggests a cooperative hypermap in which maps are used to insert messages to, and retrieve messages from, a discussion forum. Rinner (1997b) proposes the use of annotation symbols to visualize the existence of discussion messages related to map locations. The term “argumentation map”, abbreviated as “argumap”, is coined by Rinner (1999a) to

describe a cartographic index to planning debates. Further, navigation, participation, and exploration are introduced as the functional categories for using argumentation maps. Finally, Rinner (1999b, 2001) establishes a conceptual model of geographically referenced discussions.

Figure 1 shows a simplified version of the argumentation map model in Rinner (1999b). The model represents a discussion as consisting of messages which in turn contain arguments as the atomic elements of the discussion. A map is modeled as a collection of geographic objects. When a discussion is linked to a map, explicit references will be established on the level of arguments and geographic objects (turning into geographic *reference* objects). The model in Figure 1 also represents cardinalities using the star symbol for unlimited number of elements involved in a relationship. In particular, there is a many-to-many relationship between arguments and geographic objects, that is, a participant's argument in a discussion can reference several geographic objects, and a geographic object can be referenced by several arguments of different participants.

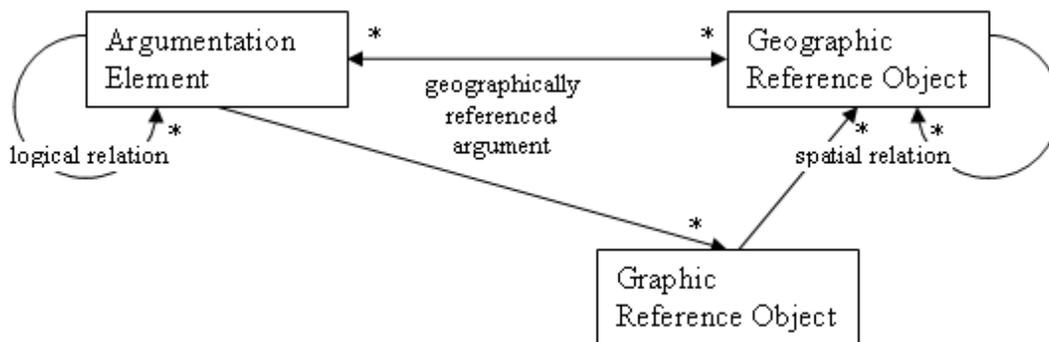


Figure 2: Argumentation map model with user-defined reference objects  
(extended from Rinner 1999b)

A recent update of the argumentation map model (shown in Figure 2) focuses on the level of individual, geographically referenced arguments, making the model more readily applicable beyond the realm of planning debates. The critical element in the argumentation map model is the existence of structured object models on both ends: the discussion/argumentation component, and the cartographic/GIS component. The structure of argumentation elements on the discussion side is based on the logical relations within an argumentation model, as discussed in the previous section. With this structure, argumentation maps are more complex and powerful conceptualizations than most geo-referenced information models including hypermaps. Geo-referenced multimedia objects in hypermaps do have a structure of linkages between them, but these hyperlinks are not typed and not hierarchical in contrast to most argumentation models. On the mapping side, an argumentation map represents the geographic footprint of argumentation elements by geographic objects that are already stored in GIS. These objects have explicit or implicit spatial relations between each other, such as proximity and directional relations. This version of the argumentation map model also provides for user-defined graphic reference objects, which allow users to specify arbitrary geographic references by creating graphic marks on top of a map.

## **ARGUMENTATION MAPS AS COLLABORATIVE GIS TOOLS**

Armstrong (1994) notes a mismatch “between the widespread single-user model of GIS and the group-based approach to decision making that is often adopted when semistructured public policy issues are addressed”. Spatial decision support systems are similarly weak in supporting groups of decision-makers. This was a driving force for the National Center for Geographic Information and Analysis when establishing Initiative 17 “Collaborative Spatial Decision-Making” (NCGIA 1996). Research within the NCGIA initiative resulted in various approaches to integrating GIS with computer-supported cooperative work (see Jankowski & Nyerges 2001), one of which is argumentation maps. Other objectives included the development of multi-criteria decision analysis methods in interactive collaborative environments. While group-based multi-criteria decision analysis alone has been addressed by Malczewski (1995) and others, and individual, map-centred decision analysis has been tackled by Jankowski et al. (2001) and Rinner & Malczewski (2002), combinations of both approaches still have to be developed. One of the most promising research activities towards enabling “group work about geographic scale problems facilitated by geospatial information technologies” was labelled “geocollaboration” by MacEachren et al. (2003) and MacEachren & Brewer (2004).

Collaborative GIS then looks at the methods and processes supporting groups of stakeholders in geographic problem-solving and decision-making. Argumentation maps support the discursive elements in geographic decision-making by providing a visual access to geo-referenced debates. The argumentation map model described in the previous section enables a variety of functions for exploring, querying, and analysing the state of a discussion as well as for actively participating in the debate. Most of these functions are based on “geo-argumentative relations” between arguments and geographic objects in the model. Two basic forms of geo-argumentative relations are possible in geographically referenced argumentation: argumentative relations between geographic objects, and spatial relations between arguments. For example, if a geo-object is referenced by an argument, and a reply to this argument refers to another geo-object, the two geo-objects enter an argumentative relation. From the view of a participant in the discussion, the two objects are related to each other even if they were not spatially related. Similarly, two seemingly unrelated arguments could be related through their spatial reference, if they refer to two spatially related geo-objects. For example, two distinct threads of discussion could refer to two neighbouring geo-objects and thus, a spatial relation between them could be revealed.

A hypothetical discussion of the highly controversial Front Street extension plan of the City of Toronto is used to further illustrate the use of geo-argumentative relations. According to City of Toronto (undated), the Front Street extension “has been a fundamental component of the transportation plan for the central core of the City of Toronto for nearly 20 years. [...] The need for the extension was confirmed in two recent studies [...]. All of these studies determined that the transportation network serving the downtown from the west was approaching capacity and that improvements were required to serve the ongoing and planned new development proposed in the waterfront and railway lands areas.” Arguments in favour of the extension, which have a geographical reference shown in Figure 3, include the limited capacity of the *Gardiner Expressway* and the useful connection of new developments on the *railway lands*. Criticism of the extension plan is summarized in Lorinc (2005). For example, the *Front Street extension* would pass in proximity of newly built townhouses on the *railway lands* rather than serving office buildings that were originally planned at that location. Furthermore, the *Front Street extension* and *parallel local roads* would further obstruct access to historic *Fort York* and “kill an

imaginative proposal for a pedestrian ‘land bridge’ over the *rail corridor*, linking a *park system on King West with Garrison Common*” (Lorinc 2005, emphases of geographic references by author). Different arguments that refer to the railway lands enter a spatial relationship between each other even if they occur in different contexts of the debate. Two separate green spaces are referred to in a single argument creating an argumentative link between these two geographic objects. These are just two examples of the implications of geo-argumentative relations.

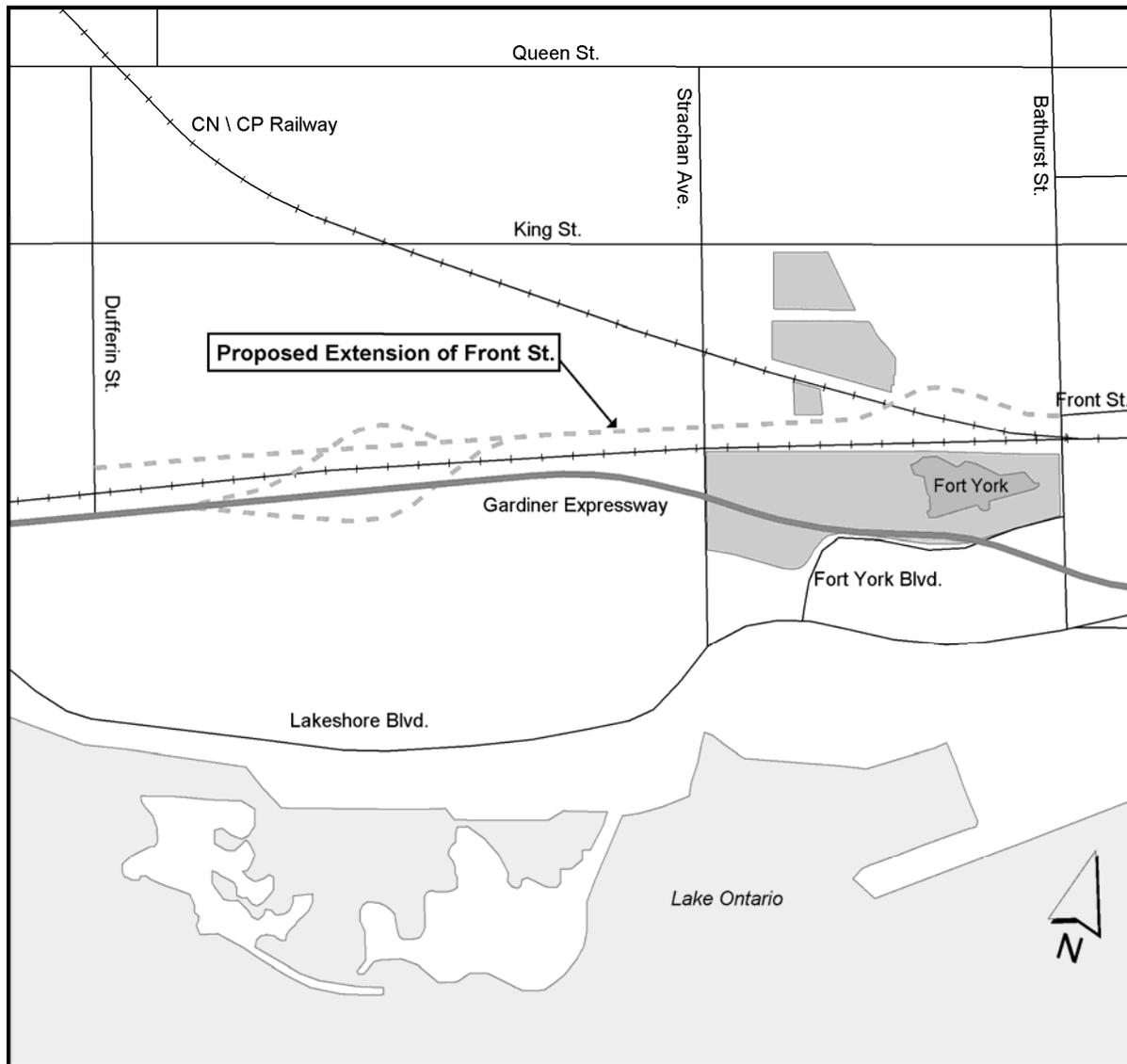


Figure 3: Sketch map of Front Street extension project

As Rinner & Schmidt (1998) point out, multi-user, spatial decision support systems need to handle both cooperative and conflictive goals of stakeholders. Argumentation maps address this issue by supporting structured argumentation models, as described above, which enable discussants to express supportive as well as opposing views.

The Front Street debate may also serve as a background for discussing the possible roles of argumentation maps in group spatial decision-making. Simon (1960) identifies four phases of rational decision-making processes: intelligence, design, choice, and review. In the intelligence phase, the need to change a course of action is to be assessed. If such a need is agreed upon, then in the design phase, alternative solutions are developed. In the choice phase, a decision is made to select one of the alternatives. In conjunction with computer-supported argument visualization, Kirschner et al. (2003) argue that “simulations, spreadsheets, and other modelling approaches can typically be deployed only after the problem has been sufficiently defined, bounded and constrained by assumptions, in other words, after much of the most intellectually demanding work has been done.” We infer that argumentation has an important role to play in the early phases of group decision-making, when the decision problem is framed (Simon’s intelligence and design phases). In larger-scale urban planning projects with their many actors – politicians, planners, citizens, industry, lobby groups, activists –, collaboration and deliberation are likely to occur in each of these phases, even if no participatory elements are prescribed. This makes argumentation maps a generic tool to go along with a collaborative decision-making process from start to end.

## **TECHNOLOGIES AND IMPLEMENTATION EXAMPLES**

There are a limited number of publicly accessible Internet applications in the area of public participation GIS (PPGIS) that make use of maps and groupware tools to support online discussions in spatial decision-making. We will briefly describe two applications that are representative of different levels of functional complexity and exploratory power. Virtual Slaithwaite (Kingston et al. 1999) is one of the earliest PPGIS published under the label “Open Spatial Decision Making”. “Spatial discourse” (Voss et al. 2004) is arguably the most ambitious approach in supporting geographically referenced discussions. Other examples of PPGIS given in the edited book by Craig et al. (2002) focus on community mapping and access to GIS technology as their main participatory aspect, and thus do not offer collaborative software functionality such as discussion support.

Virtual Slaithwaite was introduced by Kingston et al. (1999) as a case study for online decision-making. In a realistic development scenario, residents were given the opportunity to discuss local planning issues. In the context of virtual society, Steve Carver and his colleagues at the School of Geography, University of Leeds, have worked on this case study from various perspectives. Their first online application provided users with a village map and a comment frame in combination with a Web browser window. In this version, comments were placed at coordinate locations on the map and represented by point symbols. Users thus got an impression of where there were any comments. When clicking on a symbol, the corresponding comment was displayed. The subsequent Java-based version of Virtual Slaithwaite allowed the user to select a geographical object to link a comment. This application provides map-based access to discussion contributions. However, there is no support for structured (e.g. threaded) argumentation.

Hans and Angi Voss and their colleagues at the Spatial Decision Support team of Fraunhofer Institute for Autonomous Intelligent Systems (AIS) are working on an ambitious project for supporting spatial discourse. Linking the two existing software tools in AIS: the Zeno discussion forum, and the Descartes thematic mapper, was initially suggested by Rinner (1998). Voss et al. (2004) describe the most recent design for integrating structured discourse and GIS functionality.

The link between the current versions of their tools, Dito and CommonGIS, is designed to support many-to-many relations between user comments and geographic objects. The authors establish conceptual requirements as well as recommendations for achieving a consistent graphical user interface. For example, geo-referenced comments are to be organized in a specific annotation layer. Further requirements refer to technical issues such as performance, synchronization, and security.

Full implementations of the argumentation map model must integrate tools for discussion support and online mapping functions. Keßler (2004) examines these components in detail. With reference to Peng & Tsou (2003), he discusses online mapping technology in terms of the distribution of functionality over client and server. Client software that includes presentation functions and much of the business logic and data management are called “thick clients”, while clients that are limited to presenting maps that are created on the server side, are termed “thin clients”. Keßler (2004) argues for using a Java applet as the client-side mapping component since applets enable more complex functionality than dynamic HTML pages, reduce the cost for development as compared with certain proprietary Web mapping solutions, and provide a platform-independent technology. The Open Geospatial Consortium’s (OGC) Web Map Service (WMS) specification is also discussed in view of an integration of argumentation maps with existing spatial data infrastructures.

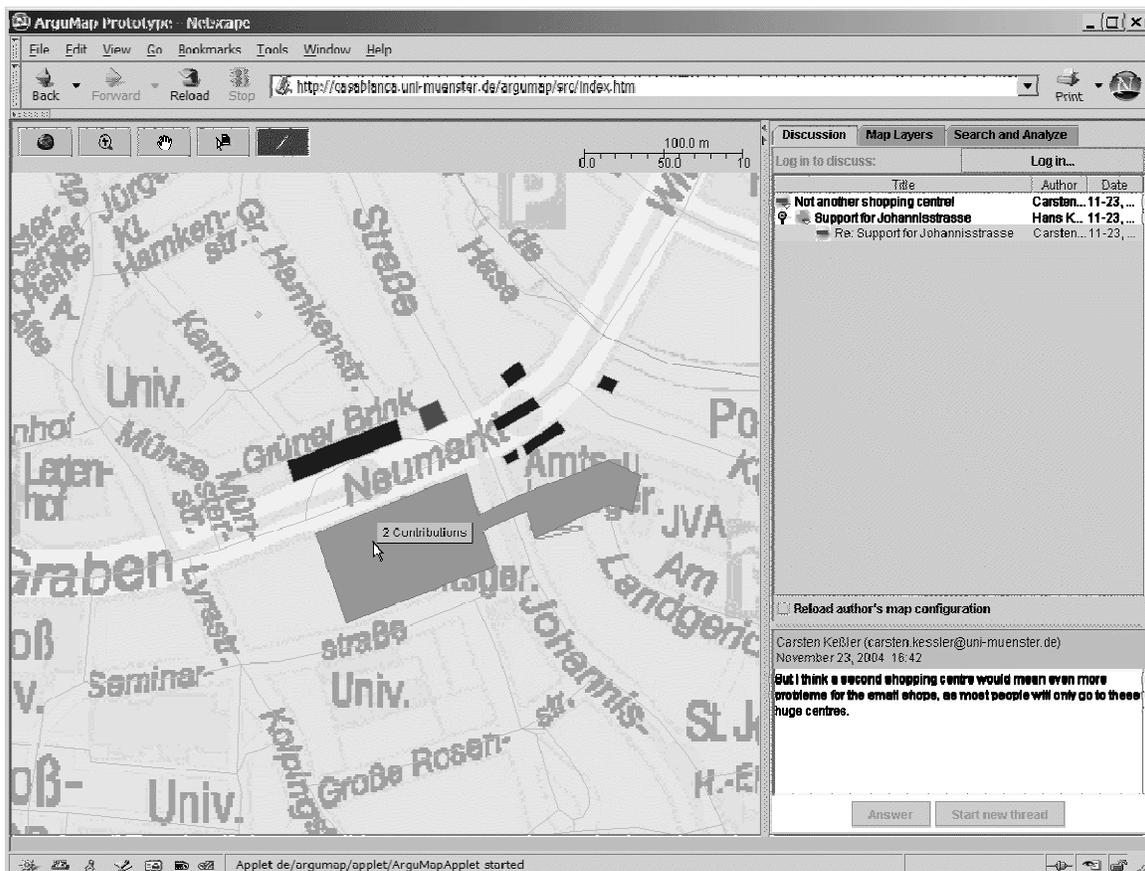


Figure 4: Screenshot of Keßler's (2004) argumentation map prototype

With respect to online discussion forums, Keßler (2004) explores Usenet newsgroups, and other customized Internet forums. He shows that newsgroups cannot easily be used to implement argumentation maps due to the need for a separate newsreader and concerns with persistent storage of messages. To create the link between a custom forum and a mapping tool, Keßler (2004) discusses Unique Resource Locators (URL) as the Internet standard for addressing documents, the OGC's XML for Image and Map Annotations draft specification, and server-side databases. For his prototype implementation, Keßler uses a MySQL database. The prototype was developed with user-friendliness and the use of interoperability standards in mind as described in Keßler et al. (2005). For example, the complexity of the user interface is limited to a few core functions, and the two components are integrated in a single window.

The prototype developed by Keßler (2004) is designed to support both, end users (participants in a discussion) and content providers (e.g. a planning agency). From the perspective of the user, the discussion and the map can be browsed separately with functionality that is usually offered by basic discussion forums and maps. This includes reading individual messages and responding to messages, or starting new threads in the forum. Messages can also be labelled using a set of simple argument types – an approach that is less complex than using an argumentation model as introduced above. From the perspective of the content provider, important functions include user management and security features such as authentication. With respect to mapping, Keßler's prototype provides functions for viewing the map, zooming in and out, and panning (moving the current extent). Finally, in terms of query and analysis of the geo-referenced debate, special symbols represent geographical references of arguments. Users are thus able to highlight arguments by clicking on related geo-objects, highlight geographic objects by clicking on discussion messages, and submit text messages together with geographic references. Geo-argumentative queries can be combined with simple search functionality in the discussion forum. For providers, an additional statistics tool is conceived to provide summary information on the current status of a discussion for inclusion in reports.

## **CONCLUSION AND OUTLOOK**

With the ever-increasing demand by competing land-uses for the scarce space resources in urbanized areas, and citizens stepping up to request participation in urban and regional planning, collaborative GIS will become an increasingly important decision-making tool. The trend of GIS to move towards collaborative uses as groupware systems is observed by Armstrong (1994) and has amplified since then as indicated in the discussion of spatial decision support systems and PPGIS. In providing computer support for discussions in spatial planning exercises, argumentation maps are an important component of collaborative GIS. It is important to note that the argumentation map concept is not specifically designed for a particular user group. It is expected to be useful for discussions between planning professionals as well as for community participation, thus contributing to PPGIS activities as well as mainstream GIS development.

The Internet and the World-Wide Web play a crucial role in providing information access to larger groups of stakeholders, and enabling their participation, in particular through support for asynchronous distributed discussions. GIS interoperability and the use of open geospatial technology standards are essential when providing such services. The prototype argumentation map by Keßler (2004) provides a starting point in offering argumentation mapping in compliance with the emerging spatial data infrastructures.

Rinner (1998) classifies map-based discussion support tools into argumentation maps, annotation maps, and alternative maps, with gradually increasing opportunities for stakeholders to influence planning projects by their comments and their own designs. However, some scepticism has been articulated by Armstrong & Densham (1995) and other researchers concerning practical issues with involving large groups of stakeholders in policy formulation, the effects of poor data quality on GIS-based decision-making, different levels of access to computer hardware and usage, and the choice of appropriate representations. Some of these issues were reviewed by Sieber (2003) in the context of PPGIS. For the Virtual Slaithwaite study that was summarized in the previous section, Evans et al. (1999) conducted a survey of users' demography and their feeling of empowerment. The feedback they received included the users' satisfaction with the possibility of submitting comments of unconstrained length through the annotation function of the system. Voss et al. (2004) describe the conceptual evolution of their spatial discourse tools (see previous section) based on a series of three user experiments.

Human-computer interaction, as well as human-human interaction through computers, requires additional study as an important aspect in the scientific exploration of the potential and limitations of collaborative GIS. This includes user testing with realistic tasks and adapting user interfaces to the needs of decision-makers. The respective opportunities and shortcomings of lab experiments vs. real-world experiments have to be analysed. Jankowski & Nyerges (2001) propose a framework for controlled user experiments in GIS-supported collaborative decision-making – such controlled experiments are a necessary condition for establishing a collaborative GIScience.

## Acknowledgements

This research was partially funded through a Discovery Grant from the Natural Sciences and Engineering Research Council of Canada (NSERC). Section 5 is based on Carsten Keßler's Diploma thesis, which was supported by a stipend from the German Academic Exchange Service (DAAD) for a stay at the University of Toronto. Carsten Keßler and Chris Sidlar provided helpful suggestions on earlier manuscripts of this book chapter. Chris Sidlar also helped with the preparation of figures. The text greatly benefited from thoughtful comments by two anonymous reviewers.

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