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Argumentation Maps

GIS-based discussion support for online planning

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Abstract

This dissertation is about linking geographically referenced discussion contributions to spatial representations. The application background is the observations of procedures and software tools used in German land-use planning. In the view of planning as an argumentative process, support tools for group discussions and public participation are becoming increasingly needed.

When people discuss spatial planning projects in a traditional paper-based procedure or with currently available computer support, e.g. in newsgroups in the World-Wide Web, the reference to geographic locations is only contained in the wording of contributions. This makes it difficult to analyze and assess the spatial references and their distribution over the planning area. The goal of this work is to initiate the development of computer tools that combine map representations with structured models of argumentation, labeled “Argumentation Map”, short “Argumap”.

For the chosen setting of asynchronous, mediated communication via the Internet, some approaches use clickable hypermaps or Java mapping applets with graphical annotation facility. But none of these treats discussion contributions as individual objects with well-defined relations among them, to be linked to individual map elements. Representing documents on a map allows for efficient orientation, navigation, and retrieval of geo-referenced documents. Furthermore, on the base of an object-oriented model of geo-referenced argumentation, efficient exploration methods of geo-argumentative distribution can be realized. This dissertation introduces the foundations for such geographically enabled mediation systems.

In order to achieve these findings, a simple class model has been developed that represents the essential entities of geo-referenced discussion, that is, a draft zoning plan consisting of plan elements, a discussion organized into argumentation elements, and spatial arguments that establish a relation between structured argumentation “space” and geographic space. Theoretical concepts for argumentative distance and topology between geographic objects have been derived from the class model as well as a set of practical use cases that helped to design a prototype demonstrator. This cursory implementation of an Argumap gives the researcher an impression of how visualization of attributes of argumentation elements, map elements and their linkage can be used to provide powerful navigation and analysis functions for stakeholders in spatial planning.

In summary, this dissertation on the one hand contributes to the field of Geographic Information Systems (GIS) insofar it introduces geo-referenced arguments that could enrich many GIS applications, in participatory planning as well as in other domains. On the other hand, Argumaps add to the set of visualization methods of discussion support tools, whenever a discussion turns around a geographic or graphic design problem.

Keywords: Argumentation Map, Discussion Forum, Geographic Information Systems, Participatory Online Planning

Zusammenfassung

Die vorliegende Arbeit befasst sich mit der Verknüpfung von raumbezogenen Diskussionsbeiträgen und räumlichen Repräsentationen. Der thematische Hintergrund liegt in den Prozessen und derzeit eingesetzten Werkzeugen in der Flächennutzungsplanung in Deutschland. Aus der Sicht von Planung als einem argumentativen Prozess wird zunehmend eine informationstechnische Unterstützung für Diskussionen in Gruppen und für die Bürgerbeteiligung gefordert.

Sowohl in Verfahren, in denen Betroffene in Bürgerversammlungen und per Brief über Planungsvorhaben diskutieren, als auch mit heute gängiger Computerunterstützung in Form von Newsgroups, sind räumliche Bezüge nur im Wortlaut von Diskussionsbeiträgen enthalten. Dies erschwert die Analyse und Bewertung der Raumbezüge und ihrer Verteilung im Planungsgebiet. Das Ziel dieser Arbeit besteht darin, die Entwicklung von “Argumentationskarten” zu initiieren, die geographische Modelle mit strukturierten Argumentationsmodellen kombinieren.

Für die gewählte Randbedingung asynchroner, vermittelter Kommunikation über das Internet nutzen bestehende Ansätze klickbare Karten und Java-basierte Mapping-Applets mit der Möglichkeit graphischer Annotation von Plänen. Keine der berücksichtigten Vorarbeiten fasst Diskussionsbeiträge als individuelle Informations-Objekte mit wohldefinierten Beziehungen untereinander auf, die mit individuellen Planelementen zu verknüpfen sind. Erst die detaillierte Repräsentation von Dokumenten auf Karten gestattet jedoch eine effiziente Orientierung, Navigation und Abfrage von raumbezogenen Dokumenten. Weiterhin können auf Basis eines objektorientierten Modells effiziente Explorationsmethoden für die räumliche Verteilung von Diskussionsbeiträgen realisiert werden. Diese Dissertation führt die Grundlagen solcher karten-basierter Diskussionsforen ein.

Zu diesem Zweck wird ein einfaches Klassenmodell zur Repräsentation der relevanten Einheiten raumbezogener Diskussion vorgestellt. Dazu gehören ein Planentwurf, der aus Planelementen besteht, eine Diskussion, die aus Argumentationselementen zusammengesetzt ist, und raumbezogene Argumente, die eine Beziehung zwischen dem strukturierten Argumentationsraum und dem geographischen Raum herstellen. Aus dem Klassenmodell werden die theoretischen Konzepte argumentativer Distanz und argumentativer Topologie sowie eine Anzahl praktischer Anwendungsfälle abgeleitet, die als Grundlage des Entwurfs zweier Prototypen dienen. Die Implementation dieser Argumentationskarten gibt einen Eindruck davon, wie die Visualisierung der Eigenschaften von Argumentationselementen, Planelementen und ihrer Verknüpfung den Meinungsträgern in der Raumplanung mächtige Analysefunktionen an die Hand geben kann.

Zusammenfassend liefert die vorliegende Arbeit einerseits einen Beitrag zur Geographischen Informationswissenschaft, insofern sie mit raumbezogenen Argumenten zahlreiche GIS-Anwendungen bereichern kann, sowohl in der partizipativen Planung als auch in anderen Anwendungsbereichen. Andererseits ergänzen Argumentationskarten die Visualisierungsmethoden von Diskussionsunterstützungssystemen in den Fällen, in denen ein geographisches oder graphisches Entwurfsproblem Gegenstand der Diskussion ist.

Schlagwörter: Argumentationskarte, Diskussionsforum, Geographische Informationssysteme, partizipative Online-Planung

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ὁ Ζήνωνος λόγος ἀναιρεῖν ἐδόκει τὸ εἶναι τὸν τόπον ἐρωτῶν οὕτως· εἰ ἔστιν ὁ τόπος, ἐν τίνι ἔσται; πᾶν γὰρ ὂν ἔν τινι· τὸ δὲ ἔν τινι καὶ ἐν τόπῳ. ἔσται ἄρα ὁ τόπος ἐν τόπῳ καὶ τοῦτο ἐπ' ἄπειρον· οὐκ ἄρα ἔστιν ὁ τόπος.

Zeno's argument seemed to do away with place, putting the question as follows: if place exists, in what will it be? For every existent is in something; but what is in something is in a place. Place therefore will be in a place, and so on *ad infinitum*: therefore place does not exist.

Simplicius 562.1, *ad* 210*b* 23; Diels, A 24
(quoted in and translated by Lee, 1967)

1. Discussing maps via the World-Wide Web

1.1. Introduction

1.1.1. Motivation

Information Technology (IT) largely influences today's spatial planning procedures. Information systems in planning bring together a wide range of document types to support actors in planning: Textual information like expertises and law paragraphs is combined via hyperlinks with diagrams, cartographic presentations, and other multimedia data. The exchange of documents and ideas is facilitated by shared workspaces and online discussion forums. The World-Wide Web (WWW) can be considered an appropriate communication medium for cooperative work in spatial planning.

Enabling communities with IT to support communication and argumentation procedures becomes increasingly important for modern, computer-supported participatory planning. The present thesis addresses the conceptual and technical problems encountered when connecting digital maps and online discussion forums. The combination of geo-data handling with IT supported exchange of opinions is driven by the vision of "discussing maps via the World-Wide Web" (Rinner, 1997a).

From the scientific perspective of cooperative work tools, planning discussions are augmented with a cartographic dimension, while from the view of Geographic Information Science, argumentative structures are added to geographic information. The goal of this work is to propose a conceptual framework to model and visualize a geographic planning project, together with related arguments of planners and concerned citizens. The second objective, which goes beyond visualization, is to use the conceptual framework for computer-supported analysis of the spatial distribution of arguments.

In this, the thesis aims at supporting users in planning debates in a manner, close to their traditional tasks and workflow, instead of forcing them to adapt current procedures to new technology.

1.1.2. Disciplines

Sketching this project from the perspective of various concerned disciplines may clarify the main issues of the general problem domain, helping the subsequent problem definition:

Geographic Information Science: Examine requirements and opportunities for spatial analysis when augmenting Geographic Information Systems (GIS) with geo-referenced arguments.

Argumentation Theory and Spatial Cognition: Learn whether and how people refer to space in public debates.

Cartography and Databases: Propose a cartographic symbol language to represent arguments on digital maps; Study map-based navigation and data access.

Computer-Supported Cooperative Work and Spatial Planning: Explore the usability of geo-argumentative visualization and analysis in cooperative design processes.

The conceptual model of geographically referenced debates proposed in this thesis is based on a combination of concepts and methods from the fields listed above.

1.1.3. Contents

The remainder of this chapter familiarizes the reader with the aspired results of the thesis by describing an explicit scenario for an "Argumentation Map" (short "Argumap") to support discussions in an online planning procedure. From this scenario, the guiding issues for the rest of the thesis are deduced.

Chapter 2 provides an overview of Collaborative Spatial Decision-Making (CSDM) including the basics of Internet GIS, an important base technology for computer-aided CSDM.

Chapter 3 attempts to formalize the information structure of plans and related discussion contributions through an object-oriented data model. Chapter 4 discusses the theoretical consequences of modeling geographically referenced debates by the proposed model, in terms of representing the spatial conceptions of people through argumentative relations between geographic objects. In chapter 5, use cases for Argumaps are described and functional requirements derived for input, presentation, retrieval, and analysis of arguments on interactive maps.

Chapter 6 presents an Argumap prototype implementation and an architecture for a second demonstrator to illustrate ways of handling argumentative relations between geographic objects.

The findings in geo-argumentative modeling are discussed in chapter 7. It concludes on an attempt to generalize the theoretical results of this thesis, to be useful for other GIS application domains than planning.

1.2. Scenario

This section presents a vision of how users could interact with an electronic planning discussion forum and online maps. The scenario provides an overall description of the use of a map-based discussion forum.

1.2.1. Background: Planner proposes online draft plan

To instantiate a resolution of the town council, planner Johnson of the urban planning department in Alphaville developed a proposal for a land-use plan modification. It consists of a draft for the new plan and a text with detailed regulations. Johnson took into account a number of laws for city planning, some earlier decisions of Alphaville councilmen and councilwoman, the general guidelines of the planning department, as well as the applicable higher-level plans.

All these documents are available in digital form: Some maps are images of scanned paper maps, some are digitized vector maps. Besides, there are digital texts, photographs, and even audio tapes. As the planners work with an Intranet system based on WWW technologies, and also belong to an Extranet, which includes planning agencies from several administrative units and levels, most of the documents exist in WWW-compliant formats.

Johnson integrates these documents in the WWW-based Argumap system, in a way to answer the potential questions, "What is the proposed plan modification?", and, "What are the bases for the proposal"? This includes cartographic highlighting of areas and plan elements which were changed in respect to the valid land-use plan, and emphasizing the modified textual regulations. Further more, hot spots on the plan and marked hyper-references in the texts are provided to open external documents in the client's WWW browser, e.g. protocols of former meetings of the town council, which are maintained in the council information system.

1.2.2. Scene A: Planners internally discuss draft plan

Planner Johnson has to reconcile the draft plan with his colleagues in neighbouring Betatown, and have it approved by the controlling regional authorities. To give the other planners access to the draft, Johnson—together with the traditional *announcement of the planning project—sets up a shared workspace and makes it accessible to all intended members.*

Planner Smith in Betatown accesses the information on Alphaville's new land-use projects via her general purpose WWW browser. After typing in login and password, she gets into the shared workspace, where she first selects to view the draft plan. Some annotation symbols on the plan draw Smith's attention to a new housing area planned on Alphaville territory, close to Betatown. Smith remembers a common resolution of Betatown and Alphaville councils on keeping this area, to both sides of the border, free of buildings. To see, whether Alphaville planners ignored this resolution intentionally, Smith clicks on the available annotation symbol near the housing area. She is led to a note, which suggests to Alphaville council to revise the former common resolution, whose wording can be found via a link in the Argumap system.

Planner Smith sends an electronic mail to her colleague Johnson, to express her uneasiness with the proposed planning area, and asks Johnson for further consultation. The next day Smith receives a reply from Johnson. Johnson explains that Alphaville needs a certain amount of new housing facilities, according to the recent population growth forecast. He also refers to the introductory section of the modified land-use plan text. Johnson attaches a screenshot of an alternative draft plan from his GIS, in which he included a free corridor between Alphaville and Betatown. The GIS analysis results, included in the message, show that the lower housing capacity gain does not sufficiently address the needs of Alphaville. Smith writes a note to her superior to suggest a political negotiation.

1.2.3. Background: City includes "on-map" discussion forum into WWW pages

Inbetween, Alphaville council voted the draft plan to be laid out for public debate. Since a few years, Alphaville has provided information about the city on the World-Wide Web. This service started as a marketing activity, but covers more and more administrative services for Alphaville citizens. Now, for the first time, the discussion of a planning project will be performed and mediated via the WWW.

Alphaville's Webmaster connects parts of the Argumap system to Alphaville's public server. Alternative textual and graphical user interfaces provide access to the non-confidential documents about the new land-use plan. The Webmaster also installs an electronic discussion forum, and informs the planners that the mediation system is ready for public debate.

The following online discussion will remain on the Alphaville WWW server for several years, as it serves as a demonstration of the living democracy in Alphaville.

As centre of the presentation, the new plan—when decided—will also inform potential investors and new inhabitants about the land-use regulations in Alphaville.

1.2.4. Scene B: Citizen explores plan and related public debate

Today, Miss Miller read in the local newspaper that the public debate on the land-use plan had been opened some days ago and that it is accessible via the Internet. Miller dials into Alphavilles WWW pages and selects the city planning area. A sketched city map denotes some detailed planning projects, while an abstract, menu-like graphical component represents the land-use plan modification, which refers to the entire territory of Alphaville.

In the land-use planning area, Miss Miller is offered several approaches to inform herself about the current modification project: First, the draft plan is offered "as is", which means that she can see an original view and download the original document in several GIS or CAD formats for further processing on the client side. Miss Miller assumes, this could be interesting for semi-professionals, who have software systems to analyze the plan in depth. A second view on the plan includes a number of non-cartographic symbols, which represent clickable links to documents which justify the scheduled modifications. But Miss Miller is most interested in a third perspective on the draft plan, which visualizes the current state of the public debate.

There are several symbols like little flags, placed over and besides the draft plan, which obviously represent the issues raised during the debate. When she clicks on a flag over a new housing area, located near the city limits of Betatown, Miss Miller is directed to a more accurate image of the plan. The cartographic zoom is done to the area the selected discussion issue refers to, while the symbols on the map completely changed: They now represent several positions, taken by other citizens with respect to the housing area issue.

Miss Miller clicks on some of these flags and reads the inter-related messages from the debaters in the online discussion forum. Some of the messages include links back to the graphical plan representation – as well to the housing area, as to other, indirectly related plan elements –, and to other documents. Miss Miller wants to express a criticism versus one of these messages. In the discussion forum, she selects this message and activates the "reply" function. In consequence, she is asked to select the logical type of her contribution in relation to the original message (e.g. "contra-argument"), and to enter the text of her contribution. Before submitting it to the mediation server, Miss Miller is asked to specify the link of her contribution to the plan. A default link yet is established to the plan element, which was referred to by the criticized original message. Miss Miller adds a second *link to a neighbouring area by selecting it in the plan view, and a third link from a list of possible meta-links, which refer to groups of objects, e.g. "all the streets in the draft plan". Then Miss Miller submits her argument.*

1.2.5. Scene C: Support for a mediator

Planner Johnson of Alphaville has been designated the mediator of the public debate. This means that he receives Miss Millers contribution and checks it for its content being politically correct. Only then, he publishes the message in the argument hierarchy of the discussion.

Today, Johnson received a message which does not match the given link to a housing area of the draft plan. He suspects that the author made a mistake when giving the spatial reference of his argument. So Johnson filters the annotation symbols on the Argumap by author in order to find, if there are other messages from the same person. There are two more contributions, one of which is identical to the first one, but is linked to an appropriate plan element. Johnson marks the first message as probably obsolete, and does not publish it, but informs the author of this fact.

1.2.6. Scene D: Planner appraises public debate

When the period of public debate is ended, planning agency Alphaville has to write a report on the objections and suggestions, they received. Planner Johnson starts an analysis session with the Argumap system. First, he views a statistic of the number of contributions and the temporal distribution of their arrival in the mediation system. The statistics show a peak near the end of the discussion period: People have not yet got used to participating early to have their positions discussed interactively, but keep the custom of sending messages shortly before the deadline!

As Johnson knows that there are some important issues raised about specific plan elements in the system, next, he inspects the spatial distribution of the contributions over the plan. Johnson zooms to some "hot" areas of the discussion and lets the system, issue by issue, symbolize the related positions and arguments. Selecting those symbols on the plan, the planner views author, title, and content of each contribution.

1.3. Problem definition

1.3.1. The relevance of online, map-based discussion

An increasing number of cities is discovering the World-Wide Web as a communication medium, not only for providing information to citizens in a one-way manner, but also for starting a dialogue between citizens and administration, and for providing administrative services online.

GMD's Institute for Autonomous intelligent Systems (AiS, `http://ais.gmd.de`) works on an application scenario "Informed Sustainability" which deals with the relation between information technology and sustainable development of human society. Sustainability can only be achieved if participants in decision-making—that is, often, all citizens—have access to community information, if they can analyze and make appropriate use of the available data and information, and if they can organize their cooperation in an effective manner. Work on cooperative community planning and design in AiS involves facilitating asynchronous, structured discourse in issue-based discussion forums. Mediation between stakeholders in urban planning has recently been included in German planning laws; the "mediator" is expected to become a new profession.

Several researchers envision maps as a generic interface to data and documents. Therefore, discussion procedures related to such data and documents should also be visualized on maps. By picturing digital maps as an essential interface metaphor to communication places in a virtual society, McKee (1996) also indicates the relevance of geo-argumentative visualization:

"Visualization of geographic information, or visualization of information geographically, helps people cope with information glut. Virtual reality applications will employ spatial representations of real spatial phenomena, but they will also employ spatial representations of non-spatial phenomena, simply because our brains are hardwired for solving problems in three-dimensional space. Important parts of the software and data for configuring and populating cyberspace will be borrowed from geoprocessing applications and geo-data archives and data feeds."

For planners, GIS-based Argumaps would provide an integrated tool for managing internal discussions and assessing public participation in a more efficient way. For example, they would be enabled to see where are the most disputed ("hot") regions of a plan.

1.3.2. The problem and why it should be solved

The aim of this thesis is to grasp the relationship between people's opinions and reality by providing a framework to handle this relationship in a computer-based information system. Within the above scenario, the thesis focuses on the relation between map elements and the argument structure of an asynchronous discussion forum. It aims at improving current approaches to online planning participation with functionality of Geographic Information Systems. The practical aim is to allow for building tools for geo-argumentative visualization and analysis. Tentatively, such a tool should answer the following questions.

From within the discussion forum:

* Where is/are the geographical reference/s of a message?
* Where is/are the geographical reference/s of contributions that reply to an argument?

From the map view:

* Who argued about geographic objects?
* When were they debated?
* How many contributions refer to them?
* What types of arguments were raised about them?
* What is the content of related arguments?
* What other plan elements were referenced together with these objects?

The spatial and temporal dimension in the first two questions may allow for different scopes: find arguments that refer to a single geographic object or to objects within a user-defined area; see at which point in time or during which time period objects were in debate.

The thesis is directed towards the following research issues:

- Can arguments be treated like attributes in GIS?
- What types of spatial references of arguments can be modeled?
- What relations between geographic objects are induced by discussion messages?
- How should these argumentative relations be visualized in computer-assisted systems?
- How can they be used for spatial analysis?

On the one hand, solutions in the domain of Web-based planning support become more numerous and evolve towards more participatory approaches. On the other hand, little research activities are known to the author that are directed towards the combination of argumentation techniques and methods of Geographic Information Science. Thus, a fundamental concept as a base for linking argumentation and the representation of geographical space is needed.

Furthermore, the resulting issues for Geographic Information Science are to be examined, i.e. how GIS can be augmented with methods found in geo-argumentative applications.

The GeoMed project (Geographical Mediation System, discussed in chapter 2) is a good example for linking computer-supported discussions to maps. Map images and vector maps are treated as specific document types in a Web-based forum. GeoMed's approach to couple a groupware system with a GIS module is adopted here, but one needs to go beyond the state-of-the-art, to be able to meet the above requirements.

1.3.3. The kind of solution sought

The core issue of the thesis is to map an argumentative "space" to a geographic planning situation. A conceptual framework for the *visualization and analysis of, and for the interaction with, relations between arguments and geographic objects* will be proposed in the form of an object-oriented model. The notions are understood as follows:

Argument A classified electronic message expressing a personal opinion about a geographical situation. (Not meant is computer science "argument", a value passed to a function.)

Geographic object An information entity that represents a real-world feature or a planned feature in its geometry and—possibly—its thematic attributes.

Geo-argumentative relation A reference from an argument to a geographic object and vice-versa.

Visualization provides map-based views on the distribution of the spatial reference of single messages, groups of messages, and statistics of attributes of messages. *Analysis* means functions for querying spatial and argumentative attribute data where queries may follow the relations between the argumentative and the spatial component of the system iteratively over multiple levels. *Interaction* addresses the creation, modification, and deletion of georeferenced messages via a computer interface, that is, the proper participation act.

The practical goal of the thesis is to provide guidelines for implementing Argumaps, i.e. hypermaps for supporting debate. Argumaps are a specific type of "cooperative hypermap" (Rinner, 1997b), which transform a land-use plan into a cartographic user interface for a group decision-making process in spatial planning.

Several methodological and technical issues that can be extracted from the above scenario, do not belong to the core issues and help distinguish the thesis from related work. First, Argumap support is limited to asynchronous, distributed group communication, in contrast e.g. to video-conferencing tools for public meetings. Next, automated consistency checking between arguments, and the evaluation of a discussion, are not considered within the frame of this thesis, no more than automatic geographic indexing of arguments through lexicographic analysis of discussion messages. Finally, the interactive or automated manipulation of draft plans by lay people is not supported by this approach. These issues are addressed in the description of the state-of-the-art in Collaborative Spatial Decision-Making in the next chapter and reasons are given for neglecting them.

1.4. The selected approach

In the initial phase of this project, written contributions of citizens to a preliminary building plan modification in the city of Bonn have been inspected. Special attention has been paid to the way people refer to geographic locations in their statements. But only a few types of geographic references could be distinguished (cf. section 3.2.2). Therefore, the theoretical possibilities of geo-referencing arguments have been analyzed on the base of the state of the art in GIS data modeling.

In an object-oriented approach, a class diagram has been developed in the Unified Modeling Language (UML) which shows types of involved entities and their relations in an Argumap. The object-oriented analysis has been operationalized through the tentative definition of "argumentative distance" and "argumentative topology", as a base for several use cases. The use cases (also visualized with UML) link the conceptual framework for Argumaps to the implementation of specific applications.

How is the success of this approach to be measured? Besides the demonstration of a sound class model, and the deduction of geo-argumentative concepts and structured use cases, a test implementation with the Virtual Reality Modeling Language (VRML) as a WWW-compliant graphics format has been done, in order to show the feasibility of the navigation and participation functions of Argumaps. A concept of a second prototype using the Descartes geo-data explorer is presented in the form of screen design proposals and UML sequence diagrams that demonstrate the necessary interaction of Descartes with the Zeno discussion forum. Both prototypes reflect the object structure of the Argumap model.

In summary, this dissertation describes a problem analysis that spans the dimensions of the problem area of map-based discussion support in geographic planning.

2. GIS and Argumentation in Spatial Planning

The use of Geographic Information Systems (GIS) and Argumentation models to support group decisions on spatial problems (as they occur mainly in spatial planning) has been investigated under the notion of "Collaborative Spatial Decision-Making" (CSDM). Densham et al. (1995) describe CSDM as a "natural outgrowth" of the research on Spatial Decision Support Systems, which moves "the focus ... from individuals to groups". Although CSDM does not include *computer support* in its full wording, CSDM research strives for tools that are based on GIS and Spatial Decision Support Systems, augmented by functions of Computer Supported Cooperative Work tools, also called "Groupware".

The following description of the state of the art in the relevant fields for this thesis is focused on the modeling of geographic objects (geo-objects) and their relations within Geographic Information Science, and on Argumentation Theory as a base for Computer Supported Cooperative Work under distributed space and time conditions. Special attention is paid to the World-Wide Web as a communication platform for Groupware in Spatial Planning.

2.1. Geographic Information Science

The methods of Geographic Information Science are illustrated with an emphasis on referencing thematic information such as planning argumentation to computer representations of geographic space. Important concepts in this respect are geo-objects, relations between them, and maps. Finally, the use of Artificial Intelligence methods in Geographic Information systems is briefly reviewed.

2.1.1. Geographic objects and spatial reference

Geographic Information Science examines the handling of data about phenomena that have a reference to the Earth. "A geographic information system (GIS) is a computer-based information system that enables capture, modeling, manipulation, retrieval, analysis and presentation of geographically referenced data" (Worboys, 1995, p. 1). It is convenient to distinguish four dimensions of geographic phenomena (Worboys, 1995, p. 164):

- Spatial dimension
- Temporal dimension
- Graphical dimension
- Thematic dimension

Among these, the thematic data are of principal interest for a GIS user, because they represent the *spatial distribution* of subject-specific geographic phenomena. For example, precipitation and temperature data for geographic regions represent the different regional climates. There are two ways of linking thematic data to the spatial dimension. The first describes the distribution of a thematic attribute over geographic space. Every cell of a geometric partition of space can be associated with an attribute value. This model, called *field-based*, can be formalized as a function from the spatial framework to a finite attribute domain (Worboys, 1995, p. 149ff). The field-based model is used for spatial phenomena like temperature or elevation distribution over a terrain.

Two observations may lead to the second model, the *object-based* model. On the one hand, many geographic phenomena are seen by humans as entities with an identity (e.g. a specific land parcel or a street). On the other hand, in a field-based model, it is helpful to form larger entities by combining neighbouring cells with similar attribute values. Both types of entities, human-identified and cell-combinations, can be associated with new attribute values. The object-based model reflects the geographer's approach to decompose reality into distinct entities. The opposite is the constructive approach in Computer Aided Design (CAD), where an artificial environment or complex product is built by collecting and organizing simple objects.

Excursus The field vs. object dilemma has induced two main streams in implementing GIS: raster- vs. vector-based systems. The field-based model of geographic space has been implemented in *raster*-based GIS, most of which lay upon a regular, rectangular grid as spatial framework. The main advantages of raster GIS are the efficiency of some processing algorithms, such as layer overlay, and the ability to represent the smooth variation of a phenomenon over space. The object-based model has led to *vector*-based GIS, whose major benefit is the possibility of identifying entities of the application domain, which is essential for problems of topology. Vector GIS are related to Computer Aided Design (CAD) and drawing tools, as well as Database Management Systems (DBMS). For the differences between GIS, CAD, and DBMS, see Cowen (1988) or Augstein and Greve (1994); for an assessment of the raster-vector debate, see Couclelis (1992); for conceptual transformations between several geographic data models, see Gahegan (1996).

With the rise of the object-oriented paradigm in computer science, the interpretation of the association between spatial and thematic properties in the object-based model has changed: The spatial properties are seen no longer as a special property, but as an attribute themselves.

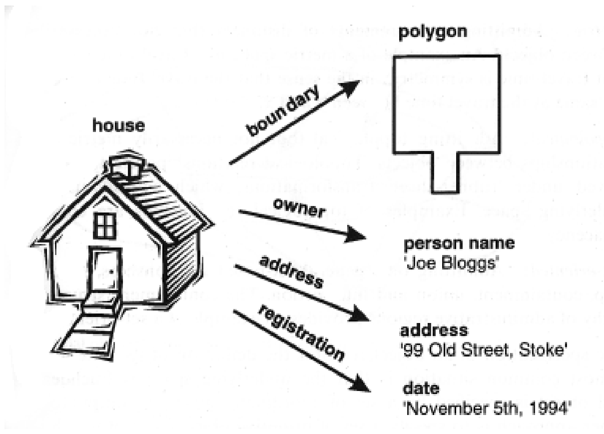

Figure 2.1.: The spatially referenced object *house* (Worboys, 1995, p. 165)

A geo-object, then, is associated with its thematic attributes as well as with one or more spatial attributes. For example, a house has an owner, a number of floors, and a polygon attribute to describe its boundary. Concerning this case, Worboys (1995, p. 164f) clarifies the distinction between spatial objects and spatially referenced objects. The house—like any entity from the application domain—is modeled as a *spatially referenced* object. It references a *spatial* object, that is the polygon that describes its boundary, plus its other thematic and temporal properties (see figure 2.1).

In the terminology used in the sequel, spatial objects are called *geometric*, while spatially-referenced objects are termed *geographic*. Thus, Worboys (1995) clearly pleads for distinct object class hierarchies for modeling geometric objects (point, line, polygon, raster) and geographic objects (house, street, county).

Important features of a geographic object (geo-object) are topological properties that are based on its geometry. The representation of topology ranges from simple Spaghetti rings over Node-Arc-Area (NAA) models up to the storage of sequences of connected parts of an object (Worboys, 1995, p. 192ff). For example, a NAA representation manages an arc as a directed link between a start node and an end node, having an area to its left and an area to its right. This example also shows that topology is not only a property type of a single object (e.g. node-arc topology for a line object), but also a class of relations between distinct objects (e.g. adjacency of two areas that share a common border line). Topological relations between geo-objects are discussed later in this chapter (see page 19).

GIS are used to model and analyze real-world situations. A GIS must answer questions that concern the relation between spatial and thematic aspects in two distinct views:

- What ... (thematic characteristic) is at a specific location?
- Where is ... (some thematic value)?

Answering the first question requires operations going from space into the attribute domain, answering the second question queries the attribute domain and shows results in space. There is little research within the GIS community concerning the thematic dimension of geographic data. An interesting issue is, for example, whether or not the structural properties of geo-objects seen by Bartelme (1995, p. 18), are not simply a matter of thematic classification and semantics of objects in a specific application area. For example, the fact that a complex object consists of several individual objects largely depends on the semantic definition of object classes of the given thematic application.

2.1.2. Geodata models and semantics

The semantics of geo-referenced data, i.e. their meaning with regard to a specific task or application area, causes problems whenever geo-data from different sources are merged or whenever different Geographic Information Systems are involved in solving a task. That is why semantics is a key issue in GIS interoperability. The most promising attempt to overcome both, the syntactic and semantic barriers to interoperability of geographic information, is the OpenGIS specification.

The process of modeling the real world that has been described in the previous section is now revised more formally, in accordance with the OpenGIS Guide (Buehler and McKee, 1998). The OpenGIS essential model distinguishes nine levels of abstraction of real-world facts. The first five levels are of interest here (Buehler and McKee, 1998, p. 38f):

1. Real World. This is the world as it is, in all its complexity and chaos.
2. Conceptual World. This is the world of things we have noticed and named.
3. Geospatial World. This is the cartoon-like world of maps and GIS, in which we select specific things in the conceptual world to represent in an abstract and symbolic way in maps and geodata.
4. Dimensional World. This is the Geospatial world after it has been measured to give it geometric and positional accuracy.
5. Project World. This is a selected piece of the dimensioned geospatial world—certain thematic layers in a GIS, for example—which are structured semantically and otherwise for a particular purpose, profession, discipline, or industry domain.

Worboys' spatial dimension of geographic phenomena is defined in the "dimensional world", with the restriction that up to this point, the OpenGIS specification is independent of a specific representation method—raster or vector data—for geo-objects. Worboys' thematic dimension is determined by the "project world" that defines entities or phenomena beyond geometry. In this context, Buehler and McKee (1998, p. 42) speak of "semantic properties" of features. (*Feature* is the OpenGIS term for geographic object.)

OpenGIS uses the concept of "information communities" to cope with variations in the semantic definition of features. An information community is composed of those producers and users of geo-data "who already share a common set of geographic feature definitions" (Buehler and McKee, 1998, p. 10). Roughly, information communities correspond to application areas, like civil engineering, farming, environmental planning. The OpenGIS specification addresses interoperability within an information community as well as between different information communities. The latter constellation requires the development of "semantic translators" between different meanings of geo-spatial features and still provides many open research questions.

The layer concept mentioned in level 5 of the above real-world abstraction is a classical GIS concept which has not been described so far. Layers are maps that contain only features that belong to a specific theme, e.g. roads, water bodies, land parcel division. Each layer, in general, covers a region completely, but only overlays of several layers provide a working map. The selection of relevant layers depends on the task to be performed. Laurini and Thompson (1992, p. 6ff) introduce the object-oriented view of space as an alternative to the traditional layer concept. Indeed, data storage in an object-oriented spatial database does not need layers to index the data. But for map production, object-oriented systems still use layer information to select feature classes to be drawn on a thematic map.

Layers can be found in vector-based as well as in raster-based GIS, but they stem from vector graphics applications. In their "argumentative approach" to design, McCall et al. (1990, p. 153) propose to "replace the conventional concept of 'layers' in CAD with a more powerful hypermedia-based concept of graphical clusters". While McCall et al. suggest coupling vector graphics with non-graphic *data*, the present thesis argues for a differentiation between (geo)graphically referenced data and *documents*. This issue is further discussed in section 4.1 with a comparison between the nature of GIS attribute data and geo-referenced documents; see also the introduction to hypermaps on page 38. This PHIDIAS concept by McCall et al. is described in section 2.3.3.

2.1.3. Temporal and graphical object properties

On page 11, two more dimensions of geographic phenomena have been mentioned, the temporal and the graphical dimensions. Spatio-*temporal* object models are discussed in depth by Worboys (1995, p. 302ff). One idea behind managing time stamps in spatial databases is keeping track of *versions* of objects. Langran (1992, p. 58ff) describes different methods of versioning in relational databases. *Alternative* geo-objects, also called *variants*, induce effects that are quite similar to versions of geo-objects. This is especially important in spatial planning, where an object may take different versions throughout plan elaboration. If no agreement is found, at a certain point in time, several alternative realizations for the same planned object may result. These are presented to be discussed and compared with each other, as in a search for an optimal position for a plant.

The aim behind considering separately the *graphical* properties of geo-objects and the geometric properties, is to distinguish the representation of the real-world shape of an object (its geometry) from the shape it takes when presented in a map on the screen or on paper (its graphical appearance). A geo-object uses as its graphical properties one or more geometric objects, like points, lines, polygons. Storing multiple alternative map graphics for one object can be useful for displaying the object at different map scales. But the graphical shape for presentation can also be generated ad hoc by a GIS, when a specific map is being drawn. "The relationship between geo-spatial and graphical objects is the subject of cartography" (Worboys, 1994, p. 393).

2.1.4. Cartographic mapping

"Cartography makes assertions about all objects that possess a spatial reference and become describable by at least one more attribute" (Hake and Grünreich, 1994, p. 7, translated from German). Thus, the subject matter of cartography is "the making and study of maps in all their aspects" where a map is a "graphic representation of the geographic setting" (Robinson et al., 1995, p. 9). Before the computer era, maps served as storage *and* presentation medium for cartographic knowledge. Nowadays, geographic data are rather stored in digital geographic databases, and most maps simply present extracts of these data.

According to Hake and Grünreich (1994, p. 15), maps have properties of symbolic, structural, and graphical models. Indeed, a map can be seen as a set of cartographic symbols, or as a product of a cartographic language. In general, the admissible symbols are listed in the map legend and their meaning is explained in natural language terms. Furthermore, most map symbols (also called *map elements*) represent one geo-object, i.e. one element of a conceptual model of the real world. Showing not only the absolute positions of geo-objects in the specified coordinate system, but their relative positions and distances, the map is a structural model of a geographic setting. Finally, as a graphical model, a map can be described by the primary visual variables (Robinson et al., 1995, p. 319f)

- Shape
- Size
- Orientation
- Hue, value, and saturation

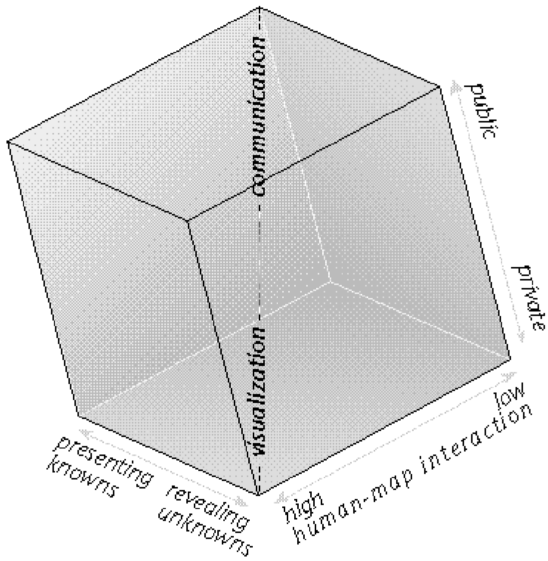

Figure 2.2.: (Cartography)3, the three dimensions of map use (MacEachren, 1994, slightly modified from `http://www.geovista.psu.edu/ica/ICAgif/MacEachren05.gif`)

Although the above reflections hold for vector maps as well as for raster maps, it is important to differentiate between them. Only in vector maps can map elements be isolated by computer tools and manipulated in their structure (position) or their graphical appearance. In most cases, this can be helpful in providing advanced functionality, but there may also be cases where users should be protected from editing map elements. This may hold, for example, when an official map is presented to the public. In this case, a raster representation would prevent users from manipulating the map and even accessing the source data. In addition, the raster image provides a true copy of the official map design.

Frank (1993, p. 6) calls maps "the only tools in common use for spatial analysis, for navigation and any other form of spatial thinking". In fact, screen maps are an important part of graphical GIS user interfaces. First, they communicate an image of raw data and of analysis results. But while Robinson et al. (1995, p. 5 and p. 310) and other authors see maps solely as a communication medium, Frank (1993, p. 6) and Worboys (1995, p. 292ff) observe that maps as a user interface metaphor also allow "direct manipulation", e.g. for data selection and data manipulation. Maps thus provide users with access to GIS operations. Fuhrmann and Kuhn (1998) focus on the design of maps for everyday use by untrained persons. The authors suggest transferring the *affordance* concept to the design of user interfaces for maps. (The affordance of a thing is what it *is for* (Norman, 1988), or more specifically, the affordance is the clue that an object gives the potential user for detecting how to handle it (Gibson, 1979).)

The communicative and the analytical function of maps are reconciled if maps are used for the *visual exploration* of geo-referenced data. Wood (1994) provides an overview of scientific visualization with maps and "maps as sources of insight". Spatial analysis performed via the

Properties of geographic objects	**Relations between geographic objects**
Spatial (position, shape)	Topology, distance, direction
Thematical	Classification, generalization, aggregation
Temporal	Versions
Graphical	Cartographic relations

Table 2.1.: Connection between object properties and inter-object relations

exploration of a map or map series creates a link between cartography and Visualization in Scientific Computing (ViSC). MacEachren (1994) describes the trade-off between map use with low human-map interaction for public communication of known information versus map use with high interaction for visualization in a private research environment (see figure 2.2). Poiker (1997) stresses the extraction of new information out of known cartographic data by the term "visual data mining". A good example of a software that allows such findings is described by Andrienko and Andrienko (1998). Their concepts include a knowledge-base with rules for cartographic design, used to create maps according to the characteristics of the thematic data at hand, and interactive manipulation of the map display in order to find peculiarities in spatial structures. This tool is further described in section 6.3.1.

2.1.5. Relations between geographic objects

In a hypermedia information system like the World-Wide Web, documents may relate to one another via hyperlinks. For spatial data, it is true that *any* piece of information is related to *any* other through their common spatial reference. It is, for example, possible to compute a distance between any two points on the Earth's surface. Tobler (1970, p. 236) invokes "the first law of geography: everything is related to everything else, but near things are more related than distant things." Some GIS use a topological data model (e.g. an arc-node model) to store a part of the existing neighbourhood relations between features. But owing to the first part of Tobler's law, only a minimal portion of all neighbourhood relations can be stored explicitly; most relations must be computed on-the-fly by GIS when it is necessary to complete a specific task.

What relations exist between geo-objects in detail? Table 2.1 summarizes the connection between object properties and inter-object relations that can be derived from the properties. On the left hand side, four groups of object properties are named following the list of page 11. The first two rows are explained in the following paragraphs; the third has been discussed in section 2.1.3; the graphical object properties in the last row may create cartographic relations between map objects (like displacement and hiding), but do not represent real-world relations and thus are not of interest here.

The geometric properties, position and shape, define topological, distance, and direction relations between geo-objects. *Topology* as a spatial relation between geo-objects (in contrast to node-arc-area topology as a property of a single, complex object) concerns neighbourhood relations like *within*, *overlap*, *touch*, and *disjoint*. The topology of two two-dimensional geometries can be described by the Dimensionally Extended Nine-Intersection Model (DE-9IM) (OGC, 1998, p. 2-13). The DE-9IM identifies the different topologies by means of the dimension of the nine geometries that result from intersecting the interior, the boundary, and the exterior of the two original geometries. *Distance* is measured in coordinate units in the Cartesian plane. *Direction* is a less formal concept.

Excursus Papadias and Egenhofer (1995) treat direction as a *qualitative* relation (e.g. north, east) and also consider the qualitative use of topological and distance relations between geo-objects (e.g. near, far). Work on qualitative spatial reasoning is linked to a vision for the future of Geographic Information Science: Egenhofer and Mark (1995) introduce *Naive Geography* as the study of formal models of common-sense geographic world. The goals of Naive Geography are to understand better how people act in their medium-scale physical environment and to use these findings for designing suitable GIS for a wider range of users.

The thematic properties also determine relations between geo-objects. *Classification* means grouping objects with the same set of attribute types (but possibly different attribute values). The number of lanes, the surface material, the regional importance and a finite number of other attributes together with a list or range of valid attribute values may be shared by all the members of the *road* class in a specific geo-data model. Two different roads are related because they belong to the same class. The *generalization* relation depends on class definitions for a GIS application domain. For example, two specific kinds of roads, like motorways and country roads, are generalized to the universal class of roads. Thus, generalization is a relation between classes of objects as well as between object instances. Finally, two objects are in an *aggregation* relation, if one object is part of the other. Road lanes could be modeled as a separate object class and thus, a single lane object can belong to a complex roadway together with other lanes. Consequently, aggregation relies on the semantic definition of geographic objects, just as classification and generalization.

Most relationships in GIS are based on geo-objects. Raster models of geographic data thus raise difficulties in handling spatial relations. Topological and distance relations are reduced to neighbourhood and distance between raster cells, respectively. Classification is important in raster-based GIS but has a slightly different meaning than in the vector case: Classifying raster cells signifies building thematic objects (or at least layers). Summing up, it may be said that raster-based geo-data are not well-suited for handling geo-spatial relations.

2.1.6. GIS and Artificial Intelligence methods

This thesis is related to Artificial Intelligence (AI) research insofar "The purpose of AI is to provide and explore computational techniques for cognitive modeling" (Bundy et al., 1984). To the aim of "Making working with computers as easy and helpful as working with ... people" (Doyle and Dean, 1996), the thesis adds the goal of making cooperation within groups of people *via* the computer easy and helpful. The use of computers as a medium for regulated communication was an early vision by the mathematician Carl Adam Petri at the end of the 1950s (Göbel, 1998, p. 16).

Openshaw and Openshaw (1997) give an overview of AI methods used to enhance GIS. The authors go more deeply into expert systems (XPS), knowledge-based systems (KBS), artificial neural networks, genetic algorithms, and cellular automata. Czeranka and Trapletti (1998) list sample applications of neural networks in geography. Bartelme (1995, p. 176-185) focuses on XPS and KBS that use rules to check the consistency of geographic databases (e.g. "a parcel belongs to exactly one county") and to trigger maintenance procedures in utility applications (e.g. "a pipe must be replaced if it is older than 20 years or its diameter is less than 3cm"). Andrienko and Andrienko (1998, 1999a) use a knowledge-base for the automatic generation of cartographically sound thematic maps (see section 6.3.1). Averdung (1994, p. 57f) uses rules in XPS to represent "imaginary world objects" of planners, that is replicas of their methodological approach and constraints.

Albrecht (1992) expresses his hope that AI methods help to represent implicit knowledge in GIS models and to discover hidden information through inference mechanisms. In an experiment with simulated data sets, Brunsdon et al. (1999) compare several data mining tools in their ability to find clusters of features with similar properties. Unfortunately, the authors put spatial data mining on a level with exploratory data analysis which contradicts the understanding of exploration used in this thesis (cf. page 17).

2.2. Argumentation Theory

The analysis of argumentation processes is a way to discover and save the design rationale of spatial planning procedures. Issue-Based Information Systems (IBIS) are presented as an example of an argumentation model and as a method to overcome the specific requirements of "wicked" planning problems.

2.2.1. Design Rationale and argumentation analysis

"A design rationale (DR) is a representation of the reasoning behind the design of an artifact" (Buckingham Shum, 1996). A city or regional plan is an artifact and planners and citizens have very much interest in understanding the reasoning behind its elaboration. During the preparation of a draft plan, inspecting records of former discussions could help one avoid earlier conflicts and mistakes. And during an actual debate, it is helpful to elicit the reasons of each planning detail to achieve an open discussion and increase the acceptability by stakeholders.

Excursus For the fields of computer-aided industry design and software engineering, Conklin (1989) calls this type of group decision support system a "design journal". A parallel can be drawn to the recent concept of "organizational memory" in economics, as the prevailing goal is to store together unstructured text and formalized documents (cf. Abecker et al., 1998).

Rittel (1972) argues that community planning problems like locating a plant or creating a city plan are "wicked problems" and gives illustrative examples of properties of this type of problems. Important criteria for wicked problems are (Conklin and Weil, 1999):

- There is no complete problem statement. The problem can be understood only when a solution is found, because issues and constraints are mutually dependent and change over time.
- There are many stakeholders so that problem-solving becomes a social process.
- There is no optimal solution and no termination condition, but the process ends when some resource is exhausted.

Wicked problems cannot be treated with rational optimization methods. Rittel (1972) calls the rationalistic methods the "systems approach of the first generation", while Conklin and Weil (1999) speak of the "traditional linear approach to problem-solving". Rittel (1972, p. 394ff) rather argues for "second generation" planning methods characterized by a number of principles that respond to the particularity of wicked problems. Among these principles are the following:

- There are no specialists for solving a wicked problem, but the necessary expertise is distributed over many people who must be integrated in the problem-solving process. The role of experts in dealing with a wicked problem is to guide the process rather than to solve the problem.
- A solution to a wicked problem cannot be imposed by authority; people do not accept being planned at. Affected people therefore must be involved in decision-making at an early stage of planning.
- Each step in working through the problem is based on political and moral attitudes of the involved persons (including the experts!) rather than on scientific expertise. The premises of decisions must be transparent to all participants.

- Objectification can be achieved by exchanging information about the foundations of one's personal judgement of a plan, to be understood by other participants.

In summary, these principles suggest carrying out planning as an *argumentative* process involving also non-experts, especially those citizens affected by the planning project. Argumentation would bring out the premises behind every planning decision and thus would increase the transparency and acceptability of the whole process. In the following, recording argumentation and decisions is further described as a method for achieving design rationale in planning.

Support for and storage of argumentation procedures in computer databases is helped by models of argumentation which have been established to structure the flow of arguments in a debate. Arguments that are expressed as *speech acts* are organized according to an argumentation grammar that defines the allowed rhetorical moves. The above motivation for recording argumentation holds, independently from the kind of group decision-making process at hand. Concerning urban and regional planning, computer support for discussion procedures is also suitable for increasing public participation in the political decisions of a community.

It is not the purpose of this dissertation to examine the advantages and disadvantages of argumentative (or communicative) planning methods. There is as much optimism as scepticism in the scientific community concerning the success of these approaches. It is, for example, not clear whether or not argumentation procedures can help in overcoming the *not-in-my-backyard (NIMBY)* viewpoint which is very popular in planning discussions. Reuter (1997) presents the related view of "planning as power-acting", emphasizing the planning parties efforts of influencing the outcome of a design process according to their own interests. The author discusses the relation between argumentation and power-acting and consequences for decision support systems. For a general assessment of the potential of (computer-mediated) communication in urban planning, see Märker (1999).

Recording argumentation can be achieved through a *backward analysis* of a finished debate or through continuous support of an ongoing debate. There are different approaches to avoid restrictions in the expressiveness of arguments: In the case of backward analysis, people can freely discuss without concern about the grammatical correctness of their arguments. The contributions are later organized according to a given argumentation model.

In the case of *continuous support*, people have to adapt their train of thoughts to the predefined structure of the given argumentation model. It is this model that determines the degree of curtailment of expression. However, participants of a discussion can be supported by a moderator in adapting their contributions.

Structured discussion support that goes beyond simple newsgroups certainly has drawbacks in representing arbitrary speech acts and in being easy to use, but it provides definite advantages that are related to the second generation methods in Rittel (1972):

- Participants are treated more equally in a structured discussion; domination of eloquent persons, community VIPs, or self-appointed experts is reduced.
- Contributions become clearer because complex arguments are broken down into argumentation elements.
- The logical relation between different arguments of one or several participants can be displayed.
- Contributions can be retrieved according to search criteria that refer not only to the contents of messages but also to some metadata like the author, the date, or the type of argument.

In addition, in a computer-based discussion forum, structuring argumentation offers great advantages for subsequently analyzing a debate as shown in section 4.2 and 5.2.

2.2.2. IBIS and the Zeno argumentation framework

According to Tweed (1998), the two most popular schemes of argumentation are Toulmin-Based Logic (TBL) and Issue-Based Information Systems (IBIS). IBIS has been introduced as a "manually operated" method by Kunz and Rittel (1970) "to support coordination and planning of political decision processes" and in general to treat wicked planning problems. The key *issues* of a decision-making problem are seen as the central elements for structuring argumentation processes. In total, the application-independent IBIS concept supports information elements of three logical types (Brewka and Gordon, 1994):

Issues the questions to be decided or goals to be achieved

Positions the alternative solutions which have been proposed for resolving an issue or achieving a goal

Arguments assertions about the properties or attributes of each position, which speak for or against choosing it

Kunz and Rittel (1970) distinguish four types of issues, factual ("Is X the case?"), deontic ("Shall X become the case?"), explanatory ("Is X the reason for Y?"), and instrumental issues ("Is X the appropriate means to accomplish Y in this situation?"). Isenmann and Reuter (1996) add a fifth type, definition issues, which question the meaning of notions used in a discussion.

Conklin and Begeman (1988, 1989) describe gIBIS, a graphical IBIS implementation "for use on large, complex design problems" that supports "thinking and communication" among distributed "cooperating team members". gIBIS is especially intended for "the capture of *early* design deliberations". gIBIS slightly extends Rittel's IBIS schema of legal rhetorical

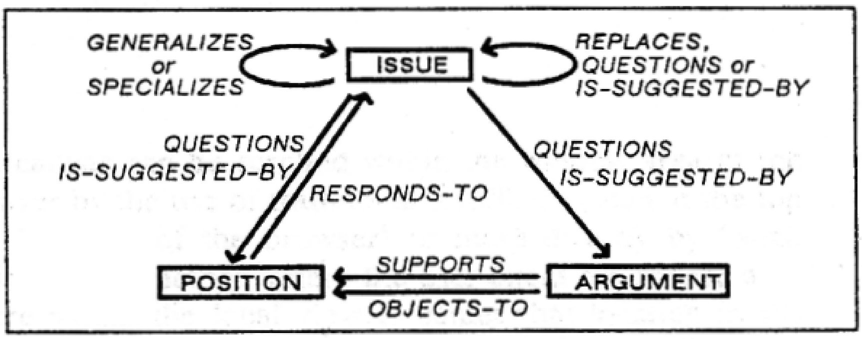

Figure 2.3.: Legal rhetorical moves in IBIS (Conklin and Begeman, 1988, p. 141)

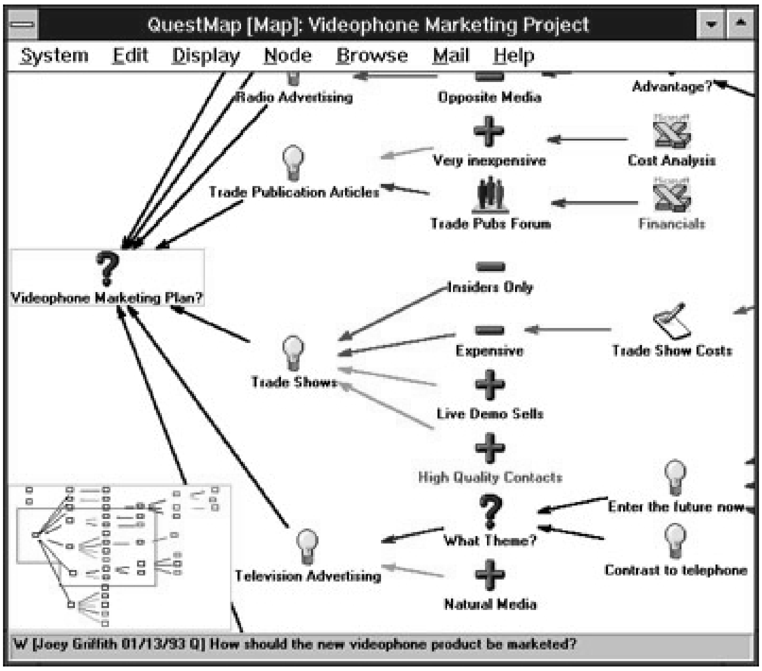

Figure 2.4.: Visualization of argumentation with QuestMap (Conklin, 1996)

moves. The original IBIS consists of three node types (*issue, position, argument*) and eight possible link types between them (*generalizes, specializes, replaces, questions, is_suggested_by, responds_to, supports, objects_to*) (Conklin and Begeman, 1988, see figure 2.3). gIBIS adds the *other* type for nodes and links, the *external* node for non-IBIS material, and the *generalize/specialize* relation for positions and arguments. Based on this model, debates can be represented as graphical networks, as implemented in the successor of gIBIS, QuestMap (see figure 2.4).

The Zeno argumentation model (Gordon and Karacapilidis, 1996) is an IBIS variant that adds reason maintenance aspects to pure argumentation recording. The authors extend IBIS with additional node types (*comment, decision, preference*) and with a labeling mechanism for dialectical graphs. A dialectical graph is a directed finite graph representing all the positions and arguments for a set of issues. A labeling algorithm defines positions to be *in* or *out*, according to a proof standard that is assigned to an issue. For example, “Preponderance of the Evidence” is a proof standard under which a position is *in*, if its valid supporting arguments outweigh its valid objecting arguments. Labeling is a dynamic procedure that is expected to stimulate IBIS-structured debates.

The *comment* node type is intended for speech acts that are independent from other nodes in the argumentation tree and is comparable to Conklin’s *other* node. The *decision* node type represents a choice among the alternative positions to an issue. Finally, *preferences* are a specific type of position that helps to deal with conflicting arguments. Preferences express a priority assessment between two positions. The well-formedness of dialectical graphs follows roughly the legal rhetorical moves of gIBIS (as in figure 2.3). The fact that Gordon and Karacapilidis (1996) model issues as sets of positions, and arguments as binary relations between positions, both instead of nodes, is not further discussed here, because it is not significant for coupling the Zeno model with external applications. An implementation of the Zeno model is integrated in the demostrators for this thesis, see further details in chapter 6.

In the literature there are some reports about shortcomings of the IBIS method. Two problem domains have to be distinguished: (1) drawbacks related to the model itself, and (2) technical problems using its implementations. Fundamental problems with structuring argumentation according to the IBIS model have been described by Conklin and Begeman (1988), Tweed (1998), Conklin (1991), and Isenmann and Reuter (1996). As an example, Conklin and Begeman observe a tendency of a discussion to “go meta”, when participants do not agree on the correct use of the IBIS structure. And Tweed names the administrative overhead, the necessary skills to recognize what is an argument, and the risk of losing the context of an argument when structuring a debate, as obstacles to recording argumentation. The discussion support aimed at in this thesis, indeed can—through coupling argumentation structures with map display—only remedy the latter problems, because it uses the IBIS structure as it is for the argumentation part.

2.3. Groupware in spatial planning

After a few words about terminology, this section describes information technology support for spatial planning in general, and for argumentation about space in particular. Hypermedia and Internet Map Servers are presented as a means of integrating geo-data with geo-referenced documents such as discussion contributions.

2.3.1. Spatial planning versus CSDM

Collaborative Spatial Decision-Making means group decisions on spatial problems, as they occur in spatial planning. The principal scenario for this thesis is public debate in the elaboration or modification procedure for legal land-use maps in urban and regional planning. But CSDM may be more than zone planning, as it designates also site selection procedures and spatial group decisions in the private industry sector. On the other hand, CSDM specifically examines cognitive foundations and computer-based techniques for supporting spatial planning, while spatial planning also covers all legal and organizational aspects related to plan installation. In the sequel we will treat problems in the overlap of CSDM and spatial planning.

Excursus In Artificial Intelligence (AI), the notion *plan* has a different meaning than in spatial planning. While an urban or land-use plan shows the target state of future terrain development, a plan in AI instead is a sequence of actions (e.g. robot navigation commands, technical construction directives) to be taken in order to achieve a goal (Hertzberg, 1989). In other words, planning in AI is finding an algorithm for the translation of a given starting state (problem) into a given final state (solution). Its complement is simulation which tries to find an unknown output, starting with known input and a sequence of transformation instructions (Görz, 1993, p. 751).

2.3.2. Information technology support for planning

The use of computers in spatial planning arose out of the system analytical approach which sees planning as a cybernetic process (Wegener, 1978, p. 23). Without the implementation of computer systems, rationalistic planning, founded upon mathematical-statistical, and quantitative methods from natural and engineering sciences, could not have been attempted. Today's GIS-based Spatial Decision Support Systems (SDSS) stem from this approach (see for example Densham, 1991; Czeranka, 1997; Malczewski, 1999).

Excursus Note that decision *support* aims at helping stakeholders in decision *making*. Decision making tools may go beyond decision support tools in that they propose decision solutions to the user (e.g. multi-criteria decision making tools) instead of simply providing relevant information for a decision by the user (e.g. visual exploration of geographic data). But the notion of CSD*M* does not exclude decision support methods as they are developed in the sequel.

Based on other publications, Wegener (1978, p. 24) summarizes the early criticism of rationalistic planning approaches. He points out that causality is unsuitable for explaining human actions, in particular human *spatial* behaviour; that the contribution of statistical data for finding planning solutions is overestimated ("data euphoria"); that planning-relevant information largely consists of qualitative, informal, and instrumental knowledge. As a consequence, Wegener advocates the view of planning as *communicative* problem-solving leading back to the recording of argumentation. This section examines computer support for argumentative procedures in spatial planning.

The dichotomy between rationalistic and communicative planning is also taken up by Jankowski and Stasik (1997b, p. 74), who distinguish *analytical* vs. *collaborative* approaches to spatial decision-making. The first "uses mathematical models to analyse structured parts of the decision problem leaving unstructured parts for the decision makers' judgement", the second uses "discussion, argumentation, and voting" in an "evolutionary process". In the sequel, the focus is on information technology (IT) support for the collaborative approach which suggests to speak of information *and communication* technology rather than of IT alone—as done, for example, by Fleischhauer et al. (1998).

Classifying planning support tools

Jankowski and Stasik (1997b) discriminate three forms of team work:

Collaboration participants work on the same task

Cooperation participants share results of different tasks

Coordination participants sequence the results of cooperative work

The authors presume that all three types of "social interaction" can occur in public planning processes *simultaneously* and require public GIS to support them. Hence, the above distinction would not be suitable for classifying IT support for planning discussions. In addition, it can be difficult to decide whether a step in a planning procedure can be called *collaborative*. For example, in a public debate over a plan, participants may disagree about establishing or modifying a plan at all, thus not working on the same task. But even in the case of a common general task, people involved in planning decisions will probably have different, conflicting goals, requiring specific computer support (cf. Voß, 1996).

Another schema refers to the exterior setting in which decision-making takes place. On the one hand, the participants in a step of a planning procedure can either meet at one place or stay geographically distributed (in different offices, at home, ...). On the other hand, communication between participants is synchronous or asynchronous. Shiffer (1997) classifies information exchange in public planning discourse into four implementation environments, according to the place / time settings. The settings are supported by the following tools (excerpt):

Same place / same time "Collaborative Planning Systems"

Same place / different time Interactive kiosks, Community GIS

Different place / same time Video conferencing

Different place / different time E-Mail lists, Internet discussion groups

An example of a collaborative planning system is given by Cowen et al. (1999), who evaluate an ArcView GIS-based video-conferencing system for industrial site selection. This tool includes a collaborative whiteboard where users can graphically annotate regions of a planning map. It should be noted that town meetings with direct (same place / same time) communication between planners and citizens are much less relevant in Germany than, for example, in the United States. Thus, in this thesis, primary attention will be paid to the *different place / different time* setting. This is also the reason for not using the place / time classification to further grouping of the tools to be described in this section.

GeoMed-F (1995, p. 75ff) reports on the usability and shortcomings of Computer-Supported Cooperative Work (CSCW) applications for urban and regional planning procedures. The application types range from electronic mail and threaded newsgroups over video-conferencing systems up to shared workspaces and workflow management systems. The focus is on capturing the highest possible amount of structure in messages in a distributed, asynchronous discussion environment, so as to provide the best results when inspecting existing contributions.

Besides the spatial distribution of participants and the asynchronicity of participation, a third major property of discussions in geographic planning is the heterogeneity of discussion groups. This is why the projected GeoMed system provides *mediation* services, that is support for a moderated discussion with an unbiased facilitator helping participants with procedural issues of the debate. Voß (1996) distinguishes Knowledge-Based Systems (KBS) applications based on the number of users and the number of goals, placing mediation systems in the *multiple user / multiple goal (MUMG)* category.

The objectives of the use of information technology to support the discussion parts of planning procedures comprise the following (borrowing from GeoMed-F, 1995, p. 10, p. 25):

- Make documents accessible and exchangeable among participants
- Structure courses of argumentation and steps of decision-making
- Archive finished discussions

and thus

- Enhance (free) participation in the procedure
- Make participants' positions explicit, integrate more of the relevant, informal decision criteria
- Make communication more efficient
- Allow for higher quality decisions

- Justify decisions to external persons
- Show and analyze conflicts, assess the effect of arguments

Most of these aims concern procedures within a planning agency as well as its rapport with other institutions and the general public.

In Rinner and Schmidt (1998), the *space* dimension was added to the user / goal schema of Voß (1996) and CSDM tools were identified as MUMG tools with support for the handling of geographic references. But the spatial dimension can be more or less pronounced and helpful. Extending the classification of Rinner and Schmidt, five levels of IT support for planning debates can be identified:

1. **Conventional paper procedure (i.e. *no* IT support)**
2. **Document management**
3. **Hypermedia structuring of information**
4. **Analysis / assessment of planning alternatives**
5. **Automated plan generation and evaluation**

In the following sections, concepts and applications will be described with reference to these *levels (or degrees) of support* they offer to the users. The question, for whom the tools are designed, will also be important, and the scientific disciplines implied in each method should become clear. The communication services identified by Fleischhauer et al. (1998) in addition to IT services, will here be described as a part of document management and hypermedia structured information.

An idealized model of land-use planning in Germany is given in figure 2.5. Planning steps are reduced to a linear workflow with iterative elements, starting with some initiative to modify an existing plan or develop a new one. The work ends with the political decision to adopt the modified (or new) plan. The emphasis here is on communication and cooperation issues in three scenarios: first, within a planning agency (identified as an Intranet problem, concerning network access); second, between the agency in charge for the project and other concerned authorities (Extranet); finally, between the planning agency and the general public (Internet). It will be emphasized when the following remarks do not apply *mutatis mutandis* to all three scenarios.

Conventional paper procedure

In the *conventional paper procedure*, there is no IT support for stakeholders in planning. Paper plans are circulated within, and sent via mail between, agencies. In a typical German

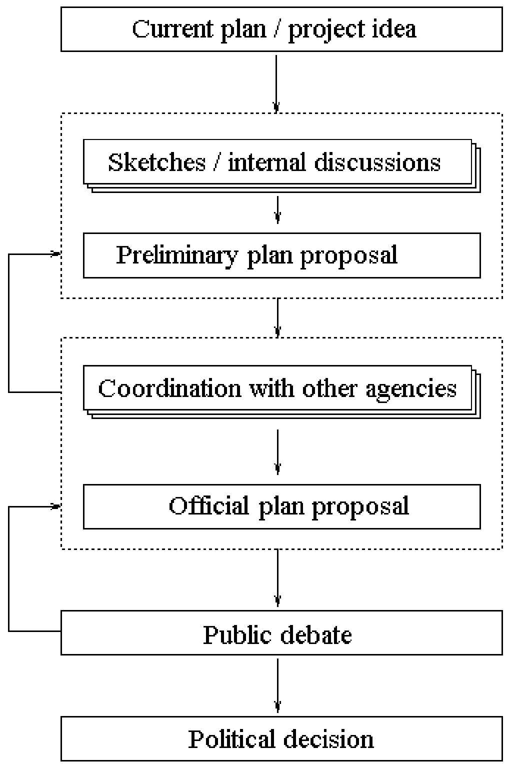

Figure 2.5.: A simplistic model of plan implementation

planning procedure, a draft plan proposal together with a commentary are exhibited in the town hall for a one month period (Beck, 1996, §3(2)). Citizens send suggestions and objections as letters to the planning council.

In addition to this formal participation procedure, public meetings are organized by the planning authority to inform the citizens about the project. But in Germany, public meetings are not part of the decision-making process in planning; they rather serve the information needs of the concerned inhabitants. The planning project is intensively discussed by the participants, but their objections do not have practical consequences, if they are not submitted as written statements to the city administration.

Document management

Planning agencies are now beginning to use electronic mail to discuss rough ideas about a planning project. Plan sketches and related comments are designed with office software, while the plan itself is developed with desktop mapping or GIS software. If these heterogeneous documents are maintained in a common database, one can identify a *document management* approach. A related functionality of IT support for planning procedures is agenda managing. Such tools aim at coordinating the elaboration of a plan between planners, including concurrent editing of plans. The "intelligent land-use planning" project (Maurer and Pews, 1995) is an example of this kind of support, though limited to aid planners. Applying the document management approach to public participation, the main advance may be the use of email to send in contributions, instead of writing letters.

Empirical tests of IT supported planning forums have always been carried out in parallel with conventional procedures. Burg (1999) summarizes four implementations with very modest results, *online* contributions ranging from 0.1% to 6% of all contributions. A similar picture was observed when the GeoMed basic version was tested in a two-week preliminary public debate in Bonn; a reasonable number of visitors viewed documents in the workspace but no one sent in a contribution online (Schmidt-Belz et al., 1998). Technical problems with the respective implementations and with Internet access in general, as well as the public's lack of confidence in the new medium can only partly explain these disappointing results.

The step from allowing email contributions to providing a threaded newsgroup forum for a planning debate is technically modest, but conceptually very large. Newsgroups support question-response sequences while the planning laws only provide that planners respond to citizens' contributions by notifying them about the result of their assessment. Thus, newsgroups and, more so, the argumentation frameworks described in the previous section offer structured discussion and argumentation support.

Hypermedia structuring of information

The GeoMed system (GeoMed-F, 1995) is an example of a tool that integrates argumentation support through the so-called mediation services, with *hypermedia structuring of information*, based on Internet techniques for linking related documents of several types. This shared workspace approach also includes a mapping tool that is used as a helper application for viewing planning maps. The tool called "Ptolemeus" allows clients to link simple graphical map annotations (like circles, text blocks) with GeoMed's discussion forum. For current information on the project's status, see contact information at `http://ais.gmd.de/MS/geomed/overview.html`.

Virtual Slaithwaite is a second example of hypermedia planning support including debates. A tool of the University of Leeds, developed around their online mapping system GeoTools, supports online public comments about planning issues. The screenshot in figure 2.6 shows the planning map with annotation dots in the right frame. In the left frame, the comment is loaded which is attached to the annotation dot selected by the user. The Virtual Slaithwaite prototype is the only map-based discussion support tool (in a wider sense) known to the author that has been tested in real conditions. Kingston et al. (1999) describe the case study in detail and report encouraging aspects. In particular, the public appreciated giving comments with unlimited length.

Other research groups present hypermedia tools that aim at providing a means to explore planned environments (audio-)visually. Shiffer (1997) describes several prototypes of "col-

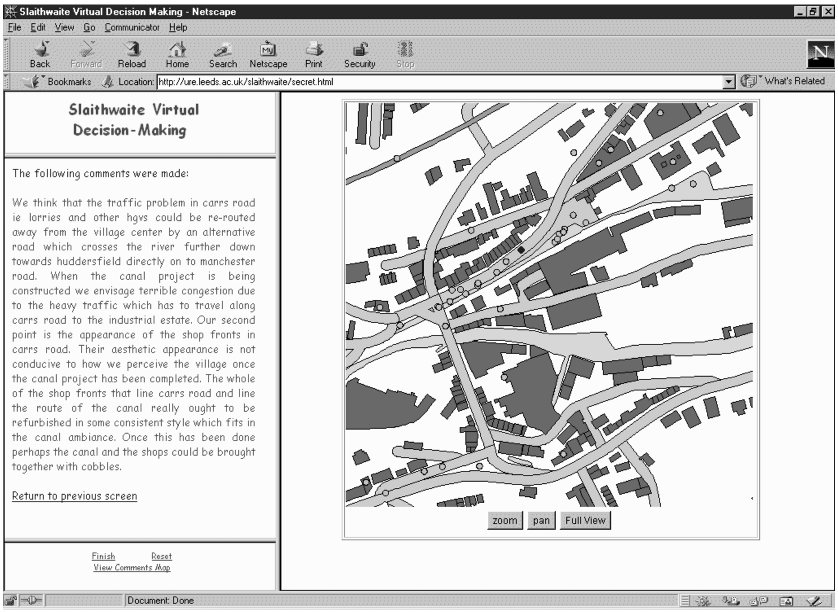

Figure 2.6.: Public comments in a online planning case study ("Virtual Slaithwaite") (Kingston et al., 1999)

laborative planning systems" that augment GIS functionality for public meetings. Among them is an audio tool to imitate the noise impact of an air base on neighbouring locations. Three-dimensional models of city planning projects give stakeholders the opportunity of visiting streets and buildings before the begin of their construction. The visitor is even more free in selecting his or her viewing perspective in 3D than it is possible in reality, standing in front of a real building or city quarter. Bodum et al. (1998) picture the use of multimedia visualization and virtual reality (VR) techniques in a real planning situation in Denmark. Coors and Flick (1998) describe a technology-driven prototype 3D-GIS used for interaction with 3D city models. Lehmkühler (1998) presents an experiment combining a 3D planning view with a newsgroup discussion forum.

The realism of 3D visualization approaches is still very limited. For this reason, Rinner (1998a) refers to the "multiple information spaces" in Lochter et al. (1996) and suggests using VR techniques primarily for indexing complex document bases. Besides the lack of realism of 3D graphical planning visualizations, a second disadvantage lays in the limited overview (in contrast to view*point*) of users on the complete project. Mann (1999) assumes that people have very good capacities in integrating several architectural paper plans with different views on a building project. Thus, even non-sequential hypermedia access and 3D navigation on a computer screen can never provide a simultaneous perception of the most important design aspects.

Analysis / assessment of planning alternatives

Jankowski and Stasik (1997b) promote public GIS (PGIS) under distributed space and time conditions, in the form of their Spatial Understanding and Decision Support System (SUDSS). They point out that PGIS must combine collaborative and analytical approaches, thus supporting negotiation as well as assessment of planning alternatives. SUDSS therefore belongs to category four, *assessment of planning alternatives*, of the above ranking list. Jankowski and Stasik (1997a, p. 2) require SUDSS to support the following functions:

1. Study and explore information about the problem
2. Generate problem solution alternatives
3. Share and discuss problem solution ideas
4. Evaluate the alternatives
5. Negotiate the alternatives
6. Vote on the alternatives

The elaboration or manipulation of a plan by the public (point 2) and public voting on plan alternatives (point 6) do not fit common German planning procedures, insofar as most people believe that lay persons in contrast to planning professionals are not capable of drawing a valid plan document and making a decision on selecting a planning option. In the remainder of the present thesis, only public discussion about *one* official plan proposal, which cannot be edited during the discussion period, is taken into account. Discussion contributions may contain alternative plan proposals, but these are considered as attachments to messages, instead of being a central document in the discussion forum, in contrast to the official plan.

Automated plan generation and evaluation

A first step towards the *automated generation and evaluation* of land-use plans is the use of knowledge-based systems. Averdung (1994) depicts an approach to support planners in creating a legally correct plan that resulted in a tool called "SupportGIS" (`http://www.ikt.uni-bonn.de/Forschung/SupportGIS/`). Willems (1994) does a domain and task analysis suitable for creating a knowledge-base for locating problems in urban planning. Schrenk (1996) asks for dynamic rule-based planning where the regulations of a plan could depend of changing planning constraints. Methods from the field of Artificial Intelligence can also be used to assist participants in planning discussions. GeoMed-F (1995, p. 26) envisions personalized advisory tools, to be realized by software agents. These could e.g. filter new contributions of other participants according to user preferences and notify the user of interesting events in a workspace.

While the latter seems close to being implemented in common software tools like mail readers, the first cited approaches are judged skeptical because of big intrinsic problems. For example, building a knowledge-base that covers most regulations of German planning laws is a huge effort that seems not worth being undertaken because of frequent changes in regulations and planning policy. Also, tools must find a good balance between troubling the designer with frequent error messages based on stored knowledge and rules, and warning him or her too late in the design process. The rest of this thesis seeks a compromise between advanced user support and feasibility of elaborate concepts. Hypermedia structuring of information related to planning discussions is considered as the level of IT support where technically foreseeable developments can best increase the usability of computer-based planning tools.

2.3.3. Argumentation about space

The above mentioned SUDSS tool (Jankowski and Stasik, 1997b) supports users in negotiating previously generated planning alternatives by way of Internet newsgroup functionality. A direct connection between plans that are discussed and the discussion messages does not exist. In his prototype, Lehmkühler (1998) uses WWW hyperlinks to connect spatial objects with a newsgroup forum, but not with single messages. Therefore, discussion in both cases is restricted to question-reply structures of newsgroups.

Geo-referenced argumentation as meant by this thesis involves models of geographic information (representing the plan as the subject of a discussion) integrated with an advanced model of argumentation, like the IBIS model. For example, Armstrong (1994, p. 674) suggests using IBIS to discuss "the relative merits and liabilities of different proposed [planning] alternatives" for future GIS-based group decision-making.

The only software tool known to the author that integrates graphic objects with a structured model of argumentation is PHIDIAS, a hypertext system for supporting designers (McCall et al., 1990). PHIDIAS combines an IBIS variant (PHI, that is "procedural hierarchy of issues") with a vector graphics module. The sample sessions presented in the paper are in the Computer Aided Design (CAD) field, namely interior design. In a graphics window, PHIDIAS provides domain-specific construction tools. During a design deliberation, the user can query a dynamic issue base that contains design-related argumentation. These issues, answers, and arguments may e.g. be about the best placement of a refrigerator in a kitchen design. The issue base can be accessed either via an explicit query statement or implicitly by clicking on finished objects in the graphics window. Thus, the designer can retrieve helpful information previously entered into the system about a CAD building block such as a refrigerator.

If one would attempt to adapt the PHIDIAS concept to planning problems, several peculiarities of CAD vs. GIS and several restrictions of the PHIDIAS concept would have to be addressed:

- Designers construct a drawing out of single elements (workpieces, building blocks), while geographers and cartographers decompose reality into map elements, to some extent in an arbitrary manner. Thus, a reference to a CAD element is definite, while a reference to a map element can bear connotations; two users pointing to a common map element, may have very different views on the real-world object that is represented at this map location.
- The objectives of interior design are generally known at the beginning of the design process and they can be measured. In contrast, objectives and constraints of planning problems evolve during problem solving. Remember that Rittel considers defining the problem as being the main difficulty with wicked problems.
- McCall et al. (1990) do not mention concurrent user access. But even if PHIDIAS would provide this feature, it must be noted that in a CAD workflow, designers have a common goal, while in different steps of a planning procedure, stakeholders have diverging goals. This fact requires a tool that supports negotiation between participants.
- The IBIS component of PHIDIAS resembles a static knowledge base, which supports a user in his/her design decisions. In a planning procedure, arguments come in and enlarge the issue base much more dynamically that in the design case, requiring other kind of administrative support and moderation.

In his paper, entitled “On Drawing Lines on a Map”, Smith (1995) comments on the importance of spatial boundaries and the difficulties of “translating ink-lines of a certain thickness on paper into working territorial borders on the ground”. This is a technical problem though related to the cognitive problem of stakeholders in planning, who may have different understandings of a plan proposal and different mental maps of the physical context of the planning project. Such “human conceptions [...] in land-use debates” are focused on by Gottsegen (1995) and the connotations that people have when reading (planning) maps are addressed by Couclelis and Gottsegen (1997). To reveal the interests and the reasoning of stakeholders in planning discussions, Gottsegen (1998) uses a derivate of Toulmin-based logic (TBL) for assessing the geographic references of stakeholders’ positions in a land-use debate. In a sample backward analysis, geographically referenced arguments are formalized with an extension of TBL and written as logical formulas. For example, “∼(put(industry, middle(residential area)))” represents the speech act “Don’t put an industrial facility in the middle of a residential area”. Gottsegen aims at conflict resolution through the evaluation of “consistency in the conceptions of regions and relationships between them”. In other words, if two discussants with related arguments refer to the same areas, using different relationship attributes (e.g. near vs. far), the formal analysis of the debate should help to detect this discrepancy and make it explicit.

Gottsegen’s approach seems to be very useful though relatively far from an implementation. Unfortunately, he does not suggest methods for visualization and querying of formalized de-

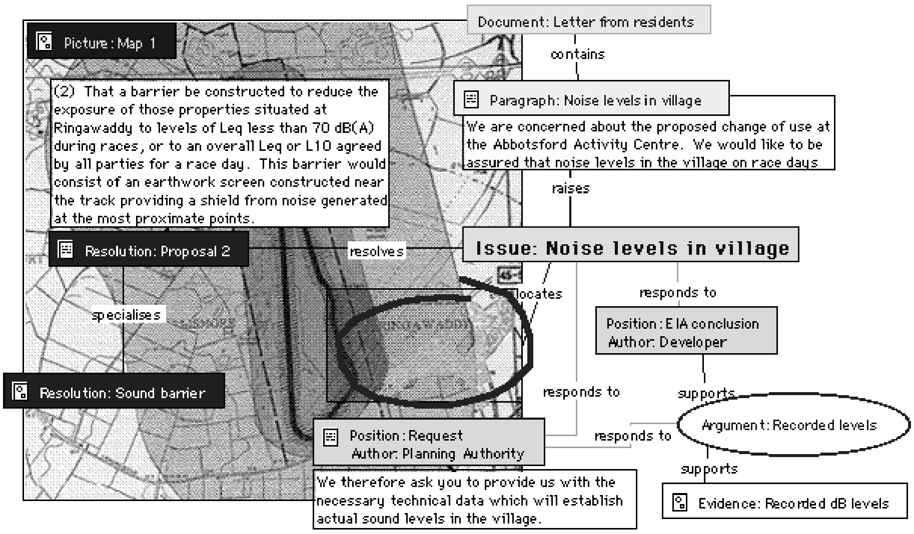

Figure 2.7.: Map-based document network using CrossDoc (Tweed, 1999)

bates. A prototype of a much more visual argumentation support tool has been presented by Tweed (1997). His CrossDoc implementation helps users in constructing map-based document networks (see figure 2.7). The main limitation of CrossDoc is that it lacks multi-user accessibility.

Like CrossDoc and the video-conferencing tool presented by Cowen et al. (1999), the Ptolemeus system that has been implemented in the GeoMed project works with commented user drawings on top of map images. The drawback is the missing link to delimited map elements. Even if a free drawing may better represent the intention of the user, linking annotations to one or several existing map elements would ease further management and analysis of annotations.

2.3.4. Data integration through Internet techniques

Argumentation processes within collaborative spatial decision-making can be supported by hypermedia document management and information structuring techniques. In an environment where multiple participants of a discussion are distributed geographically, computer networks will be used as a medium to access shared workspaces. The Internet and the World-Wide Web have raised hopes that citizens can be provided with open and free access to community documents and data. The GIS industry and research community have introduced Internet map servers and online GIS to provide access to geographically referenced data. See the articles by Fitzke et al. (1997) and Rinner (1998b), or the book by Plewe (1997) for an overview of general WebGIS concepts and techniques.

A tool for the exchange of non-geographic documents—text, images, and any other kind of WWW-compliant document types—is the BSCW system (Bentley et al., 1995, and `http://bscw.gmd.de/`). BSCW (for "Basic Support for Cooperative Work") is a groupware tool

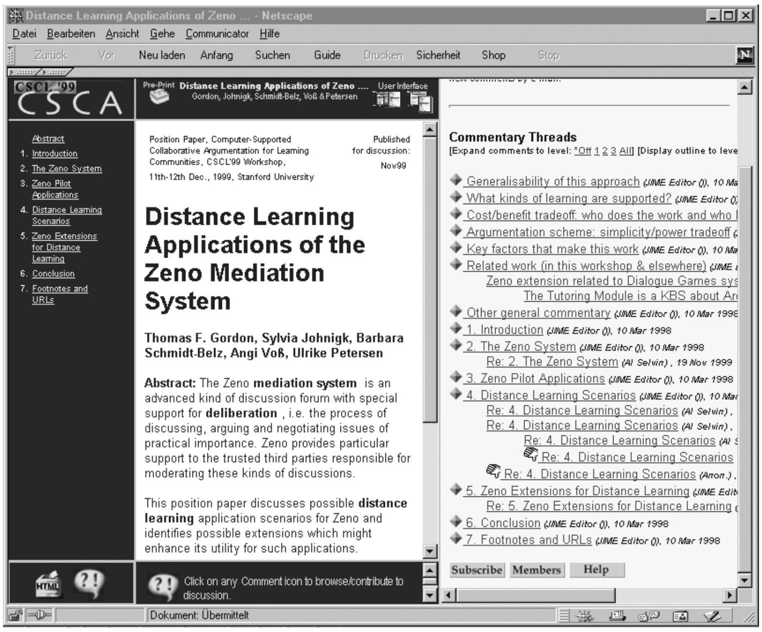

Figure 2.8.: The D3E system, applied to a paper for the workshop on Computer-Supported Collaborative Argumentation for Learning Communities (source: `http://d3e.open.ac.uk/cscl99/Gordon/Gordon-t.html`)

with shared workspaces, user management, integration of electronic mail and many other features which requires only a common WWW browser on the client side. The GeoMed system builds upon the ideas of BSCW, but complements it with mediation services that support argumentation procedures. As a central component of GeoMed, the Zeno meditation system adds discussion forums as a specific kind of shared workspace. This means in particular that the contributions to a debate are seamlessly integrated with related documents, via WWW hyperlinks (see description in section 6.1).

In a scenario where any piece of information, as long as it resides on a WWW server, is integratable in an information base, there is no *external* information. The availability of information is rather controlled by user access rights, in the sense that public access can be restricted in various sub-systems, e.g. in Extranets and Intranets.

The examples of document annotation in the WWW provide an interesting parallel to plan annotation. The publicly available DocReview tool, described by Hendricksen (1999), allows authors of HTML documents to invite colleagues to comment on their texts. When initiating a review process for a document, the author sets up areas of the document to be annotated. As a default, these review segments are HTML paragraphs (`<P>` tag). A similar approach is implemented in the Digital Document Discourse Environment (D3E) by Sumner and Buckingham Shum (1998). Figure 2.8 shows the tiled-window interface of D3E applied to a research paper. To the left is a HTML version of the paper for reading, to the right is a list of discussion threads referring to different sections of the paper. In a commercial tool, ThirdVoice (http://www.thirdvoice.com/), visitors of WWW pages can annotate these without the author's permission. Annotations can be placed at any point in the text and are stored on a server of the software company. Other visitors of an annotated WWW page who have the ThirdVoice plugin installed, see the comments in the text an can add their own ones. The parallel between commenting online texts and annotating online maps is in the reference of the input: placing comments at an arbitrary point in the text is similar to locating annotations on a raster map or map image; linking comments to predefined text segments resembles referring to elements on vector maps. Just as text paragraphs consist of phrases and words, vector elements are composed of a number of atomic (geometric) parts, lines and points. Both domains of collaborative work show the trade-off between unstructured and structured comment location, providing more (less) flexibility to the user, but less (more) opportunities for post-hoc analysis.

In planning applications, the combination of hypermedia with maps leads to the label *hypermaps*. Hypermaps, according to Kraak and Driel (1997), "are defined as georeferenced multimedia systems" and "will let users navigate data sets not only by theme but also spatially." In this definition, we have to add "documents" to "data sets", in order to include map-based access to planning documents and discussion contributions. When navigation from map objects to documents and vice versa is to be supported, one could speak of *object-based* hypermaps. This understanding contrasts with the original definition of hypermaps by Laurini and Milleret-Raffort (1990), who emphasize *coordinate*-based organization and access from raster maps. This method would not suffice for the application of hypermaps to support planning as described in the following chapters.

Hypermaps are currently worked on by the International Cartographic Association's (ICA) Commission on visualization (http://www.geog.psu.edu/ica/). In their understanding, navigation with hypermaps is closely related to data exploration as described in section 2.1.4.

Voisard (1998) describes geologic hypermaps, whose characteristics and requirements seem to be similar to the peculiarities of planning hypermaps described above. For example, geologists require links between text documents containing scientific assumptions and the thereby specified geologic objects. This corresponds to the links between subjective discussion contributions and objects on planning maps. Voisard also suggests specific link types that go beyond traditional hyperlinks. It is indeed important to note the difference between geologic or planning hypermaps and the hot links concept provided by commercial GIS products like ArcView GIS (ESRI, 1996, p. 134f): *Hot links* provide only one-way links from a map location to a related piece of information (e.g. a picture). Hot links as well as traditional hyperlinks are unique (connect to only one target), uni-directional and there is commonly no relation structure among the linked documents or data. This is in contrast to the multiple, bi-directional, and typed links between map locations and the structured argumentation spaces required to support planning discussions.

Similar to Voisard's example from geology, hypermaps that are used for discussing spatial planning projects must support cooperation between distributed people. Therefore, Rinner (1997b, p. 827) calls hypermaps which are "accessible online by multiple users in a spatial decision-making context" *cooperative hypermaps*.

Hyperlinks between map objects and some kind of thematic data or documents may not only enhance visualization of geographic data. They may also enlarge our understanding of GIS attribute data and support "out-sourcing" thematic information into autonomous, geo-referenced objects. This observation may especially hold for *documents* with a relation to the Earth' surface. In contrast to numerical (e.g. surface, population) or ordinal (e.g. land-use classification) attributes of a geographic feature, documents can be related to one another not only through their spatial references, but also through their contents.

Goodchild (1997) explores the consequences of "the transition to digital information handling" for libraries. In an analogy to central facilities location theory, Goodchild defines digitized maps, photographs, articles, or books, as *information-bearing objects* (IBOs). These "atomic information entities" are the goods that are stored, indexed, and retrieved on users' demand. An IBO, the contents of which describes a regular region of the Earth's surface, is called *geographic* IBO. In the case of an imprecise, perhaps non-rectangular geographic "footprint", Goodchild describes IBOs as being *geographically referenced*.

To establish the liaison with map-based discussions, an argumentation messages may be seen as a geographically referenced IBO. For example, a message containing an argument against a planned industrial area is to be stored in a public discussion forum, is to be indexed for hypertext browsing, and is retrieved by participants of the discussion, just like Goodchild's IBO, with the electronic discussion forum taking over the role of the digital library. The argumentation message is an IBO that is geographically referenced to the location of the planned industrial area (plus, maybe, more affected areas).

Owing to the library metaphor, the IBO concept handles quite *isolated* pieces of information. In contrast, people's arguments are not only linked to space but highly related with each other, and therefore can hardly be treated separately, one argument from the other. This makes a difference because discussion support models must represent not only spatial references of arguments but also inter-argument structures. Whereas a reader's request may be answered by a single library object, a stakeholder's examination of, and participation in, a geo-referenced debate may start with a simple IBO request, but requires further support from then on. But if one interprets IBOs as the kind of *objects* of the object-oriented approach in computer science, this would allow to add any structural and behavioral characteristics to them. This modeling approach is chosen in the following chapter.

Excursus Goodchild (1997) observes that the demand for geographic IBOs varies with the location of the potential user, in contrast to the ubiquitous goods in central place theory he is starting from. The author introduces another acronym, IGDI, for "information of geographically determined interest".

IGDI is Goodchild's answer to the issue whether the Internet will "destroy geography": As long as the real world plays a role in information *contents*, the associated information space and its usage will not be homogeneous. For example, citizens are more likely to participate in an Internet forum about planning in their home town than one of a city in a foreign country or even that of a neighbouring town. Franck (1997) supports this idea by distinguishing between space as a distance measure and space as a limited resource. It is true that the emergence of computer networks and Information Highways reduces the importance of space as a distance measure. Think e.g. of efficient communication between researchers via electronic mail and of tele-working. But Franck shows that space does not lose its function as a limited resource, but rather becomes more and more important in this respect. Urban and regional planning perform the task of allocating concurrent uses to limited geographic space and thus will gain significance in the information society age.

2.4. Conclusion

Spatial planning is successively becoming a more communicative activity within different levels of communities. Recording argumentation in internal discussions and public debates improves the usability of what was said by participants. For example, the rationale behind some decisions can be re-used in similar planning problems or in later discussions about the same planning area.

Public participation as well as the work of professionals in planning can be eased using information and communication technology, especially Internet-based technology. Geo-referenced discussion procedures require a combination of Groupware tools, which provide facilities for exchanging documents and messages, and Geographic Information Systems which provide functionality for storing and retrieving geo-referenced messages.

Neither automatic geographic indexing nor automatic evaluation of a state of a discussion seem to be realizable at the moment or acceptable by the potential users. But through the concepts of hyperdocuments and cartographic exploration, the handling of geo-referenced debates will become much easier, even with no changes in current procedures. Planning-related arguments will be clarified and implicit assumptions of discussants revealed.

As a consequence, the following model of geo-referenced discussions differs from existing approaches insofar it emphasizes the formal structure of discussion elements and the reference of discussion elements to plan elements (as opposed to coordinates or user-drawn symbols) and to relations between plan elements. The linkage between formal models of argumentation and data models for geographic information that is presented in this thesis aims at advancing both, Groupware and Geographic Information Science.

3. A model of geo-referenced discussions

The aim of this chapter is to formalize computer-supported discussions of maps. The chapter begins with an overview of the situations where people discuss spatial planning projects on the base of a planning map by means of asynchronous telecommunication facilities. The requirements for a general model of geo-referenced discussion are worked out, and the resulting Argumap model is described in detail. The object model presented here is meant to be independent of any implementation; it is the core conceptualization of the geo-argumentative situation described in the next section.

3.1. Overview and modeling requirements

Figure 3.1 outlines the situation of people discussing a spatial planning project. A person may have a distinct opinion about a planning detail, which in turn is based on his/her mental model of geographic reality and on his/her understanding of the planning project. The relationship between people's opinions and reality is difficult to grasp. The approach of this thesis is to provide a framework to handle this relationship in a computer-based information system, by means of well-defined relations between speech acts and elements of a planning map.

Owing to established German planning procedures, a draft zoning plan is taken as the pivot of discussion. This draft plan is a map and therefore a model of reality that is modified and

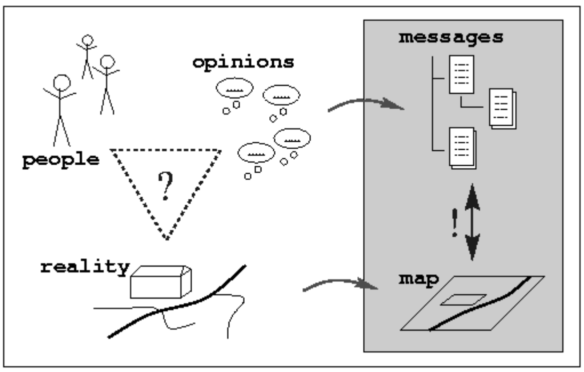

Figure 3.1.: People discussing a spatial planning project

complemented by some planning elements. The plan is, in general, agreed upon as being a sufficiently objective model of reality because it has been created by experts, e.g. city planners. In the context of computer-supported planning, plans are digital objects. In addition, the opinions of people are manifested in the form of electronic messages in discussion forums. A “loosely” geo-referenced kind of discussions could be run via a Usenet newsgroup with news articles referring verbally to a map image somewhere on the World-Wide Web.

The Argumap model described in the following sections provides a conceptual framework to improve this technique in both respects: Discussion messages are broken down into argumentation elements that are hierarchically structured according to an IBIS-type model of argumentation (cf. chapter 2). And the geographic references in an argumentation element are made explicit by linking them to map elements instead of referencing the map as a whole. The map representation type (vector vs. raster map) does not influence the concept of Argumaps, because people’s references will generally concern geographic objects. (Technically, indeed, there is an important difference, because in the vector case, geo-objects are directly represented by map elements whereas they do not exist as data entities in a raster image.) The purpose of an Argumentation Map is to use some attributes of argumentation elements, map elements and their linkage, to provide powerful navigation and analysis functions for the stakeholders in spatial planning.

An additional requirement on the Argumap object model is to cover both, spatial constructs and spatial concepts. A spatial *construct* is something “visible” on the earth, like a road, a lake, or a hill. A spatial *concept* is a mental model of a person that joins spatial constructs with opinions, e.g. the main station must better be integrated in the city centre, and especially with emotional feelings, e.g. the streets around the main station are dark, frightening. Spatial concepts play an important role when discussing a planning project and thus should be handled by argumentation support tools.

The purpose of presenting an Argumap model here is to dissociate clearly those aspects of geo-referenced discussions that have to be taken into account from those that can be omitted. In its class names and its use of attribute lists, the model reflects its focus on the planning domain. But a transfer of the overall structure of geo-referenced argumentation to other application areas seems feasible and is discussed in the final chapter.

The following diagrams have been designed according to the Unified Modeling Language (UML) (Rational, 1997; Harmon and Watson, 1998). The use of the syntax elements is explained in appendix A.

3.2. The Argumap model

As shown in figure 3.2, the proposed model for geo-referenced discussions is composed of the following six entities:

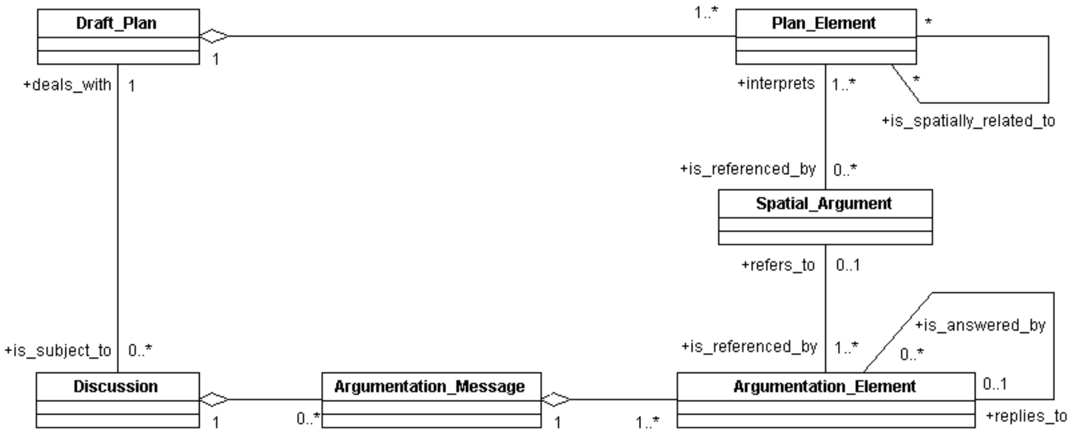

Figure 3.2.: Overview of the Argumentation Map model

- Draft plan
- Plan element
- Discussion
- Argumentation message
- Argumentation element
- Spatial argument

A draft plan can be subject to several planning discussions. This is represented by the *is_subject_to* relation in figure 3.3 and the cardinality of zero or more instances. Examples from a planning workflow are internal discussions among planners of one authority, participation of other agencies, and public debates. Each discussion concerns (*deals_with*) exactly one draft plan. It could be argued that with the application of information and communication technology it should become possible to consider alternative planning proposals in the form of several distinct draft plans or of a single draft plan with several alternative planning measures drawn on it. Indeed, concerning the public participation in city planning, the German legislation requires that citizens be informed of alternative planning solutions (Beck, 1996, §3(1)). But in general, at an early stage of planning, the city administration submits a single plan proposal to the public. And a distinction is to be made between this official draft plan and possible alternatives proposed by other interest groups during the planning procedure. It seems not to be a restriction in the usability of an Argumap that only one map, the official draft plan, is provided for locating arguments. The cardinality of one for the *deals_with* relationship, therefore, is not considered to be an obstacle to free discussion, particularly since any discussant may include plan alternatives or links to external drafts in the full wording of his/her contribution.

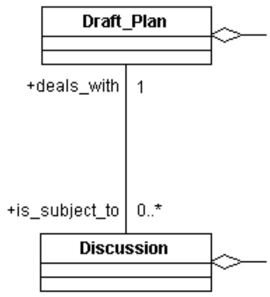

Figure 3.3.: Draft plan and discussion

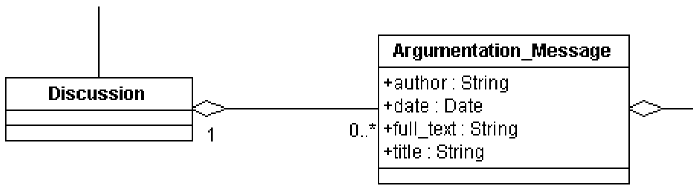

Figure 3.4.: Argumentation messages

Figure 3.3 shows the presently common, *loosely* geo-referenced, type of discussion. Draft plan and discussion objects in figure 3.3 have no attributes. The remaining entities of the model overview shown in figure 3.2 and the associations between them are discussed in the following paragraphs using similar enlarged details as for the relation between draft plans and discussions.

3.2.1. Argumentation elements

According to the Zeno model of argumentation (see sections 2.2.2 and 6.1), a discussion is divided into *argumentation messages* as shown in figure 3.4. An argumentation message has the properties *author*, *title*, *date* (of arrival at the server), *full text*. The author is the name of the person or institution who wrote the message. In the Zeno forum, participants are identified through their role. A person could for example discuss as a planner during working hours and as a citizen in his/her free time. Thus, to represent roles of participating professionals, the *author* attribute would contain the name of an organization or a title, instead of or in addition to the person's name. It is an open issue of privacy protection whether or not Internet discussion forums should reveal the real-world identity of participants. To cope with both cases, the author attribute can contain a pseudo ID ("guest", "anonymous") in the case of hidden identity.

The *title* property contains the user-defined title of the message. Users are to be instructed

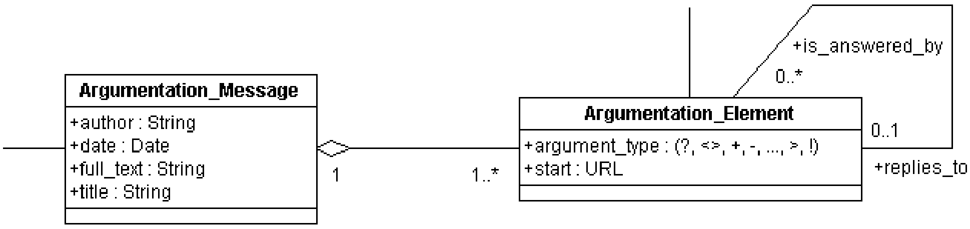

Figure 3.5.: Argumentation elements

to choose short, meaningful titles to appear in message lists. The *full text* attribute of an argumentation message contains the statement of the author in its original form, as it arrives at a discussion server, for example via electronic mail or as a newsgroup contribution. The date and time of arrival are automatically stored in the *date* attribute.

Each argumentation message contains one or more logical parts, its *argumentation elements* (cf. figure 3.5). Argumentation elements partially formalize the contents of an argumentation message. An argumentation element has an *argument type* property that defines its role in a discussion tree, and a start location in the full text of its parent argumentation message. The symbols in figure 3.5 hint at the possible values for the argument type in the Zeno model, that is issue (?), position (<>), pro argument (+), contra argument (-), comment (...), preference (>), or decision (!).

An argumentation element either stays independently at the root of an argumentation tree, or it *replies_to* one previously stated argument. In turn, each argumentation element can be answered by several other arguments (*is_answered_by* relation with cardinality of zero or more). For example, two pro arguments and one contra argument may reply to the same position. The exact Zeno model with its constraints on the relations between argumentation elements—e.g. a position can only reply to an issue or another position, not to a pro argument (see Gordon and Karacapilidis, 1996)—is not reproduced in the model, because it is not constituent for linking arguments to map space.

3.2.2. The geographic location of arguments

This part of the model shall provide users with a means of linking their arguments to plan locations. Examples of geographic references of discussion contributions that have been found in a traditional planning procedure are: the author's home location, the street network in the planning area, a single street, a complete municipal district, and the entire planning project. Plan elements that could represent these geo-references are very varied: a point or polygon, a linear network, i.e. a set of polylines, a single line, a larger plan area, or the plan as a whole. These plan elements are approximations for the geo-references expressed in the wording of discussion contributions.

In the idealized Argumap scenario outlined in the introductory scenario (cf. chapter 1), geographic references have not been added subsequently to a verbal statement, but together with it. Thus, authors would be asked to submit geo-references together with their contributions. In this respect, the Argumap model proposes new and more accurate possibilities for linking arguments to a plan, in comparison to the purely descriptive way in traditional participation procedures. Furthermore, it is presumed that an author will find a suitable plan element for all his/her geo-referenced arguments. Thus, cognitive and modeling problems of mapping real-world objects to plan elements are not discussed here. In the case of a parallel use of Argumaps with traditional ways of public participation, it would be possible to index manually those arguments that have not been provided with a geographic reference by their author.

Authors of geo-referenced arguments in computer-supported discussions should be enabled to specify different kinds of geographic references. First, one has to distinguish references to map coordinates from references to map objects. The first are suitable for raster maps, the latter are possible when a vector map is available. Both coincide if point objects are referenced because their location is identifiable through a single coordinate pair. Relating discussion contributions to vector objects is largely preferred in this thesis in order to allow object-based analysis of the spatial distribution of arguments, as described in later chapters.

Most GIS and drawing software provide users also with an area selection tool in the form of a rubberband rectangle. When a user selects a map area, in the raster case it can be handled through the coordinates of two diagonally opposed corners. In the vector case the selected area has to be mapped to a set of map objects that intersect the rectangle (lying completely within, or overlapping the reference area). In computer implementations of Argumaps, it should always be possible to link arguments to meta-objects, i.e. sets of objects or object-independent map areas, in order to augment the users' ability to freely express their geo-referenced arguments.

A draft zoning plan like a German land-use plan ("Flächennutzungsplan") consists of a graphic description in the form of a map and a verbal description ("Erläuterungsbericht"). Both refer to existing objects and planned objects. For example, an existing municipal district is characterized in its population structure, in order to argue for a neighboured new housing area. Planning objects can coincide with existing objects that are changed in some property. For example, the land-use of a part of a district is changed from pure housing to a mixture of housing and commerce. It is assumed that a distinction between map and textual description of planning areas is not necessary for the purpose of this work. In other words, any regulation of the textual description can be associated with one or more map element(s). This or these can therefore serve as reference for an argument that relates to the textual plan description.

Arguments in a planning debate need not always have a geographic reference. This is true for statements containing a general opinion for or against a planning project. A participant

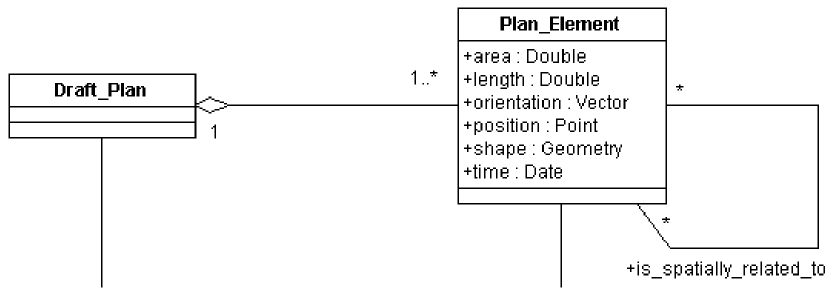

Figure 3.6.: Plan elements

could e.g. contest the necessity of modifying a valid land-use plan at all. It would not be sensible to provide a map reference for such an argument. Thus, it is helpful that arguments may be accessed by the index provided by the argumentation model (cf. section 3.2.1), in addition to the map.

In summary, the model of geo-referenced discussions provides means to link arguments to plan elements, i.e. spatial objects. As shown in figure 3.6, a plan element belongs to a draft plan. On the other hand, each draft plan consists of a number of plan elements—at least one, but generally many more.

3.2.3. Properties of plan elements as target of arguments

The properties of a plan element can be grouped into geometrical, graphical, temporal, and thematic properties. According to Worboys' interpretation (cf. section 2.1.1), existing topographical objects have geometrical and graphical properties, while planned objects, that do not yet exist in reality, would only have graphical, i.e. map presentation-related, properties. In addition, spatial topology is the property that distinguishes geo-objects from geometric ones. But whereas the classification of properties can be important for GIS modeling purposes, for Argumaps, all relevant object properties should be presented to the users in a uniform list.

The properties of plan elements, as displayed in figure 3.6, are *position*, *shape*, *length*, *area*, *orientation*, and *time*. The property set of a plan element partially depends on its geometrical type. Plan elements are assumed to be objects of type point, line, or polygon. The *position* property represents the coordinates of a point object or the location of a label point of a line or polygon object. The *shape* property is void for a point object or raster coordinate, but represents the actual curve of a line object and the boundary of a polygon. The *length* property can only be used for line objects, the *area* property only for polygon objects. In other cases the properties are set to a void value. Length and area often are not stored in a GIS but rather are calculated on demand. They could therefore be modeled as a method—e.g. getLength() for line objects—but the model presented here does not take into account this kind of implementation details.

Time-related attributes could represent the commencement of construction of a planned object, the completion date, the average life time, or the destruction date.

The plan element class, as modeled so far, does not represent thematic properties. The idea is to keep the geo-argumentative model as general as possible. The results could be further refined for specific domains or planning levels (e.g. land-use vs. building plan) that influence the allowed classes of geo-objects. Then, thematic properties could be the land-use form or restrictions to it, the importance level of roads, etc..

The link between the argumentative level of a planning debate and the geographic space, subject to discussion, is visualized in figure 3.7. This detail of the complete model shows that argumentation elements refer to zero (see introduction to this chapter) or one *spatial argument*. Conversely, a spatial argument is referenced by one or more argumentation elements. The minimum cardinality of one is chosen to demonstrate that spatial arguments largely depend on the arguments that refer to them. This means that a spatial argument becomes visible for the model, only when at least one argument refers to it.

A spatial argument represents a user's *interpretation* of plan elements. A plan element can be interpreted by zero or more spatial arguments. The spatial argument with its *theme* property is a means of referencing either one plan element together with a property, or several plan elements together with a relation between them. For example, a discussion participant who disagrees with the planned surface of an industrial area, could link his/her argument to a spatial argument that interprets the industrial area polygon on the map and its area property. If a participant wants a new bus stop to be closer to his/her house, his/her spatial argument would address the bus stop point and the home location (point or polygon), together with the distance relation between the two. The spatial argument thus represents a user-centered view on reality and can be used to join related objects under a specific theme. In practice, the theme information would be implemented as a choice from a list of property and relation names (keywords), in order to store semi-structured information.

3.2.4. Spatial relations as target of arguments

The allowed properties of plan elements addressable in a discussion contribution are shown in figure 3.6. Concerning allowed relation themes the model leaves an administrator the flexibility of providing a list of useful spatial relations. For example, the OpenGIS Simple Features Specification (OGC, 1998) contains a sample set of "Spatial Relations between geometric objects", namely Equal, Disjoint, Intersect, Touch, Cross, Within, Contains, or Overlap. Whenever a discussion contribution contains such a relation predicate (e.g. "the railway must not intersect the forest"), a spatial argument exists, the theme of which is a topological relation between two or more geo-objects (represented by appropriate map elements). It seems reasonable to use an unspecified "topology" value for the theme property above, instead of a fine-grained but possibly confusing list of spatial relations.

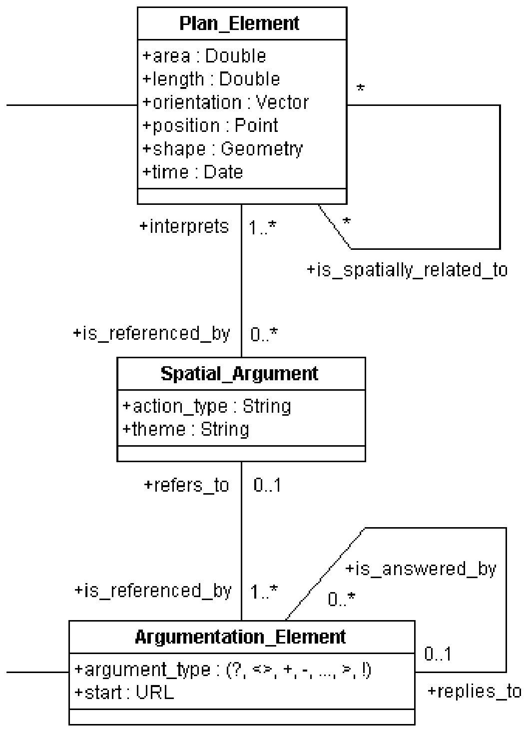

Figure 3.7.: Spatial argument

Further spatial relations, as described in chapter 2, are distance and direction. These are found in many argumentation elements and thus are on a level with topology. Distance and topology are not completely disjoint concepts, insofar as short distances could be confused with “touch”, “cross” or “intersect” relations. Example: “The railway should pass farther away from the houses.” is similar to “The railway should not touch the housing area boundary.” It can be assumed that the distance related statement will be more popular because of its fuzziness, and thus, the distance relation would be used for modeling the spatial argument of the participant.

The other two types of relationships among geo-objects, mentioned in chapter 2, are aggregation and classification. On the one hand, in figure 3.7, aggregation of simpler geo-objects to form more complex ones is implicitly modeled through spatial arguments, because these collect plan elements to build high-level, conceptual entities. On the other hand, aggregation is not provided in the plan model of figure 3.6, where plan elements cannot be complex objects. A draft plan is seen as a flat collection of plan elements. Complex objects need not be modeled in the geographic database, because they are conceived by the viewer of a plan and can be handled through spatial arguments, as described above.

The classification of geo-objects into thematic categories is a relation that helps to organize larger sets of geo-objects. In the planning domain, the classification of a planned object (e.g. a industrial area) also determines the intended land-use function of the object. Thus, classification can very well be the target of an argument. For example, the statement "don't establish an industrial area here" concerns the classification of an area, not its existence in general. As said before, thematic classification depends on a specialization of the Argumap model for a domain and is not the purpose of this thesis.

Variants and versions of geo-objects in the sense of chapter 2, relying on an alternative or a temporal relation to a base object, are not included in the model. This has the advantage that implementations will not require the plan to be stored in a geographic database capable of managing versions of objects.

Reference map elements	**Allowed *themes of arguments***
single	position, shape, length, area, orientation, time, other
multiple	topology, distance, direction, classification, other

Table 3.1.: Possible *themes* of spatial arguments

Table 3.1 summarizes the use of the *theme* property of spatial argument objects in the model. If the spatial argument refers to a single map element, its theme may concern one of its properties, including an *other* flag that indicates that another property is addressed in the referencing argument. This is particularly helpful for addressing thematic, application-dependent properties that cannot be included in the set of properties in the general model presented here. If the spatial argument collects multiple map elements, its theme may be one of the predefined geographic relations or an *other* relation, what could again be helpful in representing application-specific facts.

3.2.5. The design intention of the argument

The *action type* property of a spatial argument reflects the intention of the author of the corresponding argumentation element with respect to the referred geo-object(s) and their property or relationship. Some sample demands that could be contained in arguments are:

- Keep an object as it is
- Create a new object
- Remove an object
- Change its position (move) or its shape
- Change its length, area, or number of components

- Change/keep another attribute of an object

- Keep two objects as they are
- Remove one out of two objects, or both
- Establish a minimum distance between them (implying a position change for at least one of them)
- Change/keep another attribute of one or both, according to a specified constraint

The allowed values for the action type of spatial arguments are thus proposed to be *keep*, *change*, *create*, or *remove*. The sense of the *keep*, *change*, and *remove* actions should become clear reading the above examples. The *create* action is the logical converse of *remove* and suggests itself in the context of user statements like "I would like to have additional sports facilities in that district". A certain difficulty arises from the fact that the required object cannot be referred directly by a map pointer, because it does not yet exist on the draft plan. Instead, the user has to refer to a nearby object (the district) that would either contain the new object or touch it. Unfortunately the model does not allow one to specify the new object, as it is not contained in the official draft plan. This choice was made to keep the discussion simple by limiting it to a single reference plan.

3.3. Observations

Some observations concerning potential geographic references of arguments shall be added that are not covered by the above model but could be considered for implementing Argumaps:

- It might be useful to allow the user to distinguish a primary geo-reference from secondary geo-references of a discussion message or even allow the user to provide a free weighting factor within a predefined range, to show the relative importance of different reference objects for his argument.
- Problems with granularity of geo-references may occur, if inspecting and writing contributions take place at different map scales. In order to cope with generalization problems of geo-referenced arguments, hierarchical concepts in map generalization and spatial reasoning (see Car, 1998; Timpf, 1998) and a level-of-detail concept (see Coors and Flick, 1998, and a prototype in section 6.2 of this thesis for an application of the VR modeling language) should be taken into consideration.
- The geo-references of two related argumentation elements, e.g. a position and a contra argument to it in an Issue-Based Information System, are not independent of each other.

Instead, a concept of automatic inheritance of geo-references from higher level contributions to their replies could be imagined. In this work, such derived geo-references are not stored redundantly with each argument, but must be found through appropriate traversal of the messages in a discussion forum.

The object model for Argumaps presented in this chapter provides a means of linking an argumentative space to geographic space representation on a digital map. The model is not formal enough to support logical (predicate) modeling as in the approach by Gottsegen (1998), but it provides sufficient structure to detect argumentative relations between geo-objects (see next chapter) and to implement Argumaps (see chapters 5 and 6).

4. Argumentative relations between geographic objects

This chapter discusses the potential of the model described in chapter 3 to support geo-referenced debates. Section 4.1 describes why arguments with relations to geographic objects cannot be interpreted as attribute data to these objects in a classical GIS sense. As a consequence, section 4.2 outlines a view of arguments as an extension of geographic space. Finally, in section 4.3, argumentative relations between geographic objects are taken as approximations for spatial conceptions of discussants in geographically referenced debates.

4.1. Arguments as GIS attributes?

In the following paragraphs, some characteristics of the spatial and the argumentative level of the Argumentation Map model of chapter 3 are shortly recapitulated. Then, the nature of the link between geographic objects and arguments is analysed from the GIS perspective.

In the object-based model of geographic information, discussed in chapter 2, Geographic Information Systems handle geo-objects with attributes. The two typical questions asked to GIS (see page 13) reveal two kinds of information,

- geo-objects and relations between geo-objects via attributes (*Where* is ... ?)
- attribute values and relations between attributes via geometry (*What* ... is *here* ?)

For example, the Where-is question can deliver several disjoint geographic objects that have the same value for an attribute, thus can be grouped together in a map layer. The What-is-here question can deliver values for two attributes in a region, allowing to calculate the correlation between these attributes.

On the side of the discussion forum, arguments are also treated as individual objects with their own attributes, including a unique identifier. Arguments have a very different appearance from alphanumerical GIS data; they have potentially large (in terms of word count) contents and can be understood in isolation, without an explicit link to geo-objects. Additionally, a discussion has an internal structure, that is arguments refer to each other in a predefined way, given by the argumentation model, e.g. the IBIS model. Characteristics like uniqueness, complexity, and internal relationships are not present in classical, alphanumerical GIS attribute data. From a formalistic viewpoint, thus, arguments *cannot* be called "attributes" of geo-objects. From the contents' perspective, arguments reflect *soft* information, as defined by Malczewski (1999, p. 12) ("opinions ... of decision-makers, based on intuition ..."), in contrast to classical GIS attributes that contain *hard*, numerical data.

But are arguments geo-objects on their own? The verbal geo-references in the text of discussion contributions link arguments to some geo-objects, in this case planning objects. According to the notions introduced in section 2.1.1, geographic objects would reference *geometric* objects. Indeed, according to the Argumap model, plan elements referred to by arguments, are geometric objects as they do not contain any thematic information that would qualify them for being geographic objects. But, as clarified in section 4.3, the geometric shapes on a planning map are simply vehicles for discussants to refer to real-world geographic objects. Thus, arguments refer to geo-objects instead of being geo-objects themselves.

In summary, arguments can neither be treated as attributes of geo-objects nor as geo-objects themselves. Argumentation Maps link together geographic (planning) objects and argumentative objects. Argumaps represent

- relations between arguments via geo-objects
- relations between geo-objects via arguments

For example, two arguments could be related to each other, if they reference two adjacent geo-objects, or several spatially distributed geo-objects could be related, if an argument refers to all of them. Hence, Argumaps link together different spaces, as described in the following section.

Excursus It can be assumed that the characteristics unique identity, complexity, and internal relationships can be found in geo-referenced information in a number of application domains, like those mentioned in the context of data integration through hypermedia (section 2.3.4). Generally speaking, the main difference between GIS attribute data and this type of information seems to be that it consists mostly of *documents* rather than *data*. A distinction must also be made between complex, geo-referenced information with relationships on the one hand, and flat multimedia documents that are linked to a map through *hot links* by some commercial GIS vendors on the other hand.

The following section defines argumentative relations between geo-objects and geo-argumentative spaces as a theoretical framework for the map-based retrieval of arguments, described later in the present thesis (cf. chapter 5). The definitions use the fact that discussion contributions provide an additional dimension to geo-objects. The final section of this chapter depicts the usefulness of argumentative relations between geo-objects for clarifying what is behind some discussion contributions.

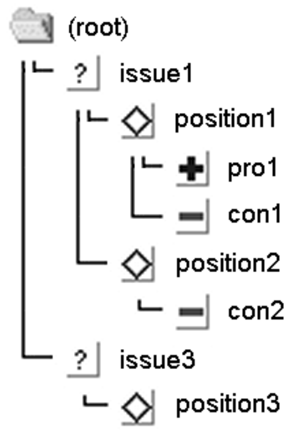

Figure 4.1.: Distance between arguments as an indicator for geo-argumentative distance

4.2. Geo-argumentative spaces

In general, the analysis of the spatial distribution of geographic phenomena is essentially based on the distance and topology relations, i.e. on the distance between geographic features and on their neighbourhood. For example, starting from a specific element of the plan, it may be interesting to know, which other elements are neighboured to the first one in terms of *argumentative* proximity; it may be useful to be able to say how close two plan elements are with respect to the arguments they are referred by. In this section, a rough definition of argumentative distance and argumentative neighbourhood of geo-objects is given. The distance function rests on the proximity of arguments within the argumentation model—demonstrated within the IBIS model—, while the neighbourhood is defined on the base of that distance function.

4.2.1. Argumentative distance

Issue-Based Information Systems (see section 2.2.2) organize argumentation elements in a *forest* model the layout of which depends on the argument type and on the reply relation between elements. In general, a discussion consists of a number of *trees* with an issue or position at the root of a tree, and positions and pro and contra arguments replying to it. The depth of a tree is not limited because pro and contra arguments can be hierarchically nested.

As a first approximation, the proximity of argumentation elements can be defined as *near* (or 1), if elements belong to the same issue-position tree, and *far* (or 2), else. The number 0 would be reserved to express that an element is *identical* to itself. For example, a pro argument and a contra argument that belong to the same issue, are near (pro_1, con_2 in figure 4.1); two positions that respond to two distinct issues, are far from each other ($position_1$, $position_3$

in figure 4.1). Obviously, this definition does not take into account that two distinct issues, together with their depending argumentation tree, may be semantically very close. This is due to the fact that argumentation models do not attempt to formalize the contents of a debate.

In the above example, two arguments replying to one position (pro_1, con_1 in figure 4.1) would be rated as equally distant from each other as two arguments replying to two distinct positions under the same issue (pro_1, con_2 in figure 4.1). In this case, one would expect the latter arguments to be rated more distant.

A second approach to defining geo-argumentative proximity addresses this drawback by using the number of steps required to traverse the argumentation tree from one argumentation element to another element as the distance value d between them. Thus, $d(x, y) = 0$ means that x is the same as y, while $d(x, y) = k$ (= 1, 2, ...) means that y can be reached in k steps (or moves) from x, traversing the argument tree (or argument graph, for certain other argumentation models like the Toulmin model) node by node. For example, $d(pro_1, position_1) = 1$, $d(pro_1, con_1) = 2$, $d(pro_1, position_2) = 3$, $d(position_1, position_3) = 4$ with the argumentation elements of figure 4.1.

This proximity measure fulfills the requirements of a *distance* for a *metric space* (cf. Worboys, 1995, p. 139):

- $d(x, y) = 0$ for $x = y$ and $d(x, y) > 0$ for $x \neq y$, for argumentation elements x and y.
- $d(x, y) = d(y, x)$ (symmetry).
- $d(x, z) \leq d(x, y) + d(y, z)$ (triangle inequality).

With the second distance measure, arguments in distinct subtrees can be nearer to each other than arguments within the same subtree, if the latter is very deep. For example, $position_1$ in figure 4.1 is closer to issue$_3$ than pro_1 to con_2, which are under the same issue. As a variant, the distance could be set to ∞ (infinity) for elements under different issues. But for the uniformity of the definition, this variant is not further considered in the present concept.

The transfer of the distance relation between argumentation elements into the geographic domain is naturally achieved via the links from arguments to geo-objects. This is to say that two geo-objects s and t have the argumentative distance $D(s, t) = d(a, b)$, if argument a refers to object s and argument b to object t, and $d(a, b) \leq d(x, y)$ for any arguments x, y referring to s, t. The argumentative distance $D(s, t)$, thus, is the minimum number of steps to take when starting from map element s and inspecting its referring arguments, before encountering a reference to object t.

The argumentative distance between two geo-objects resembles the lexicographic distance, cited by Worboys (1995, p. 139 and fig. 3.50), where the distance between two cities equals "the

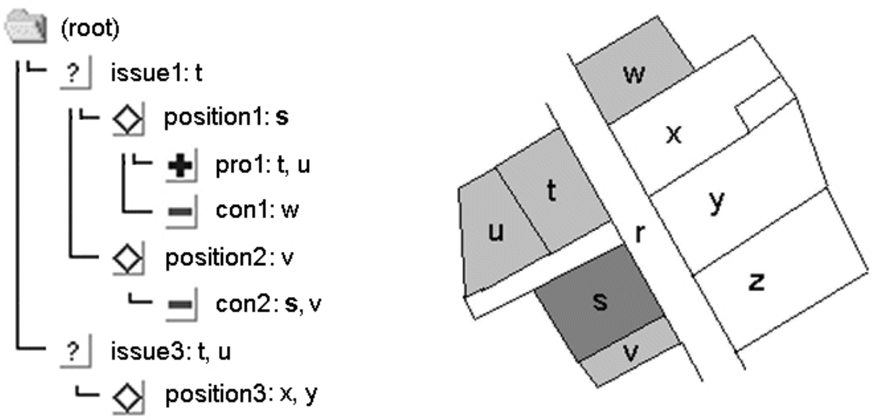

Figure 4.2.: Geo-argumentative neighbourhood

absolute value of the difference between their positions in a list of cities in a fixed gazetteer." In both cases, the distance values are *discrete*, a fact that restricts the comparability between distances. Moreover, it is evident that the set of all geo-objects in a map together with this distance measure is not a *metric* space (see above) because the argumentative distance can be 0 for distinct objects. This is the case whenever two objects are referenced by the same argument. Despite these formal restrictions, it has been shown that argumentative distances between geo-objects can be a base for a consistent definition of (non-metric) geo-argumentative spaces.

4.2.2. Argumentative topology

Worboys (1995, p. 141-143) defines the "natural topology" of a metric space through "open balls" around a point, i.e. sets of points that are within a certain distance of the point—its *neighbourhoods*. Building the analogue in geo-argumentative spaces means collecting in a set those geo-objects that can be reached by a certain, limited number of steps between geography and argumentation.

For example, in figure 4.2, the neighbourhood of object s with the distance 1 is highlighted. The figure demonstrates that a geo-argumentative neighbourhood need not be connected, due to the discontinuous nature of the geographic references of arguments, similar to a public transportation example cited by Worboys.

Argumentative distance and topology allow to model argumentative relations (near, far; neighboured) between geo-objects. The following section outlines the usefulness of geo-argumentative relations for finding implicit assumptions of discussants in spatial decision-making problems.

4.3. Spatial conceptions

Argumentative relations between geo-objects, particularly argumentative topology, are aggregations of spatial features under the theme of the referring arguments. One argument that refers to several geo-objects, creates a distance relation of 0 between the objects, or two arguments, one of which replies to the other, creates a neighbourhood with distance 1 between their referred objects.

Users of a planning discussion forum, like other people, have a mental concept of space that influences their construction of arguments. When a user groups together geo-objects, it is reasonable to assume that these objects have a strong link in the mental concept of the user. For example, a claim for more street lights for several roads near the railway station, could be an indicator of a specific fear area for the author of the message. Or, if people repeatedly ask for a relocation of a railway line between their housing area and a nearby park, these people obviously consider the housing area and the park as a contiguous zone of living and recreation.

The analysis of argumentation elements together with their linked geo-objects and the addressed geographic properties and/or relations, thus, can be used to detect implicit spatial concepts. This perspective helps to overcome the artificial and user-unfriendly partition of space into discrete geographic features, as enforced by CAD and GIS software that are now used in planning procedures. It may reveal cognitive aspects behind planning-related arguments and decision making.

From the viewpoint of data modeling, argumentative relations between geo-objects are a kind of aggregation relation. As proposed in the Argumap model in the previous chapter, these aggregations are not to be stored with the spatial objects (plan elements), but only exist through the link between spatial and argumentative level via the *spatial argument*. This is to reflect the dynamics of a spatial planning debate and the mutual independence of plan elements and argumentation elements.

5. Argumentation Maps

This chapter demonstrates the usability of the conceptual framework for Argumentation Maps presented in chapters 3 and 4. It first introduces a classification of GIS-related functionality and describes potential Argumap systems with reference to these functional groups (section 5.1). Section 5.2 presents Argumaps from the perspective of user tasks, called *use cases* in object-oriented terminology. In section 5.3, requirements for GIS to support Argumap implementations are derived from the functional and use case description.

5.1. Input, presentation, retrieval, and analysis of geo-referenced arguments

5.1.1. Grouping GIS functions

Maguire and Dangermond (1991) introduce the functionality of GIS on base of a classification that "follows the logical progression of a GIS project from data capture, transfer and edit, through store and structure, on to restructure, generalize and transform, then query and analyze and, finally, present." In total, the authors propose ten groups of GIS functions, which could roughly be summarized under data *input, management, analysis, and presentation.* These four groups are often used to describe GIS functionality because they reflect the process of getting geographic data, storing and manipulating them, analyzing them, and presenting the results in the form of maps. This process-oriented view may be consistent with complex GIS projects that are managed with traditional monolithic GIS software, e.g. ESRI's Arc/Info.

In a more modular computer software environment, as introduced with network-based computing, it makes sense to reconsider functional modules of GIS. For example hypermedia linking increases the possibilities of presentation and data retrieval by end-users. In lightweight WebGIS applications (e.g. ESRI's ArcExplorer), data management becomes to a certain extent transparent to the user and thus could be omitted from the functional classification. Furthermore, data retrieval was often seen too close to analysis while it is getting more and more attention in desktop-based and Internet-based GIS applications. In today's GIS workflows, presentation is not always at the end of a task sequence but may be used to get an overview of some data and prepare deeper analysis steps.

This is why an alternative schema, “IPRA”, is introduced here, and used to analyze Argumap applications from the GIS perspective. IPRA stands for “Input, Presentation, Retrieval, Analysis”, where input functions include data management. Augstein and Greve (1994) already use the functional groups presentation, retrieval, and analysis to differentiate tools for spatial data handling. The corresponding classes for cartography, data retrieval, and data analysis range from the least powerful to the most powerful tools, but only consider data *output* functionality. Fitzke et al. (1997) added data *input* functions in the context of GIS applications in the Internet. The motivation of Fitzke et al. for introducing the schema at that time was to group and sort GIS functions by their approximate complexity. In the following sections, IPRA is defined in detail and then applied to Argumaps.

5.1.2. The IPRA schema

The functional groups in IPRA do not differ from those listed above, except for the fact that input and management are united, and retrieval is separated from analysis (cf. Cowen, 1988; Maguire and Dangermond, 1991). Therefore, only novel functions are emphasized in the sequel, e.g. those to be found in WebGIS applications.

The input functions include searching for, selecting, and downloading ready datasets from an Internet server, besides traditional ways of creating geographic data (digitizing, vectorizing, converting).

Presentation is needed directly after data input, in order to verify the data quality and the characteristics of data, and then decide on further data needs or initiate data retrieval or analysis.

The importance of data retrieval increases automatically with more and more GIS data becoming available. Part of these data are accessible online and linked with other maps and WWW documents. This opens new information potential of existing data that were often limited to be retrieved as isolated pieces of information.

Only if data retrieval does not provide enough insight into a geo-spatial situation will end-users ask for GIS analysis functions. Exploration as described in section 2.1.4 becomes an important analysis technique for geo-referenced data. The exploration task shows that graphical presentation, data retrieval, and analysis build a group of related functions that might be iterated several times in many applications.

5.1.3. IPRA for Argumentation Maps

Input and management

From a GIS perspective, data input for an Argumap means to identify and name the geographic reference of discussion contributions and the properties of the referenced geo-objects and relations between them. Alternative solutions vary in the amount of user interaction with the system.

At one extreme, the geographic reference is provided by the author of a message by clicking on the appropriate coordinate location(s) on the draft plan. In the object-based geographic setting proposed by the present thesis, giving the geographic reference is supported (and at the same time limited) by the fact that the user is not allowed to set arbitrary coordinate references. Instead, clicking on the plan will be interpreted by the Argumap as a selection of a geographic object. Such selections can also be done by selecting the name of the object from a list of geographic features on the planning map. Users with difficulties in finding appropriate reference objects can be aided by the mediator of a debate, if there is one.

At the other extreme, geographic references of a discussion messages could be found by a lexical analysis of the messages' contents. With the help of AI techniques it would be possible to extract geographic terms and statements from the message text and search geographic names in a gazetteer. Links between the message and geo-objects would then automatically be established. This automatic geographic indexing of arguments is not used here, because the required techniques in *text mining* and the basic geographic gazetteers are considered not yet ready for use. Current applications are still mostly based on counting occurrences of isolated words, instead of understanding the rules of using geographic names. In addition, it is assumed that many untrained users would rather be irritated by too much interference of the computer in their tasks. Indeed, a combination of both, that is asking the user to select geo-references among automatically extracted proposals, could be interesting to implement in the near future.

The tradeoff between automatized, pre-structured user support and technically simpler, unrestricted expression options for users also exists for the input of object properties and geographic relations referenced by arguments. On the one hand, lexical analysis of the messages' contents could extract property names and values together with qualifiers, such as "number of lanes of a road", "four lanes", "too many", as well as spatial relations with qualifiers, such as "too close". This would be very demanding for the lexical extraction and matching algorithms. On the other hand, doing without any pre-structuring would prevent comparability between arguments. Thus, this thesis proposes a middle course in the form of user selection among a predefined set of object properties and types of inter-object relations, respectively.

The storage and management of these input data is done by establishing a database schema that reflects the object model of chapter 3. For example, the management of geographic references could be achieved by storing and manipulating object identifiers for the reference objects of a discussion message. Problems arise if the data model of the GIS that contains the plan data does not provide IDs for plan elements. For example, ESRI's Shapefile format only indirectly provides object IDs via a link to a feature table. The OpenGIS feature ID specification which is currently in progress, may be used as a future reference model for persistent geographic references. Feature IDs will be based on a concept of nested name spaces ("scopes") like Internet IP addresses, which allows to identify GIS objects world-wide (OGC, 1999).

Presentation

Discussion contributions with a geographic reference will be represented on top of a map by *annotation symbols*. On a vector map, such symbols will be positioned at the label points of map elements. If more than one contribution refers to a geo-object, a single annotation symbol associated to this object should be modified (in size or shape) in order to show the number of links it represents. If a contribution refers to more than one plan element, positioning the symbol becomes an issue. A first option would be to draw annotation symbols on every referred plan element. Second, a single symbol could be drawn on the plan element that is first referred, assuming that users are advised to input geo-references in the order of decreasing importance. Finally, visualization of annotation symbols could be done on a separate, translated layer over the map; vertical lines between map elements and annotation symbols would represent single or multiple references. The first option has been chosen for the present thesis, not to confuse untrained users with unfamiliar types of spatial representations.

The previous remarks on positioning annotation symbols on a planning map assume that there is a single design of symbols. A user could select specific spatial properties and attribute values of arguments through choice menus, in order to filter the amount of contributions represented on the map. For example, only messages of a specific author during a specific period of time could be shown. Or only symbols for contributions addressing neighbourhood between plan elements could be drawn. Table 5.1 puts forward suggestions for representing attributes that have a predefined set of allowed values, through the design of annotation symbols. Symbols would show whether a single geo-object is referred, or multiple objects with a spatial relation are addressed; the group of object properties, namely geometric, thematic, temporal, or graphical; the type of spatial relation, e.g. distance or topological; the action type of the argumentation element; or finally, the argument type according to the argumentation model (cf. Argumap model in chapter 3).

Symbols representing attributes of arguments as described in the previous lists, can only be used if a symbol on an object represents a single contribution or if symbols for multiple contributions can be combined graphically. The annotation symbol on a geo-object would e.g. represent the existence of an argumentation element of type *issue* and two *positions* linked to that object. Expressive symbols such as those proposed here do not offer easy combinations. The Descartes viewer presented in section 6.3.1 provides a means of visualizing membership or occurrence values, i.e. spatial variables with boolean values. This could be useful for showing whether or not arguments of a certain type are linked to a plan element.

It may be helpful to use hierarchies and classifications in the visualized properties to control the drawing of annotation symbols. For example, show only argument types of the third

<table>
<tr><th>Symbol</th><th>Property visualized by symbol</th></tr>
<tr><td colspan="2">Symbol shows how many objects are referenced by each argument</td></tr>
<tr><td><code>1</code></td><td>object property (of a single object)</td></tr>
<tr><td><code>2+</code></td><td>inter-object relation (between two and more objects)</td></tr>
<tr><td colspan="2">Symbols for properties of single object</td></tr>
<tr><td><code>[]</code></td><td>geometric property</td></tr>
<tr><td><code>ABC</code></td><td>thematic property</td></tr>
<tr><td><code>t</code></td><td>temporal property</td></tr>
<tr><td><code>g</code></td><td>graphical property</td></tr>
<tr><td colspan="2">Symbols for relations between two and more objects</td></tr>
<tr><td><code>|...|</code></td><td>distance relation</td></tr>
<tr><td><code>-><-</code></td><td>neighbourhood relation</td></tr>
<tr><td colspan="2">Symbol design according to action type</td></tr>
<tr><td><code>=</code></td><td>keep</td></tr>
<tr><td><code>+</code></td><td>create</td></tr>
<tr><td><code>-</code></td><td>remove</td></tr>
<tr><td><code>-></code></td><td>move</td></tr>
<tr><td><code>#</code></td><td>change attributes</td></tr>
<tr><td colspan="2">Symbol design according to IBIS argument type (borrowed from GMD's Zeno system)</td></tr>
<tr><td><code>?</code></td><td>issue</td></tr>
<tr><td><code><></code></td><td>position</td></tr>
<tr><td><code>+, -</code></td><td>pro, contra argument</td></tr>
<tr><td><code>(...)</code></td><td>comment</td></tr>
<tr><td><code>!</code></td><td>decision</td></tr>
</table>

Table 5.1.: Design proposal for different sets of annotation symbols

level in the IBIS model, i.e. pro and contra arguments; or show arguments referring to any geometric property, i.e. position, orientation, shape, but not topological ones. The possibility of using this technique to achieve clear Argumap presentations depends on the availability of hierarchies and classifications as characteristics of the properties to be visualized.

Retrieval

The annotation symbols which are drawn on top of a planning map have to be hyperlinked with the argumentation messages they represent. The map together with the symbol layer builds a user interface to related documents. The hyperlinks from the map to the discussion forum are typed links and support goal-oriented data retrieval if the symbols' appearance reflects some property of the related arguments.

Data retrieval for Argumaps means answering the questions

- What argument qualities are here?
- Where are arguments with these qualities?

where the spatial qualities and characteristics of the problem space (the discussion) can be

- location (geo-reference)
- geometry type, value
- topology
- time (stamp)
- author (name or role)
- contents (full text search)
- argument type
- action type

The results of geo-argumentative queries maybe hierarchically structured in several dimensions, for example

- space: global view - region - plan element - coordinate point
- time: whole time - period - time point
- author: role - person

- argument type: issue - position - argument

Geo-argumentative queries can be performed iteratively, i.e. a query can be driven on the result set of a previous query. The result are induced (or transitive) geo-argumentative relations. A specific geo-argumentative query language seems not to be needed, because the retrieval criteria mentioned so far can all be stored in a relational database system; thus, the vocabulary of standard SQL should be sufficient.

Analysis

Classical spatial analysis functions such as geo-statistics, buffering, overlay, and network analysis is available for Argumap users if the geographic component is based on a GIS. Exploration as a lightweight analysis function plays an important role in using Argumaps, as will be described in the the following section on use cases.

Serious work on geo-referenced argumentation will include multiple iterations of data presentation, retrieval, and exploration, in combination with GIS analysis. For example, when an analyst has found a geo-object with interesting arguments attached to it, he/she could build a buffer around this object to find plan elements that are situated within 500 meters distance and read arguments attached to them. Or objects with reference to ecological concerns of a discussant could be overlaid with a natural resource plan in order to find actual conflict areas.

5.2. Argumap use cases: navigation, participation, exploration, analysis

Use cases help to specify system requirements (Harmon and Watson, 1998). Argumap use cases involve three actors, the user, the discussion forum, and the GIS component. The overview in figure 5.1 shows the general relations between actors and use cases: the user wants to discuss a map, while the forum provides attributes and content of discussion contributions and the GIS provides a map display and tools for processing geo-references of contributions.

Table 5.2 shows a mapping from IPRA, that is input, presentation, retrieval, and analysis of geographically referenced discussion contributions, to the use cases participation, navigation, exploration, and analysis. The order of detailed explanation of the use cases in the following sections is changed with respect to IPRA, insofar as participation (corresponding to input) has been moved back behind navigation. The reason for this shift is that a discussion site will mostly be prepared in such a way as to present visitors with a first view on interesting issues of the debate. Thus, users will generally first navigate through an existing structure, before inputting their own arguments.

GIS function	Argumap use case
Input	Participation
Presentation	Navigation
Retrieval	Exploration
Analysis	Analysis

Table 5.2.: Correspondence between IPRA and Argumap use cases

5.2.1. Navigation

Users inspect the current state of a map-related discussion by navigating from the map into the forum and vice versa, in a hyperlinked environment. Rinner (1999) gives examples of two navigation workflows that answer the questions "Which issues have been raised in this area?" and "Where are the references of contra arguments to this proposal?".

The annotated planning map is used as a cartographic interface to the discussion forum. In the navigation use case, annotation symbols represent single discussion contributions. Visualization methods showing aggregated data about contributions, for example the number of arguments per map element, belong to the exploration use case described later. The symbolization of contributions at appropriate map elements can be filtered according to the non-spatial attributes of the Argumap model, e.g. showing only the arguments of a specific author, or those submitted on a certain day during the public participation period. Navigation requires interactive annotation symbols so that a click on the symbol opens (moves the window focus to) the discussion forum and displays the corresponding discussion message. On the other side, the forum should provide a means of jumping to an appropriate map view for each discussion message.

In summary, the role of the forum in the navigation use case is to display the contents of contributions and to provide the Argumap with attributes required for visualizing, filtering, and hyperlinking annotation symbols. The role of the GIS is to provide the planning map and tools for automatic and interactive zooming and selecting a map extent.

5.2.2. Participation

To participate in an Argumap-based planning debate users create new, geographically referenced contributions. The GIS component of the system must provide a means of capturing the users' selections of map elements as reference objects of the new arguments. The forum prompts for all other input and stores the given attributes and the text of the argument in its database.

Discussion contributions are to be submitted to an Argumap in the form of semi-structured messages as advised by Conklin and Begeman (1988), with reference to Malone et al. (1986).

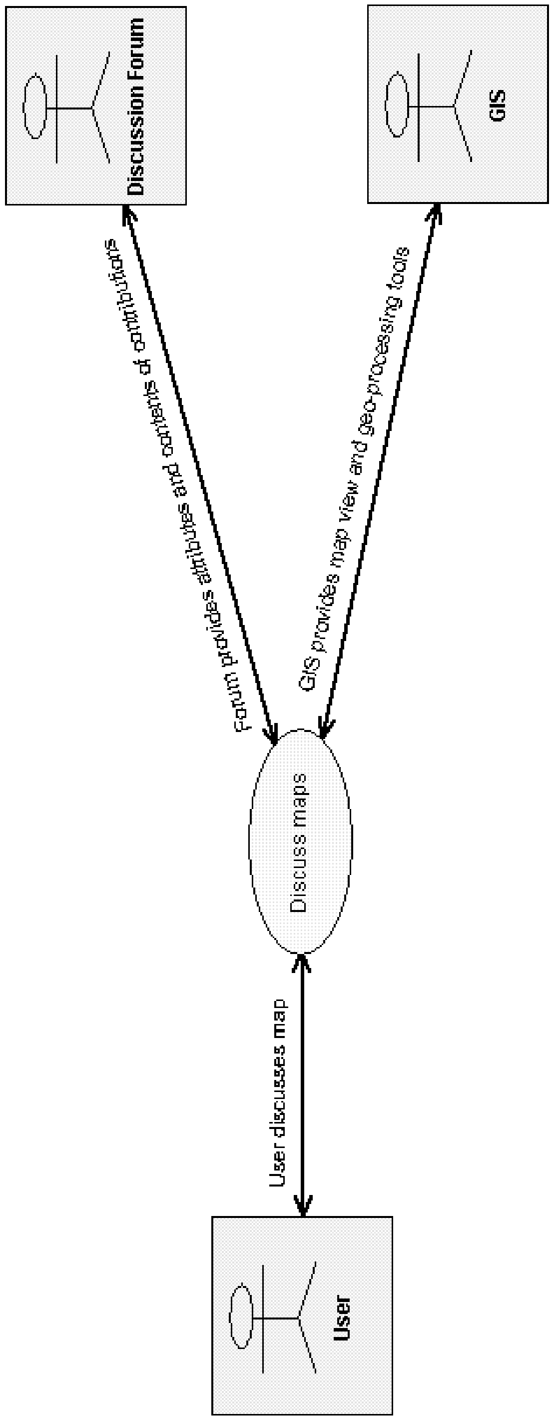

Figure 5.1.: Overview of use cases for Argumentation Maps

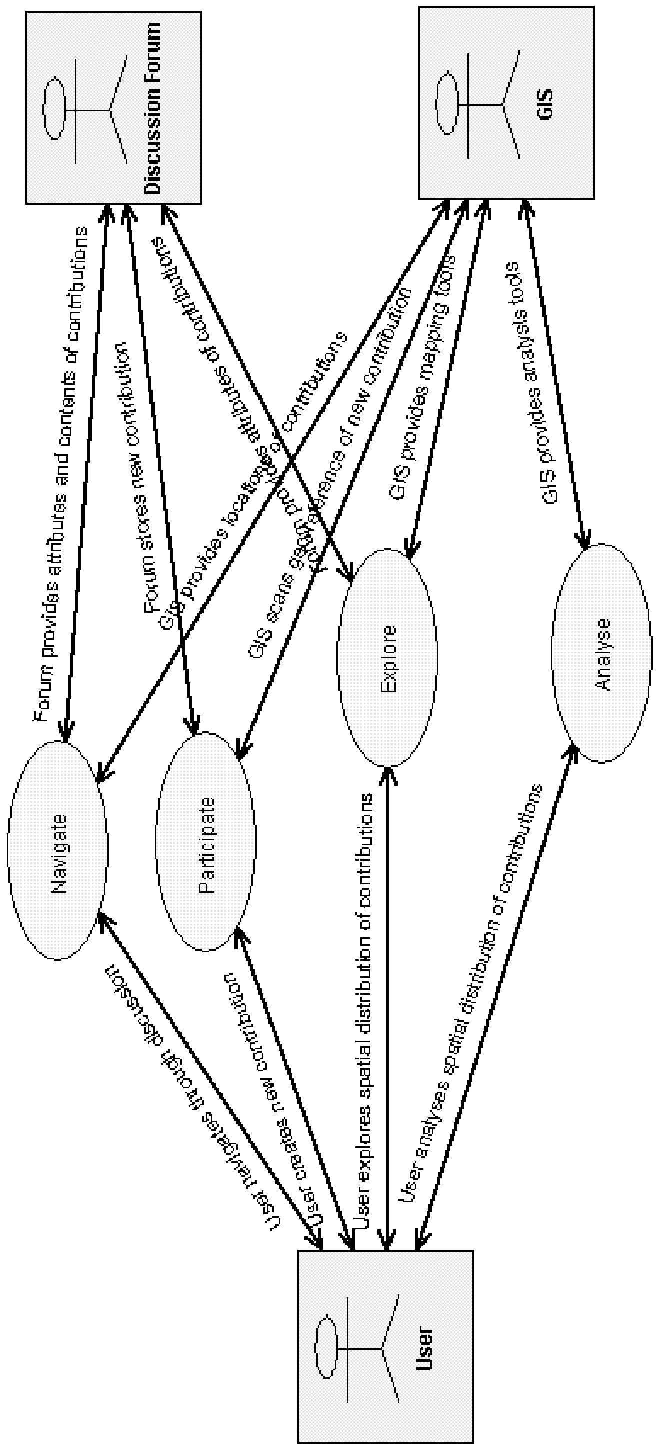

Figure 5.2.: Detailed use cases for Argumentation Maps

The *title* and *contents* of a contribution can be created in free writing, possibly with a constraint in length and language type (raw text, HTML), as provided by the discussion forum. The specification of the name of the *author* of a message should not be free but will be constrained by a login procedure of the discussion forum (except for very open discussions where authors do not have to authenticate themselves). The current data of the receiving server's operating system is stored as the *date* of an incoming message. The rest of the input is pre-structured by an instance of the Argumap model that provides enumerations of allowed values for the attributes *argument type*, *action type*, and *theme*. The *geographic reference* of the new contribution is also pre-structured by the set of elements of the specific draft plan. The available argument types for a new contribution are constrained by the type of the existing contribution, it responds to.

May a user select a geo-object and add a new contribution linked to it, that is, is participation allowed from a map view, instead of a discussion view? In general, no, because the argumentation model can hardly be kept consistent, if contributions can be added from outside the discussion forum. For example, a new message would not respect the existing issues linked to the reference object, but could contain related contents. This would very much hinder the utility of the Argumap for other users. Thus, participation should be initiated only from within the discussion forum, if the latter relies on an argumentation framework (which is an assumption in the present thesis). An exception is possible, if there is a mediator and he/she has enough resources to insert new, external messages at the right place in the argumentation model.

5.2.3. Exploration

In the exploration use case, citizens and planners have the opportunity to visually analyze the distribution of arguments over the planning area. For example, users may be interested in seeing how many contributions refer to the elements of the draft plan; or they may compare the numbers of arguments submitted by two different authors per plan element. Thus, the spatial distribution of arguments is accessible through counting (aggregating) contributions with specific attribute values and assigning the number of contributions to the plan elements linked to them.

Exploration is supported by appropriate cartographic visualization methods for geographically referenced data. Examples for presentation techniques are given in figure 5.3. Mapping techniques are provided by the GIS component of an Argumap system while the aggregated data about discussion contributions to be visualized are retrieved from the discussion forum.

As mentioned in the description of foundations for Argumaps (see page 17), exploration techniques require functions for interactively manipulating the map. This can be illustrated by the features of the Descartes system (cf. section 6.3.1): pointing on map elements to view their attribute data, changing colours of polygon shading to have an intuitive colour scale (e.g. green to red for positive to negative values), clicking on a map element to define a new attribute value for comparison, and so on.

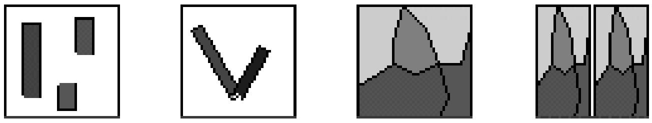

Figure 5.3.: Examples of cartographic visualization techniques for statistical data: barcharts for a single variable; barcharts for two, incomparable variables; choropleth map with continuous values or classified data; comparison of variables in multiple choropleth maps (after Andrienko and Andrienko, 1999a)

5.2.4. Analysis

The analysis use case provides a link to classical spatial analysis with GIS which is based on measuring and counting, building distance buffers around geo-objects, and intersecting layers to create new geo-objects that respond to selected criteria. For example, intersecting buffers of 200 meters around roads with zones of public land in a planning area results in a new map layer, containing parcels that are well-connected to the transportation network and are available at low cost.

GIS analysis can be useful in combination with argument navigation or exploration. First, GIS functions like selecting and buffering can be used to *pre*-process navigation or exploration. For example, the scope of a navigation session could be enlarged by jumping from a plan element to contributions referring to its neighbored plan elements; or, the area subject to exploration could be restricted to a previously generated buffer around the most disputed plan elements. Second, GIS functions can be used to *post*-process (i.e. modify) a plan after the visual assessment of a discussion. Independently from the order of operations, spatial analysis can be based on Euclidean metrics as well as on the argumentative distance that has been defined in chapter 4. For example, a buffer can be build of objects that are within argumentative distance of 3 from a given object.

5.3. Requirements for GIS to support Argumap implementations

A first attempt to describe requirements for Geographic Information Systems that could be used as a component in Argumap implementations was presented by Greve and Rinner (1999). Their findings are revised and enlarged in the following sections which discuss suitable GIS data models, GIS functions, features of the user interface, and the requirements to the computing platform in general.

Data model

Using an object-based GIS data model (see chapter 2) is much preferable to using a field-based model, because of better location options for geo-referenced arguments as proposed in section 3.2.2. This suggests, but does not necessarily require that the presentation form of the draft plan is a vector rather than a raster map. Instead, in the raster case, there should be an object database behind the map presentation (see client-server requirement, below). Object-based does also not mean object-oriented—the Argumap model can well be realized with a relational database or a storage of GIS objects in the file system, as is still current with commercial GIS software.

The navigation use case relies on links between discussion contributions and sets of geo-objects that form a specific kind of complex objects. But as the retrieval of geo-argumentative relations requires only a simple mapping table between contributions and geo-objects ($m : n$ relationships), there is no need for complex objects to be stored in the GIS database. This further requirement could, indeed, eventually increase the speed of the geo-argumentative presentation and retrieval through specific indexes.

Functionality

The navigation and exploration use cases require the GIS component to provide the usual functions for map presentation and map manipulation, such as zoom in, zoom out, and pan.

Furthermore, Argumap navigation needs the ability of presenting annotation symbols on top of the planning map, and managing hyperlinks or hot links attached to these symbols. Participation in an Argumap-based debate requires that the mapping component supports interactive selection of geo-objects by the user, and that it can export the Identifiers of selected geo-objects. Argumap exploration makes use of thematic cartography and interactive tools for the exploration of geo-argumentative distribution.

The implementation of the analysis use case would require the availability of spatial analysis functions like distance measurement, building buffers around geo-objects, and intersection of map layers.

User interface

The geographic component of an Argumap is envisioned to consist of a graphical map window with several option or choice menus and tool bars, depending on the actual use case to be supported.

The map itself is the user interface for visual perception of geo-referenced arguments and for the selection of reference objects via mouse click. Option menus serve to filter symbols (navigation use) or data (exploration use) to be visualized on the map. Direct manipulation tools (see chapter 2) are required to support the exploration of the geo-argumentative distribution.

Computing platform

For their multi-user function, Argumap systems will be realized as client-server systems. The server part is required to store the data about links between discussion contributions and map elements. These links could be stored in a specific Argumap server or as additional information, together with the discussion contributions or the map, in the respective servers. The user mostly interacts with an Argumap client which is connected to the server(s) via the Internet. The client should run within a common WWW browser such as Netscape Navigator. The Java platform would be appropriate to provide an applet as a client that would not require any specific plugin to be installed with the user's browser.

5.4. Summary

In this chapter, Argumaps have been described from three perspectives. First, the functionality of Argumaps was classified into input, presentation, retrieval, and analysis functions. Then, the usage of Argumaps for navigation, participation, exploration, and analysis of geographically referenced debates was depicted. Finally, the technology requirements of Argumaps for being implemented on the basis of Geographic Information Systems have been discussed.

In summary, this chapter demonstrates that the class model of chapter 3 supports adequate Argumap realizations. It has been emphasized that users are demanded more input operations than in the case that they discuss a draft plan without explicit geographic references attached to arguments. Argumentation is also slightly constrained by the semi-structured input forms envisioned for the input functionality, or participation use case respectively. For example, the contents of an argument must be matched to a pre-defined set of themes that fits the concept of chapter 3 for properties of plan elements and relations between these. But only the additional input of explicit, typed geo-references by authors of discussion contributions enables the explorative analysis of the current state of a debate.

The proposal of annotation symbols design made in table 5.1 and other choices such as the lists of input variables described for the participation use cases are meant to be an indication of what could be useful for implementing Argumaps. This information cannot be prescribed because the purpose of this dissertation is to explore the field of computer-supported georeferenced debate instead of just establishing a single, valid Argumap implementation.

The requirements for GIS-based Argumaps are also kept on a rather general level so that many current Internet Map Servers and Java-based GIS libraries may be suitable candidates for the GIS component of an Argumap. Indeed, it can be expected that more adequate geoprocessing tools will appear when interoperability as promoted by the OpenGIS Consortium will become a common feature of GIS software. Open, clearly defined software interfaces would allow better links between GIS and any kind of external tools, among them newsgroup and discussion servers.

The IPRA schema that was used to describe potential Argumap functionality, is supposed to provide an up-to-date means of characterizing GIS applications in general. It suggests ordering geo-processing functions from the perspective of function complexity as well as from the sequence of actions in map-based exploratory data analysis.

6. Demonstrators

This chapter presents two mockup implementations of argumentation maps that demonstrate the opportunities and challenges to be expected when attempting to realize the concepts established in this thesis. Both prototypes are based on the Zeno mediation system described in the first section, below. The first was implemented from scratch and uses the Virtual Reality Modeling Language (VRML) for a three-dimensional graphic representation of map-based discussions (section 6.2). The shortcomings of the first demonstrator suggested to start working on a second one. This tool employs an existing Java viewer, GMD's Descartes system, for the interactive visualization of the spatial distribution of arguments (section 6.3).

6.1. The Zeno mediation system: Participation in spatial planning

Zeno is a groupware tool that offers special support for moderated and unmoderated discussion procedures. It has been developed since 1996 by the *Cooperative Design* group, now *Mediation Systems* team, within GMD, the German National Research Center for Information Technology (see team homepage at `http://ais.gmd.de/MS/`). The Zeno concept arose from research in AI and law, and more specifically in Computational Dialectics (Gordon, 1994) and mediation systems (Gordon et al., 1997; Rinner and Schmidt, 1998; Märker, 1999).

6.1.1. Features

At first sight, Zeno is a WWW-based shared workspace system that was partly inspired by GMD's BSCW ("Basic Support for Cooperative Work") system (Bentley et al., 1995). The workspaces can be used to upload and download documents and thus help a group of persons to exchange information in very different contexts. The capabilities of Zeno encompass

- the number of participants with a range from a few cooperating team members up to thousands of people in a public participation procedure
- the diversity of the supported group, which may be a team of co-workers with a common design goal, but may also be a heterogeneous discussion group with diverging interests

- the direction of information flow, which can range from composing together a document up to a situation where an official uploads relevant documents, while normal participants may only retrieve information

Closely related to shared workspaces, Zeno provides other features of common groupware tools. Among these are access control which can be specified for each document; logging of any database transaction; user management with accounts, password, storage of addresses and email lists; user preferences including support of different languages and a customizable personal bookmark list; and support for workflow agendas and a calendar system.

A special type of shared workspaces are discussion forums. These are designed to store and provide access to argumentation messages. Forums in Zeno contain three default subdirectories, "incoming", "published", and "index". The first receives incoming messages by discussion participants in their original state. The second contains those messages that are approved by the mediator. Published messages may have been modified by their author on the mediator's demand, e.g. if the content was imprecise or offensive to another participant. If the discussion procedure is unmoderated, incoming messages are automatically published. The index of a forum is a specific view on the published messages that depends on the argumentation model the forum is based on. At the moment, one model is realized in Zeno, the IBIS model (cf. chapter 2).

Figure 6.1 shows how icons represent different types of arguments and how a tree browser displays the interdependence of arguments by their order and indentation. The argumentation browser provides a type of visualization for discussions that has been adapted from common file managers or desktop explorers of different computer operating systems. Clicking on the title of a message displays the complete document, together with information on its author, date, and argumentative context (see figure 6.2).

To enable users to add new contributions to a forum, Zeno provides a message composition window. Contributions can be edited as HTML or text documents. In the case of HTML, links can be provided to arbitrary Web pages, including other contributions on a Zeno server (cf. technology description below). In general, new contributions reply to existing ones. Therefore, it is important that users specify the type of relation between their message and the reference contribution, e.g. pro-argument or contra-argument. If a user is not capable of defining the appropriate reference contribution and the type of argument, the mediator may help him before the new message is published. In the IBIS model, issues and positions are the only types of argumentation element that do not necessarily reply to existing contributions but may start a new segment of discussion.

Features planned for later versions of the Zeno system include support for several argumentation models, instead of only IBIS; automatic evaluation of positions to be "in" (active) or "out" (inactive) with an appropriate visualization; and, where the procedure allows it, rating and voting functions to help users come to a decision. With these enhancements and the

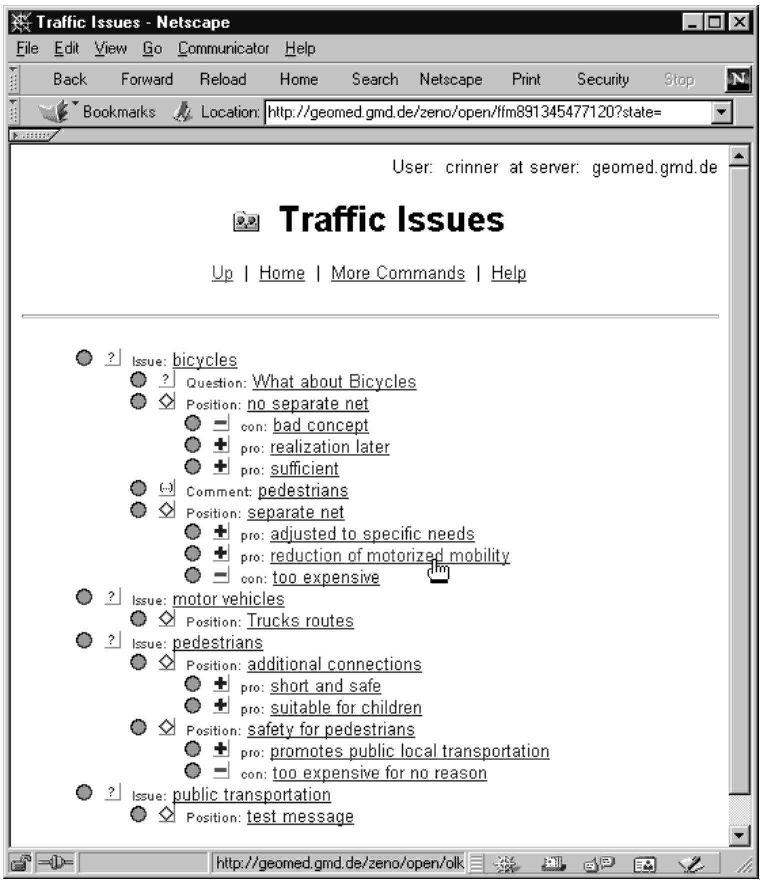

Figure 6.1.: The Zeno argumentation browser

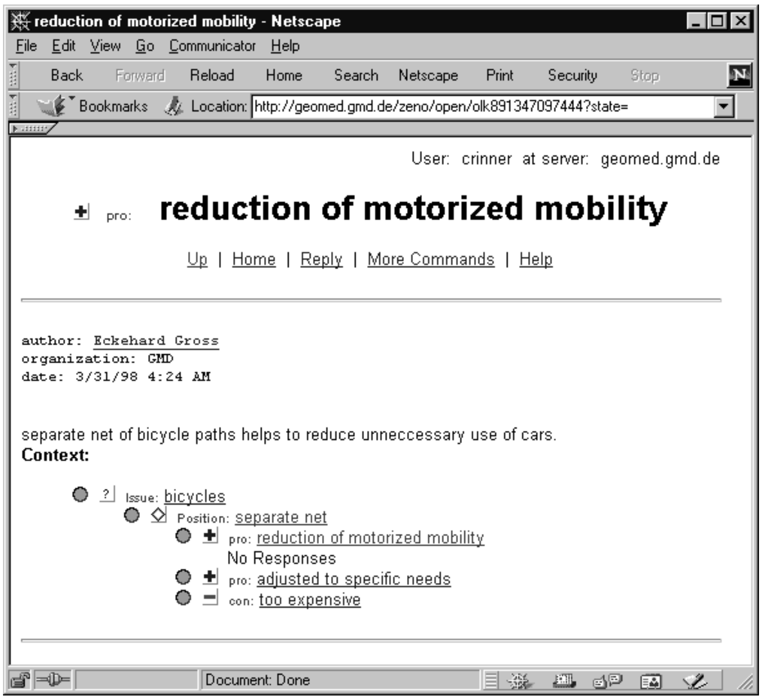

Figure 6.2.: Display of a contribution in Zeno discussion forum

implementation of Argumentation Maps linked to discussion forums, Zeno will come close to the optimal community design tool envisioned in Pipek et al. (2000).

6.1.2. Technology

While the BSCW system uses the Python programming language on the server side, Zeno is implemented in pure Java. The reason is that platform-independence and acceptability by the computer industry for commercial applications were crucial requirements within the GeoMed research project (EU Telematics Application Program, IE-2037), which partly funded the Zeno implementation. In contrast, many client-server systems in the GIS sector are limited to platform-independence of the client modules, but use proprietary technology on the server side. Examples of this are some commercial Internet Map servers that run only with specific WWW servers under Windows NT. This type of client-server system would not have met the GeoMed requirements.

The Zeno client is a Java applet, which can be loaded and started with a common HTML browser, e.g. Netscape Navigator, Internet Explorer, or Hotjava. As the applet was developed for version 1.1 of Java, Sun's Java plugin is required for browsers that do not support Java 1.1. In addition, the user has to download and install the Swing class library, which is used for the graphical user interface of the Zeno client. Finally, the user is advised to download and install on his/her computer the current version of the client software, instead of loading the applet each time he/she accesses a Zeno server. The communication between the Java client and the Zeno server uses Sun's Java Remote Method Invocation (RMI) technology. RMI provides access to Zeno's Java objects residing on a remote server, much as the CORBA technology provides access to remote objects (independently from a specific programming language). RMI requests can be transmitted on top of the hypertext transfer protocol (HTTP), the standard protocol for accessing text pages on the World-Wide Web. This is advantageous in case firewalls hinder the transfer of protocols other than HTTP.

Recently, an alternative access to Zeno servers has been implemented as a pure HTML client that demands less installation effort of the users. In this case, client requests are transferred to the server through the parameters of a HTML anchor element or through the parameters of a HTML form. The parameters include the document identification, while the user identification is checked with the HTML browser of the client machine. The results of server-side processing are returned to the client browser as a new HTML page. This technology is currently realized through the Java resources of the Jigsaw server of the World-Wide Web consortium (W3C). "The resource module is some representation of your information space. It is responsible for generating reply objects out of the incoming request objects." (Jigsaw Architecture, `http://www.w3.org/Jigsaw`). It is comparable to other proprietary WWW server APIs and to the CGI (Common Gateway Interface) standard.

The Zeno server consists of *resources* representing the relevant entities in a shared workspace

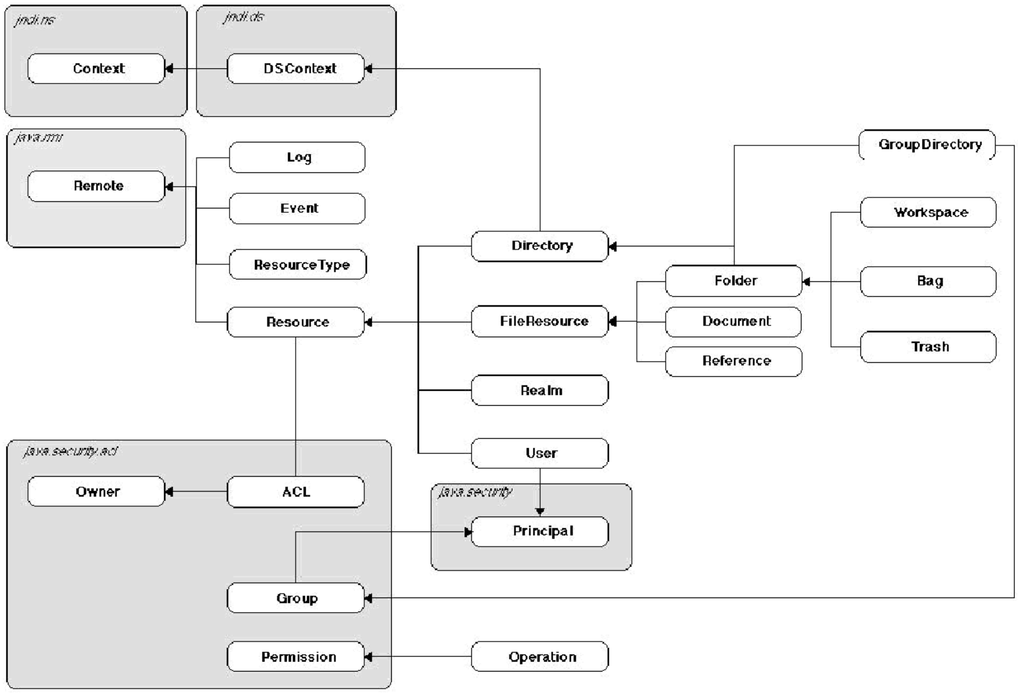

Figure 6.3.: The Zeno architecture

system, for example documents, workspaces, and users (see figure 6.3). Metadata about these entities are managed in a relational database system, currently the lightweight database engine mSQL. The Zeno classes access these data through a subset of the Java Database Connectivity (JDBC) protocol. The documents that lie behind the metadata entries are stored as files on the Zeno server or on any WWW server, but can be identified through a unique ID. Access to the document's contents, therefore, is provided via a URL that is composed of the Zeno server address and the document ID.

Before a document is delivered to the client, the Zeno server checks for access rights. For displaying private workspaces or reading non-public documents, the user is asked for a login and password. Every resource has an *access control list* (ACL) attached to it that defines which user or user group may perform what types of actions on it. Examples of actions are read, write, inspect, and list, depending on the type of resource. Zeno uses Multi-purpose Internet Mail Extensions (MIME) to identify document types in order to select appropriate icons for listings and appropriate helper application for displaying documents that cannot directly be opened in the WWW browser.

6.1.3. Evaluation

The Zeno system has been evaluated in several real-world projects as well as in role playings. Parts of the evaluation was supported through a cooperation with the planning department of the city of Bonn within the consortium of the GeoMed project.

Some evaluation events were imposed on the basic version of Zeno that was built with the look and feel of the BSCW system (see above). Schmidt-Belz et al. (1997) report a validation of Zeno by two groups of test users. Their assessment of the design, handling, and functionality of the basic version has been used by GMD to re-implement the improved full version described in the previous sections. Schmidt-Belz et al. (1998) add a real-world experiment to the previous planning games. Citizens of Bonn could access Zeno, retrieve information and participate in a discussion about a planned housing area during a two week anticipated public participation procedure. The slightly disappointing results have been mentioned in chapter 2 on page 31.

In contrast to these practical experiences with Zeno, Märker (1999) performs a theoretical evaluation of the potential of Issue-Based Information Systems in general as a communication medium in planning procedures. On the one hand, the author comes to the conclusion that IBIS *can* support an early, equal, open, and transparent participation of stakeholders in (urban) planning. On the other hand, Märker estimates that the technical selectivity of network-based IBIS applications will limit the factual participation opportunities for a large number of citizens and that the use of IBIS depends on the good will of the authority in charge of the planning procedure.

6.2. Zeno and VRML: Navigation in 3D discussion space

In Rinner (1997b) and Rinner and Schmidt (1998), an argumentation map prototype has been presented which uses the Virtual Reality Modeling Language (VRML) for a graphical representation of geo-referenced arguments on online maps. Before describing the functionality and technical realization, a short overview of VRML is given in the following section.

6.2.1. VRML

The Virtual Reality Modeling Language (VRML) is a file format for describing three-dimensional interactive graphical scenes that can be accessed via the World-Wide Web. Since December 1997, VRML has been an international standard (ISO/IEC 14772). 3D objects are stored in files ending on ".wrl" for "world" or ".wgz" for zipped worlds. When made available on the Internet, WWW servers must transmit these files with the MIME type "model/vrml". The receiving HTML browser will use a plugin or helper application to display the scene and let the user navigate through it. An example of such a plugin is Cosmo Player by SGI.

VRML descriptions are built with authoring software, by using a simple text editor, or by conversion from other graphical data formats or graphics software (including 3D GIS, e.g. ArcView 3D Analyst). A VRML scene is a hierarchy of nodes with fields; nodes define graphical objects, fields describe the appearance of nodes. Besides administrative nodes (e.g. WorldInfo) and constraints on user navigation (NavigationInfo, Viewpoint), nodes describe graphical shapes (Box, IndexedLineSet), their appearance (Material), and their transformations (Transform). Specific node types support the automatic (Anchor, BillBoard, LOD) or programmable (PlaneSensor) interaction of the visitor with the scene.

An important feature of VRML scenes is their embedding in the WWW hyperlink structure. On the one side it is possible to include remote data such as images, sound, and movies in a VRML file by simply referencing their URL. On the other side, VRML objects can be linked to remote VRML worlds and any other type of WWW-based data. The possibility of having visitors click and jump from within a VRML scene to external HTML pages led to the idea of using VRML to define abstract, 3D indices to present and provide access to complex information (Lochter et al., 1996; Däßler and Palm, 1998). Work on hypermaps as described in chapter 2 on page 38 partly uses VRML for linking geographically referenced information to maps (e.g. Fairbairn and Parsley, 1997; Buziek and Hatger, 1998). Fuhrmann and Kuhn (1998) judge VRML a promising "medium for interactive animated maps".

Rinner (1998a) notices that VRML is an object-based data format, though not an object-oriented one in the strong computer science sense. The vector definition of *2D* line and polygon objects in VRML makes it feasible to translate geographical data from common CAD and GIS formats like DXF to VRML. Rinner (1997b) gives code samples for a line object. The vector capability, the importance of which was established in section 2.1.1, and the WWW compliance of VRML graphics support its use for Internet mapping in two dimensions. Rinner (1998a) presents a viewer for topographical data that uses a VRML browser as a map window with included VRML-defined mapping tools for zoom in, zoom out, and pan. Topographical objects are modeled with IndexedLineSet and IndexedFaceSet nodes and linked to attribute data, so that a mouse click on a line or area displays related attributes in a second frame of the WWW browser. The author translates topographical objects from the German ATKIS format into customized VRML geometry objects with attributes defining their appearance (colour) and their interaction function (attribute link).

The discussion of this map viewer lists severe problems of cartographic presentations with VRML, including the lack of copy protection and the impossibility of defining cartographic symbology (Rinner, 1998a). The geoVRML working group (`http://www.ai.sri.com/geovrml/`) discusses "means for representing geo-referenced data in VRML". But the focus of the group is on coordinate systems (Rhyne, 1999), time referencing, terrain representation, and accuracy, rather than on sound cartographic presentations. Because of poor cartographic capacities of VRML, the prototype described in the following, does not emphasize the *mapping* part of an Argumap; the map is a raster image, instead of the preferable vector data. Rather this prototype demonstrates WWW-based navigation and participation functions with interactive annotation symbols on top of a coarse cartographic representation of a spatial planning situation.

6.2.2. Functionality of a VRML-based Argumap

The VRML Argumap allows a user to create a symbol that represents a new contribution to a map-based discussion. While the map is represented by a two-dimensional image, the annotation symbols are three-dimensional flags that can be dragged to an appropriate location on the map. The colour and size of the symbols depend on the argument type chosen by the user. Also, the user has to provide a URL to be linked to the symbol. In principle, this is the URL of the discussion contribution in the Zeno forum, which is to be represented on the map. The function described so far belongs to the *participation* use case of chapter 5.

The *navigation* use case is implemented in two ways. First, the VRML scene can be manipulated through the user interface of the embedded VRML browser. The manipulation tools include zooming and panning in 3D. Second, the annotation symbols are clickable VRML objects. A mouse click on a symbol in the map window opens the associated URL in a second window of the Web browser, that is a document window that contains the Zeno client.

The VRML prototype realizes *exploration* insofar as the navigation functions can give the visitor of the map scene an overview of the more or less disputed geographic regions.

6.2.3. Implementation

This prototype of an Argumap combines an embedded VRML viewer and a Java 1.1 applet on a HTML page. When accessing the page with a VRML-enabled HTML browser, a VRML file is loaded into the VRML viewer and the Java applet is started. The VRML scene originally contains a map image as a texture on a flat, rectangular shape.

The GUI of the Java applet consists of a text field for the message URL, an option menu for the argument type of the message, an apply button ("Create flag"), and a text area for status messages. When the text field is filled with a valid URL and the apply button is pressed, the Java applet adds a symbol of the type indicated by the option menu choice to the VRML scene in the main memory of the client computer. A screenshot after several such steps is shown in figure 6.4.

The user interaction with the VRML scene includes dragging the flag symbols to a position on the map, and opening a URL by clicking on the flag corpus. Dragging of symbols is realized through a *PlaneSensor* node and an event routing mechanism that transforms the symbol's position according to the mouse movement registered by the attached sensor. In the current version of the demonstrator, the change of position is only effectuated in the main memory, but not stored in the VRML file on the server. Opening a URL via mouse click on the flags is implemented through the VRML Anchor node.

Further interaction with the VRML graphics is limited to the tools provided by the VRML viewer, above all navigation in three dimensions. In conjunction with approaching and retiring

Figure 6.4.: Prototype of an Argumentation Map, implemented with VRML and Java (available at `http://ais.gmd.de/~crinner/phd/argumap/argumap.html`)

from the map object, a level-of-detail concept makes sure that in a distant map view, only top-level annotation symbols (representing *issues*) are visible, while when approaching the map, more and more symbol types appear. Thus, the distant view can give an overview of areas in debate while a closer look to an area shows all arguments located there, and enables the user to browse a complete part of a discussion. The level-of-detail concept in computer graphics is the equivalent of generalization in cartography, but has a different original goal: reducing the time for rendering a scene, instead of providing less overloaded maps to the users.

The communication between the Java applet and the VRML viewer is realized through the Java API of the Cosmo Player software (package vrml.external). This method is called "External Authoring Interface" (EAI, see `http://www.cosmosoftware.com/developer/eai.html`) and allows a Java applet to influence the contents of a VRML scene within the same WWW browser window. The EAI is an "Informative Annex" of the VRML 2.0 specification, i.e. viewers do not imperatively implement it.

On starting, the Java applet gets handles for the VRML viewer and objects. This enables the applet to add new flag symbols to the VRML scene. Prototypes are used for typed flag objects with behaviour; the task of the Java applet is limited to the instantiation of prototypes, as advised by Marrin et al. (1999). Figure 6.5 shows the overall architecture and data flows of the VRML Argumap prototype. See also the VRML and Java source code with a detailed

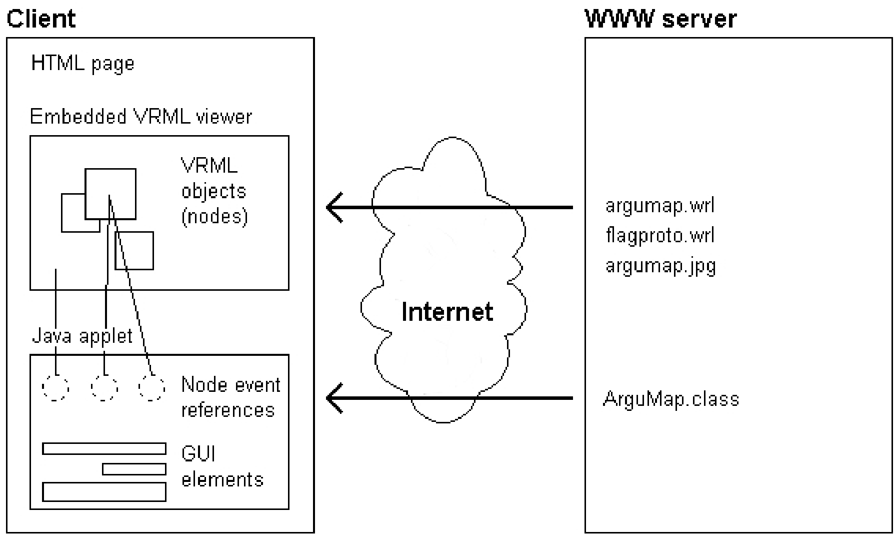

Figure 6.5.: Architecture and data flows of VRML/Java Argumap

explanation in appendix B.

6.2.4. Discussion

The VRML prototype gives a good idea of how Argumap functionality can be realized through a combination of Java, WWW-compliant raster or vector graphics, and the Zeno system. The use of a 3D graphics language eases the separation between 2D map and 3D annotation symbols, helping user navigation.

For technical reasons related to the link between VRML and Java, this implementation does not achieve full *participation* functionality. It is not possible to store new annotation symbols on the server. Moreover, there is no direct communication with the Zeno discussion forum. Instead, users have to copy the URL of their arguments from the Zeno window after submitting a message, and paste it in the Argumap GUI.

The *navigation* function of the VRML prototype partly depends on what is offered by the embedded VRML browser. Free navigation in three dimensions as provided by typical navigation controls results in specific problems when dealing with geographic data instead of abstract graphical data. For example, a pure 2D map view should be looked at from an orthogonal viewpoint, approaching the map should be limited in order to never cross the map plane and view it from the backside, and flat map images can rapidly be lost after a few incautious navigation commands. But with a certain technical effort, navigation can be bound to sensible movements over a map. In the map viewer in Rinner (1998a) user navigation is switched off and replaced by Javascript-controlled map zooming and panning, thus preventing any uncontrolled user movement.

The VRML prototype realizes *exploration* through the navigation functions, providing a kind of density map of the spatial references of discussion contributions. An interactive manipulation of the VRML map, directed towards playing with the data behind the annotation symbols, would be difficult to implement because of the limitations of VRML for cartographic presentation, mentioned above, and the complexity of manipulating VRML scenes from external programs.

In summary, the VRML prototype of an Argumap allows one to implement some part of the use cases established in section 5.2. The development ended at a point where input and presentation function of the IPRA model (cf. section 5.1) have been realized, but data storage and analysis functions are still missing.

Some of the missing features of this solution could be overcome by techniques available in conjunction with VRML, Javascript and Java. However, this is not true for the shortcomings in the exploration and analysis functions. Furthermore, this solution will necessarily be limited to a specific VRML browser and thus to specific operating systems. For this reason, a second demonstrator for Argumaps has been conceptualized, which is described in the following section.

Nevertheless, VRML remains interesting for representing geographic information in the Internet. This is true in urban planning, where 2D geo-data are combined with 3D visualizations, as well as in 3D domains like geology. Instead of representing arguments, annotation symbols can similarly be used to display any other kind of information, attached to geographic objects, e.g. legal documents, scientific reports, photographs, or animations.

6.3. Zeno and Descartes: Exploring geo-argumentative distributions

The second demonstrator of Argumaps follows a different approach to software development, insofar as it uses an *existing* viewer for map data, instead of implementing yet another Internet map viewer as in the first demonstrator. The Descartes system has been chosen for its outstanding spatial exploration functionality and for its availability in the GMD work environment.

The combination of Descartes with the Zeno mediation system has first been outlined in Rinner (1999). The demonstrator has been specified and designed so that it could be implemented by GMD or another owner of Zeno and Descartes licenses. The mockups presented here are based on different editions of the Descartes system as described in the following section. The

Argumap demonstrator's functionality is presented on the base of the established use cases (section 5.2). Section 6.3.2 sketches Argumap sessions based on the Descartes modules FinderMap, ShowMap, and MovieMap, while section 6.3.3 describes an optimized architecture based on a combination of the features of these three tools.

6.3.1. Descartes

Descartes is a client-server system that uses Artificial Intelligence methods to generate thematic maps of geographically referenced statistical data. These maps can be displayed and manipulated in a Java Application on a local computer or accessed via the Internet as a Java applet in a WWW browser.

Descartes has a server component, implemented in C++, that runs with common WWW servers like Apache. With an administrator tool ("Application Builder") a data provider converts geometry data to Descartes' binary geometry file format, and related attribute data, stored in dBase files. The administrator should establish semantic relations of and between data fields that structure the data to a certain extent (cf. Andrienko and Andrienko, 1999b). For example, he/she could group fields that sum up to 100 percent of a spatial characteristic (like male and female population) or fields that are comparable (like birth rate and death rate). On data retrieval, the server component uses this information, together with a knowledge base of rules for cartographic design, to generate several alternative visualization techniques, like bar charts or pie charts, or choropleth maps. Details of the applicable visualization methods with reference to required properties of the data are presented in Andrienko and Andrienko (1999a).

The Descartes client is a Java applet through which a user selects a data table and one or more fields as mapping themes. After the creation of alternative presentation methods by the server, the user can open these as maps in the applet. The functionality of the applet includes common mapping functions (zoom, pan, overview, layer management), and map manipulation, that is changing the appearance of thematic representation (colours, height of bars, etc.) through operations in the data space (choosing an object for comparison, changing classification). Dynamic links between map displays for one application transmit changes of one display to all open maps.

Thematic maps in the full version of Descartes can be saved for later reuse. This creates a dataset that can be visualized with the ShowMap applet. The resulting map shows a fixed set of attributes but keeps full interactivity. Importantly for Argumaps, a ShowMap presentation can also be created from other software than Descartes. For example, Dialogis Software and Services Inc. have recently presented their dialoGIS extension as a ShowMap-based local Java application for exploring ArcView data.

Another recent development is the FinderMap client-server system, which was developed to support group cooperation in scientific projects. The application allows researchers to position a symbol at a coordinate location on a world map, add some project information as a WWW link, and store this information on a server. The contact symbols on a FinderMap are clickable so that the map provides an overview and lets the visitors navigate to distributed research projects on a WWW platform.

Spatio-temporal animations can be visualized with another Descartes derivative; the MovieMap applet pictures moving point objects as well as events on stationary objects. An animation control panel allows one to start, stop, and reset the cartographic movie. A specific date within the animation period can be selected and the length of a time step of the movie can be changed. In the case of moving objects, the animation displays the changing positions of selected objects with connecting lines on top of a map. In the case of events, the animation highlights map objects when an event occurs. The user can choose whether previous positions/events continue to be displayed or whether only positions/events of the actual time step are visible.

The data input and navigation function of FinderMaps have a strong relation to the Argumap use cases established earlier in this thesis. Only the positioning of symbols at coordinate locations instead of geo-objects is incompatible with the Argumap model of chapter 3 and the exploration use case of section 5.2, because explicit links map elements were required. MovieMaps offer a way of visualizing the course of a debate by successively displaying symbols for contributions according to their date of submission. The ShowMap applet enables visual exploration of the spatial distribution of discussion contributions. The mockups described in the following section use these three Descartes variants separately. Afterwards, the envisioned architecture of a Descartes-based Argumap is presented on the base of command and data flows in the hope that the capacities of the ShowMap, FinderMap, and MovieMap applets can be combined with the Descartes server component.

6.3.2. Functionality of a Descartes-based Argumap

Navigation

The user accesses the Argumap in his WWW browser, either as an occasional visitor to a community homepage that provides links to current planning projects, or as a user of the Zeno discussion forum who seeks a map-based overview and access to discussion contributions.

The Argumap combines a representation of the planning map with annotation symbols attached to plan elements. Owing to restrictions of the Java 1.1 Abstract Windowing Toolkit (AWT) concerning topographical symbology, the planning map should preferably be presented as a raster map. Important plan elements can be drawn as vector objects in their own layer on top of the planning map. (This could not be implemented with the raster-based FinderMap applet used for this mockup.) Mapping functionality includes standard functions as provided by Descartes. The annotation symbols are also on their own layer so that they

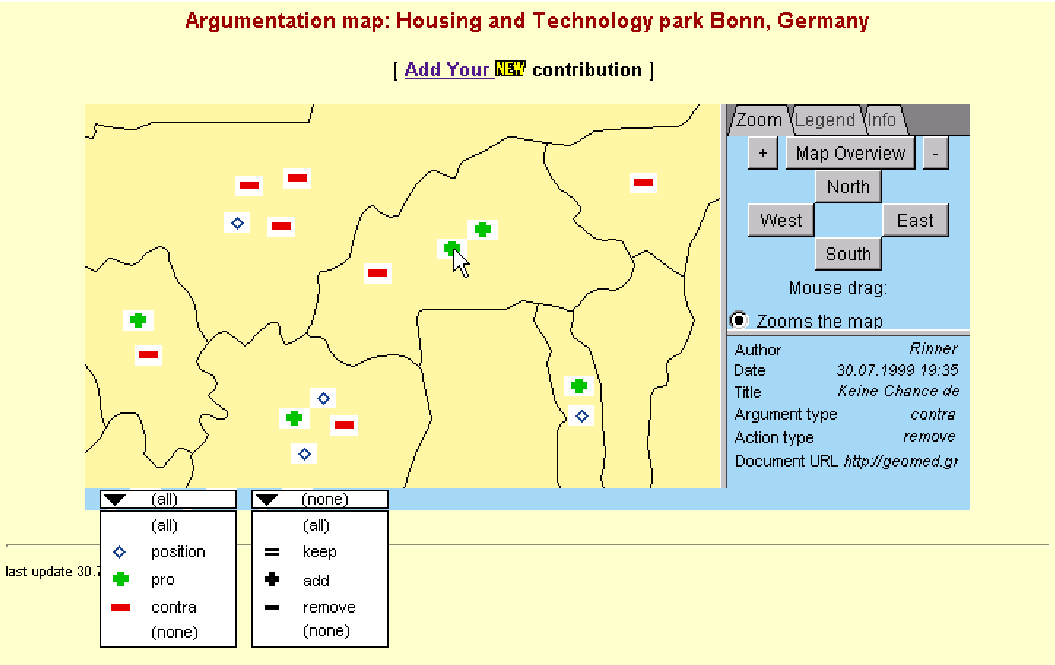

Figure 6.6.: Using the FinderMap applet to show locations of positions, pro and contra arguments on a "plan", including filtering options for argument type and action type (design proposal based on a screenshot from `http://www.dialogis.de/`, "dialoGIS | FinderMap | Researchmap")

can be switched on or off, thus providing the possibility of simply viewing the draft plan, without a reference to the ongoing debate.

Within the navigation use case users can access single discussion contributions from the map view. Moving the mouse cursor over an annotation symbol will show the title of the related message in the map's status line. Clicking on a symbol opens the related message in the Zeno mediation system. When using Zeno's HTML client, it is not necessary to distinguish links to documents from links to a argumentation tree browser, because documents are always displayed in their argumentative context, with hyperlinks to related arguments. By contrast, a listing of several argument links must be generated, if a user chooses to view all contributions for a plan element.

A display filter for annotation symbols in the form of a selection list reduces the complexity of the display. It allows the user to display only arguments of a single type, or arguments of all types down to a specific type in the IBIS type hierarchy. In a second filter selection, the reader can choose to see only contributions of a specific author or contributions that contain a specific keyword (full text search). Figure 6.6 shows a design proposal for these functions added to a screenshot of the FinderMap applet.

The inclusion of animation control tools would be useful for displaying and accessing discussion messages for specific dates or periods of time, see below and figure 6.9. Navigation also

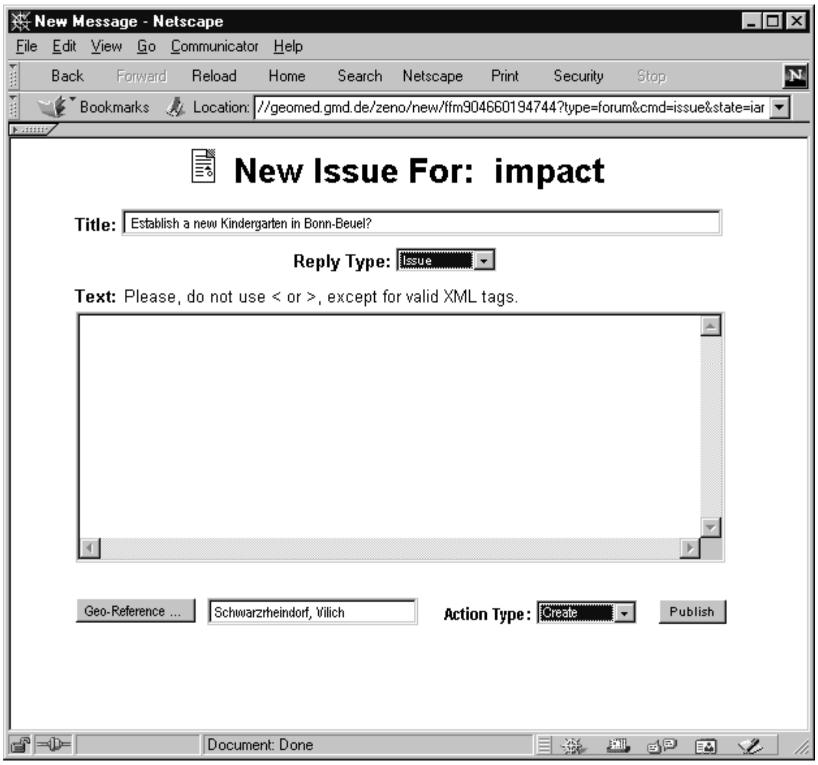

Figure 6.7.: Geo-referenced message composition in Zeno (modified after a screenshot of `http://geomed.gmd.de/client/zeno.html`, "HTML user interface")

includes opening Descartes from a Zeno window. A "Show location" button will be attached to the argument display in Zeno. On clicking this button a Descartes window appears with the planning map zoomed in and centered at the geo-objects referred to by the argument.

Participation

The participation functionality of an Argumap comprises the login to a discussion forum (which notifies the system of the author's name), the input of the text of a new discussion contribution, and the input of further attributes as defined by the Argumap model in chapter 3. The input of a new contribution starts in the Zeno discussion forum, because user management and argumentation model are implemented there and provide a part of the required input (author name, argument type and relation to other arguments). To Zeno's "New Message" window must be added an input field for the argument's action type as well as a button for defining the geographic reference for the new message (see figure 6.7).

When the user presses the "Geo-Reference ..." button, Descartes is started or, if already running, gets the window manager focus. The user selects one or more geo-objects that are related to his/her message by positioning FinderMap symbols on the map. After submitting the geo-reference, the names and IDs of the geo-objects that lie below the symbol positions appear in the Zeno message composition window and are stored in the metadata of the new

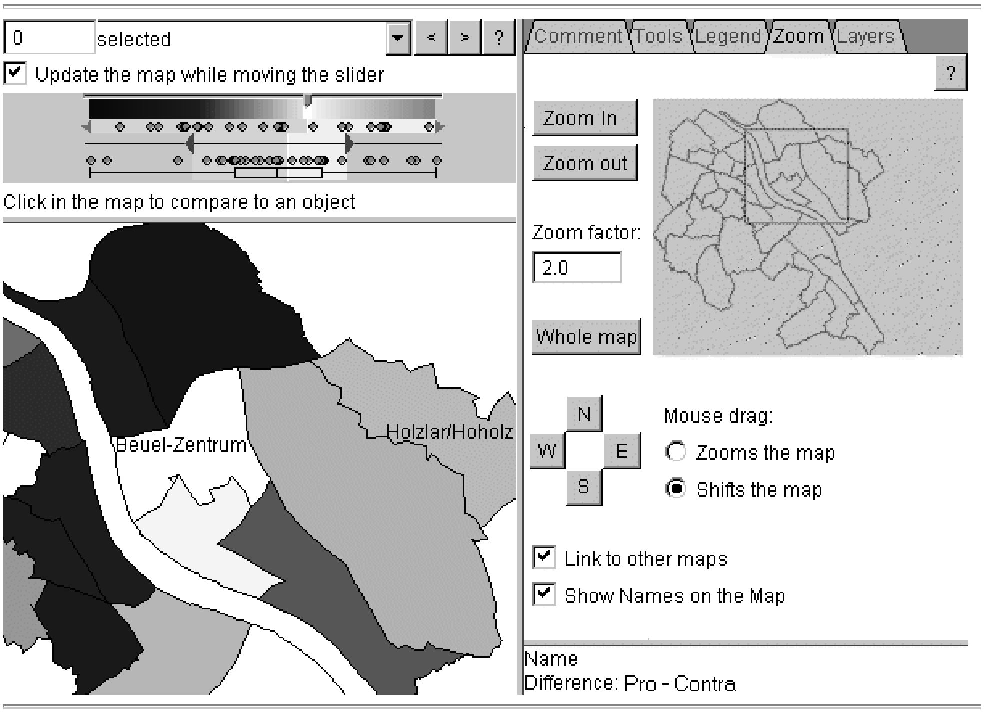

Figure 6.8.: Using the ShowMap applet to visualize the difference in the number of pro-arguments and contra-arguments per plan element (modified after a screenshot of `http://borneo.gmd.de/and/java/iris/app/elect/m19.html`)

contribution.

Exploration

Part of the navigation functions described above can also be useful for exploring the spatio-temporal distribution of arguments. For example, filtering the display of symbols to show only contra-arguments would not only make the latter accessible, but would also indicate the most conflicting locations of the debate; or running the chronological appearance of messages would show shifts in the discussion's focal point with time. The difference is in the use pattern: navigation aims at getting information about an ongoing debate, in order to prepare a new contribution; exploration rather helps the planning professional to summarize and build a report about a finished discussion procedure.

Descartes supports map exploration in the proper sense through dynamic manipulation of visual variables, specifically the colour of polygon objects, and the shape and size of bar and pie charts. Andrienko and Andrienko (1999a) give detailed explanations for dynamic visual comparison in choropleth maps, dynamic manipulation of bar charts, dynamic focusing on a value subrange of a numeric variable, dynamic classification and cross-classification in choropleth maps. These techniques allow an analyst of a geographically referenced debate to

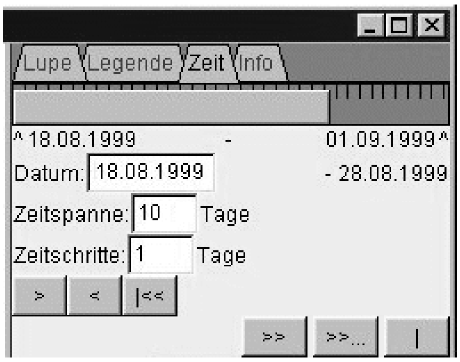

Figure 6.9.: Map animation tool of the MovieMap applet (German language version). The history of a discussion could be displayed by selecting a starting date, the number of days to be activated, and the number of days for stepping forward; the tool allows to move forward (or backward) step by step for detailed inspection, or to display the animation as a whole (modified after a screenshot of `http://www.dialogis.de/`, "dialoGIS | MovieMap")

compare numbers of arguments with specific attributes (argument type, action type, date, or author; see model in chapter 3) for several geo-objects, and to determine *classes* of geographic objects with similar argumentative characteristics.

An example for using a classified choropleth visualization of the difference in the number of pro-arguments and contra-arguments is given in figure 6.8. Figure 6.9 shows the MovieMap applet's "player" tool for a temporal animation of a debate.

With the limited set of attributes of the Argumap model in mind, it may be reasonable to let the professional user choose the desired visualization technique and thus implement the Argumap on the base of applet clients with little or no server-side processing. But in the following description of an integrated Argumap with Zeno and Descartes, the Descartes server will provide assistance in selecting appropriate visualizations for a set of attributes, transferred from Zeno.

6.3.3. Architecture

This section describes command and data flows for selected Argumap sessions, in order to clarify what is required to dynamically link Zeno and Descartes. The person interacting with the system takes several role names according to the action he/she performs: Author, Visitor, Analyst. The actions of the person are noted like software functions. For technical reasons, it was not always possible to display the right parameter types in the following sequence diagrams and to show iterative function calls.

Figure 6.10 describes the sequence of actions for the input of a new contribution. The user interacts mainly with the discussion forum. First, he/she initiates the reply session by selecting a reply button in an argument display. Zeno opens a message composition window like

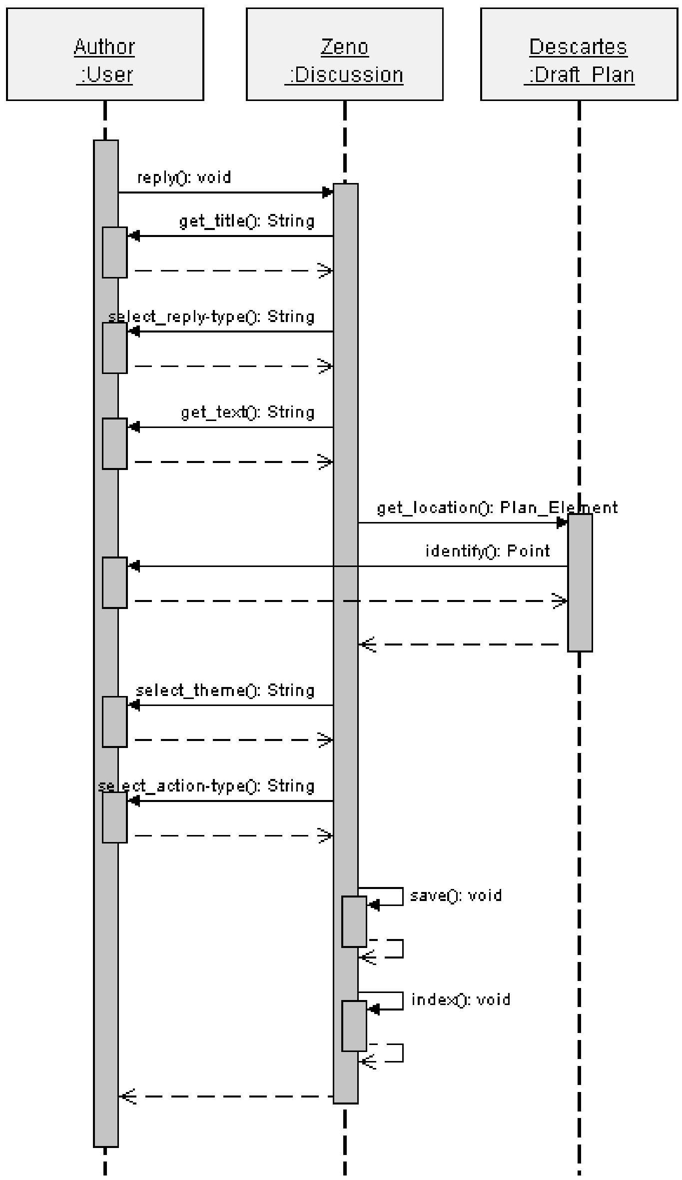

Figure 6.10.: Sequence diagram showing the command and data flow between Zeno and Descartes for the input of a new contribution

the one shown in figure 6.7 and requires textual input of the message's title and full text, and the selection of the reply type.

As soon as the user hits the "Geo-Reference ..." button, Zeno asks for a geographic reference on the draft plan associated with the current discussion forum. Descartes takes over the control and asks the user to point to a location on the map. Then, the GIS identifies the plan element that lies at that location and returns its ID to Zeno. This method must be iterated as long as the user wants to add further reference objects. Depending on the number of geo-references, the user must then select the theme and the action type of the message. Reply type, theme, and action type variables will be of an ordinal data type, which could be replaced by a string ("issue"; "orientation"; "change") as in the figure.

After collecting and checking the user input, the forum stores the data in its database. If an index is used to support full text search facilities in the forum, it is updated.

Figure 6.11 shows a sample navigation session that is based on a map view in Descartes. Before any user interaction, the Descartes component must get data on all geo-referenced arguments to be able to visualize them. This data includes the title, the argument and action types, the theme, and the geographic reference objects. Arguments are visualized through annotation symbols that represent a user-selected attribute by their shape and colour, for example the argument type. A set of annotation symbol types is provided for the allowed values of argument attributes according to the model in chapter 3.

By interacting with the map, the user may—at any time during the session—perform zoom and pan operations, in order to view the most interesting map regions. If a map view is too densely populated with annotation symbols, the user may filter the annotation symbols according to their attribute values. In the diagram, filtering is performed for the argument type property. After any filter operation that changes the graphical presentation, a matching of the actual argument base between Descartes and Zeno should take place, as indicated by the "get_arguments" function in figure 6.11. A regular update could also be useful to keep track of very active debates, where new messages are submitted permanently.

Viewing the Argumap is not limited to passive observation of argument positions, but when moving the mouse over a plan element, a list of titles of the arguments located there is displayed in a frame of the Descartes client. If the user clicks on a plan element he/she can access the contents of discussion contributions related to that location. If the plan element is referred to by multiple arguments, the Zeno system compiles a list with titles of all related contributions and displays the contents according to the user's selection. In order to display the geographic reference, Descartes provides the geographic name for the identifier stored in Zeno.

The "read_context" method demonstrates that a navigation session can also largely take place in the Zeno forum, by accessing and reading related messages in the argumentation browser. The entire workflow described so far may be iterated several times, jumping back and forth

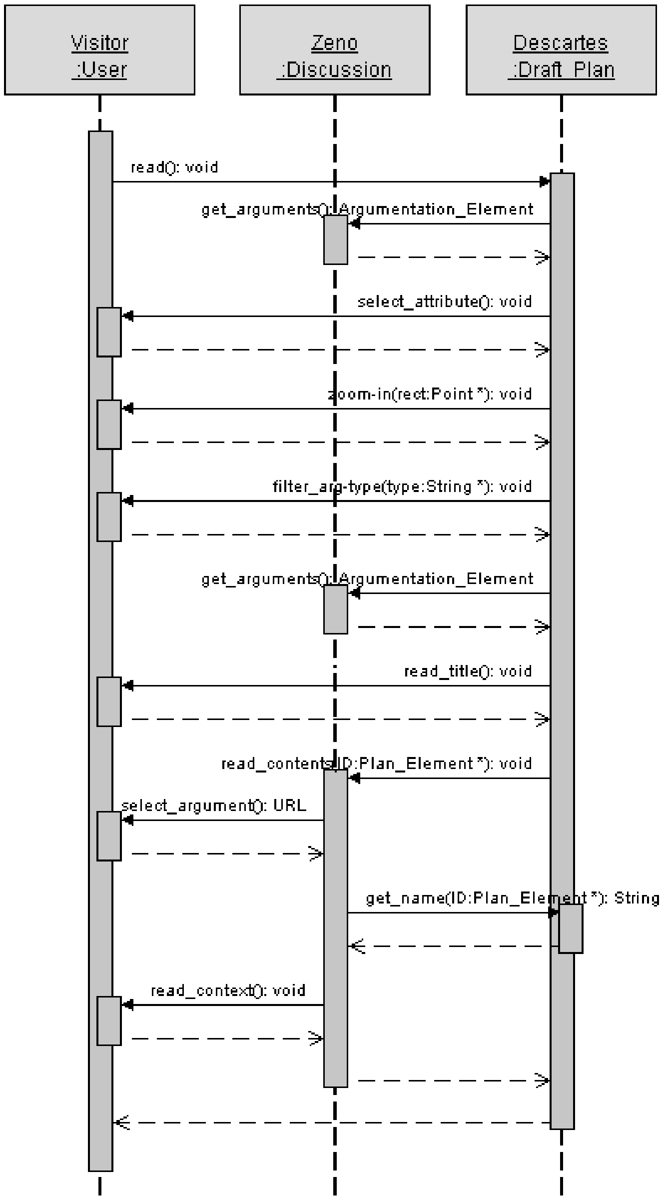

Figure 6.11.: Command and data flow for a navigation session

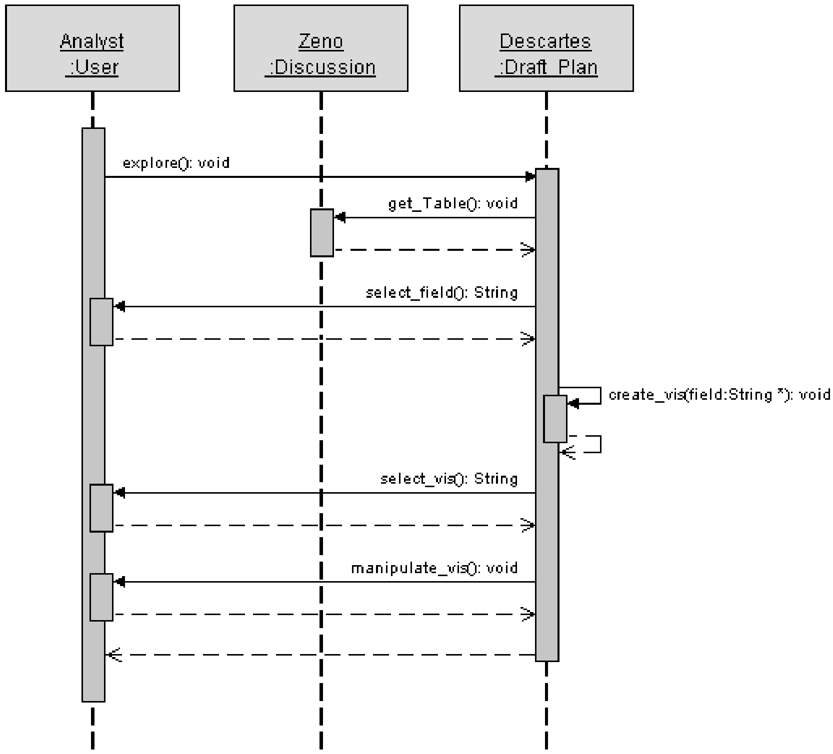

Figure 6.12.: Command and data flow for an exploration session

from Zeno to Descartes. Through these multiple data exchanges the navigation use case puts high demands on the link between Zeno and Descartes.

Figure 6.12 gives an overview of the exploration function of a Descartes-based Argumap. Importantly, Zeno must provide a tabular summary of the total number of arguments per geo-object, as well as the number of arguments of the different argument types, themes, and action types, the number of contributions per author and geo-object, and the number of contributions per date and geo-object. The granularity of these data (time period, classification of authors) depends on the actual discussion procedure. Then, the user is asked to select data fields to be visualized.

The Descartes server will have a knowledge base with information about the properties of the Argumap attributes and the relationships between them. Thus, the system can create appropriate thematic maps and let the analyst select among them. Exploration then is performed via map manipulation functions offered by Descartes. This workflow can also be iterated at the intermediate steps, field selection and visualization selection.

6.3.4. Comment

The design of Argumap use cases with Zeno and several Descartes derivatives addresses the shortcomings of the VRML prototype, primarily improving the exploration function, and demonstrates the feasibility of the Argumap concept. The dynamic connection between Zeno and the proper Descartes system could not be implemented within the frame of this thesis. However, the above sequence analysis did not reveal any principle difficulties to be faced when combining the discussion forum with the cartographic explorer.

Through the planned integration with another Java GIS, the Lava/Magma system by PGS, Descartes provides additional perspectives related to the Argumap analysis use case. A first prototype of this integration already exists and will be further developed within the European Union CommonGIS project (`http://taws08.jrc.it/`).

Both demonstrators could be further developed in order to support the full scope of envisioned Argumap uses. For example, the VRML solution would provide storage functions to save argument locations, and, possibly, functions for interactive exploration of map and annotation symbols. The Descartes solution could provide 3D display and navigation, if the Java 3D library would be used. Both approaches seem worth improving and being submitted to an empirical analysis.

7. Conclusion

This final chapter, first, gives a summary of the thesis and highlights the main contributions to the field of geographically referenced discussing. Then, to conclude this dissertation, the issue of how to continue work on Argumentation Maps is discussed, and related further research questions are suggested.

7.1. Summary

Argumaps support asynchronous discussions in online planning procedures with GIS methods, especially using maps as a user interface. The foundations have been laid out in chapter 2 with an overview of the area of Geographic Information Science (GI Science) and Argumentation Theory. GI Science has been presented with an emphasis on geo-data modeling and aspects of cartography and map use. Argumentation Theory has been summarized stressing the Issue-based Information Systems model. In a third section in that chapter, the combination of GI Science and Argumentation Theory to support Collaborative Spatial Decision-Making has been analyzed, both on a methodological level, and with reference to existing computer tools. The most important CSDM settings for this analysis were asynchronous debates in spatially distributed groups of persons with diverging interests, such as the situation in a German public participation procedure in land-use planning.

One of the major shortcomings of the few, existing approaches is the missing analysis capacities of the tools. This supported the idea of asking users to specify the geographic reference and other attributes of their arguments explicitly, in order to get a base for structured analysis and achieve more explicit discussions. The Argumap model proposed in chapter 3 provides a good base for designing Argumap systems which achieve these objectives. In an intuitive way, the model specifies the overall entities to be considered when examining geo-referenced debates. Chapter 4 derives some theoretical findings from the model, mainly a definition of argumentative distance and topology, and discusses how the abstract understanding of geo-argumentative spaces allows us to represent spatial conceptions of discussants in planning debates.

The visionary scenario of computer-supported planning discussion in the introductory chapter is made more concrete by grouping the functions Argumaps should provide, and establishing prototypical use cases that become possible if support tools are based on the proposed Argumap model. The functional and use case description of chapter 5 as well as its list of requirements for GIS to support Argumap implementations are used to describe two prototype implementations in chapter 6. The first has been realized to demonstrate how users could navigate through geo-referenced discussion contributions and how they could give new arguments an explicit spatial reference. The sketch of a second prototype is used to envision how users could assess an ongoing or finished planning debate, by means of visual exploration of the distribution of arguments over the draft plan and in combination with GIS spatial analysis functions.

7.2. Outlook

The present introduction to Argumaps could be complemented by several enhancements. First, an actual implementation of the Zeno and Descartes prototype would be useful to complete the demonstration of appropriateness of the established use case classification. A refinement of the Zeno and VRML prototype would also be interesting for practical use and for generating further research opportunities related to 3D display and navigation.

Second, evaluation of Argumaps is needed and could be performed with one of the completed prototypes. Nyerges and Jankowski (1997) present a comprehensive framework for investigating the use of participatory GIS, which should be taken into account for structuring empirical tests of Argumaps.

Furthermore, a combination of Argumaps—as conceived in the present thesis—with other tools and methods, like the intelligent land-use plan and SupportGIS mentioned in chapter 2 on page 31 and 33, respectively, could be useful. A link between Argumaps and multicriteria decision-making tools, such as GeoChoice Perspectives (`http://www.geochoice.com/`), would allow stakeholders to discuss the choice of the "right" criteria for the evaluation and ranking of planning alternatives. All this would be steps towards using planning maps as cartographic user interfaces for a complete planning laboratory for professional user groups.

Artificial Intelligence methods could be helpful to improve Argumap functionality. For example, the use of *text mining* to find geographic references in discussion messages could assist users in spatially indexing their arguments; and a map robot for constraint-based construction of plan alternatives and assessment of geo-referenced argumentation could be designed on the base of expert systems.

A GIS-related research question that could not be worked out in this dissertation concerns theories of attributes of geographic objects. The specific nature of discussion contributions linked to map elements in an Argumap suggests to examine whether there are other applications that work with textual entities with a complex, internal hierarchy, leading to theories of "soft attributes" or "stand-alone attributes" for GIS. Specifically, the issues related to specific needs for connecting *documents* (instead of data values) to map locations and/or geo-objects should be further explored.

In the GIS field, it is well-known that real-world entities can only approximately be modeled by database objects, because they often have undetermined boundaries. An approach to cope with resulting problems is to define fuzzy or fractal boundaries. It could be interesting to examine relations between argumentation elements and fuzzy geo-objects, as well as to interpret geo-argumentative relations themselves as fuzzy objects.

In general, geo-referenced argumentation also occurs in other geographic application areas than in planning, e.g. in spatial resource allocation of companies and in geomarketing. Therefore, Argumaps could be very useful in a wide range of applications, and finally cross the borderline to virtually spatial applications, when the vision of "visualization of information geographically" by (McKee, 1996) becomes reality.

A. Notation of the Unified Modeling Language (UML)

The following pages describe the three types of Unified Modeling Language (UML) diagrams used in this dissertation: class, use case, and sequence diagrams. The diagram definitions in terms of semantics and notation are quoted as parts of the complete definitions in Rational (1997).

A.1. Class diagram

Semantics

A class diagram is a graphic view of the static structural model. The individual class diagrams do not represent divisions in the underlying model.

Notation

A class diagram is a collection of (static) declarative model elements, such as classes, interfaces, and their relationships, connected as a graph to each other and to their contents. From the levels of details given in figure A.1, this thesis uses the analysis-level details (b).

Relationships between classes of objects used in this thesis are aggregation and association. In figure A.2(a), the *Whole* class consists of zero or any number of *Part1*s, while *Part1* belongs to zero or one *Whole*s. Association is a more general concept where two classes play a certain role in a named relation, as shown in figure A.2(b).

A.2. Use case diagram

Semantics

Use case diagrams show elements from the use case model. The use case model represents functionality of a system or a class as manifested to external interactors with the system.

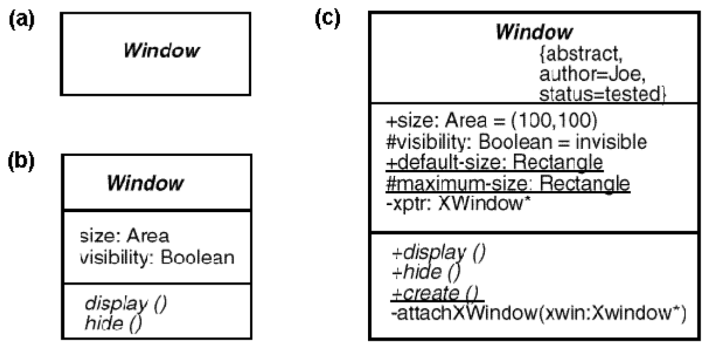

Figure A.1.: UML class diagram: (a) details suppressed, (b) analysis-level details, (c) implementation-level details (after Rational, 1997)

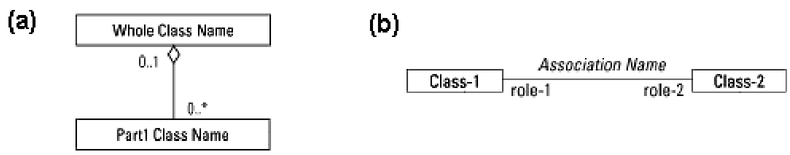

Figure A.2.: Relationship between classes: (a) aggregation with multiplicity, (b) association with role names (after Rational, 1997)

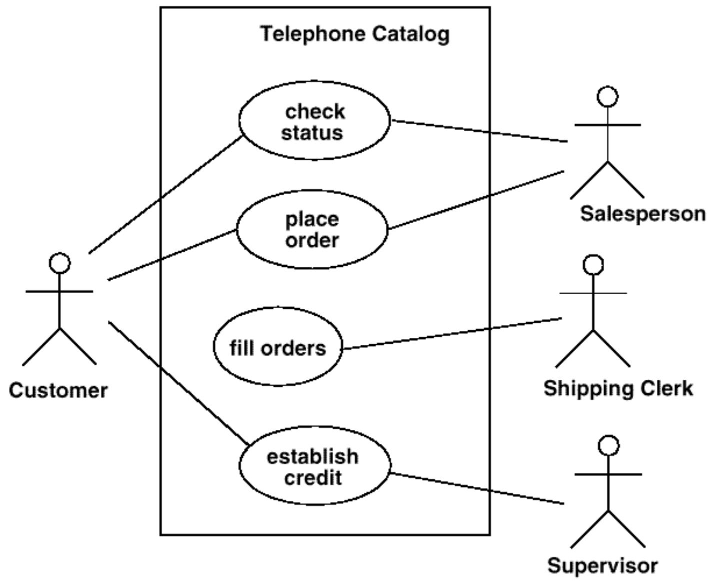

Figure A.3.: UML use case diagram (after Rational, 1997)

Notation

A use case diagram is a graph of actors, a set of use cases enclosed by a system boundary, communication (participation) associations between the actors and the use cases, and generalizations among the use cases.

In addition, Harmon and Watson (1998, p. 113) give the rule that “actors on the left side represent people, while actors on the right side represent systems”.

A.3. Sequence diagram

Semantics

A sequence diagram represents an Interaction, which is a set of messages exchanged among objects within a collaboration to effect a desired operation or result.

Notation

A sequence diagram has two dimensions: the vertical dimension represents time, the horizontal dimension represents different objects. Normally time proceeds down the page. There is no significance to the horizontal ordering of the objects.

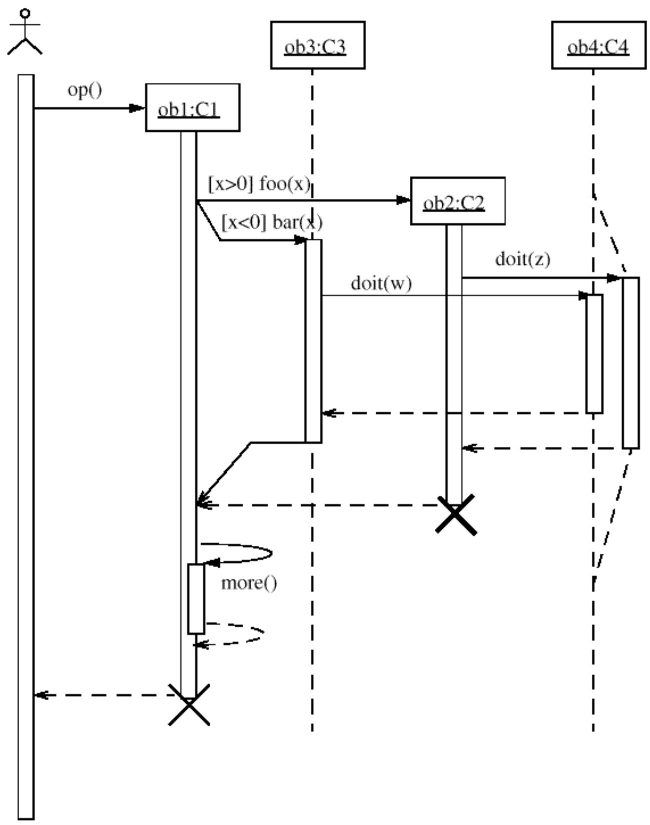

Figure A.4.: UML sequence diagram with focus on control, conditional, recursion, creation, and destruction (after Rational, 1997)

B. Source code of Demonstrator 1

The following sections describe the source code of the HTML, VRML, and Java files of the first prototype of chapter 6. These files build the most important parts of the Argumap client in figure 6.5.

B.1. HTML file

The HTML file is the frame for the VRML graphics and the Java GUI area. It reserves a part of the WWW browser's window for an embedded VRML viewer and another part for the Java applet.

```
<embed src="argumap.wrl" border=0 width=500 height=250 vrml-dashboard=false>
```

The VRML viewer is started when the browser encounters the *embed* tag with a VRML world as the source file. The VRML viewer's navigation controls are suppressed by the Cosmo Player-specific *vrml-dashboard* parameter.

```
<applet code="ArguMap.class" width=500 height=125 mayscript></applet>
```

The Argumap GUI is loaded as a class file in Java bytecode that is located in the same directory as the HTML and VRML files. The *mayscript* parameter, which is specific to the Netscape browser, establishes a live connection between the Java applet and JavaScript code. Without this parameter, the Argumap Java applet could not get a reference to the VRML viewer from Netscape's built-in JavaScript methods.

B.2. VRML files

This section explains the VRML source files "argumap.wrl" and "flagproto.wrl" that define the overall VRML scene and the prototype for flag symbols, respectively. VRML files begin with a line indicating the format, version, and the character set (Unicode Transformation Format 8). The *WorldInfo* node allows the programmer to give the scene a title and provide information such as project description, author, date. The *title* string would be displayed as the WWW browsers window title if the document contained only the VRML scene, without a surrounding HTML page.

```
#VRML V2.0 utf8

WorldInfo {
    title "Annotated Dransdorf map image"
    info "VRML Scene by Claus Rinner, 01/98"
}
```

The *Background* node provides colours for the sky and the ground behind the geometric objects of a scene. In the code given below, only one background colour is specified and set to a light grey RGB value. User movement can be constrained through the *NavigationInfo* node. Here, the type of navigation controls is set to the *EXAMINE* mode, which means that the scene can be manipulated in three dimensions as if the visitor held it in his/her hands (see figure B.1). The headlights of a fictional helmet were set on in order to get brightly shining VRML objects. A viewpoint is defined through the position and the orientation of the visitor. Positions in VRML are specified as (x,y,z)-triples with a right-handed coordinate system, where x goes to the right, y points up, and z is directed towards the user. An orientation is given as a rotation around an axis by an angle. Here, the axis (1,0,0) is the x-axis, while the angle is 0.5 radian. That is, the entry view is slightly inclined ahead. The *description* field of a viewpoint is the label listed in the VRML browser's viewpoint menu (figure B.1, to the left).

```
Background{
    skyColor 0.8 0.8 0.8
    groundColor 0.8 0.8 0.8
}

NavigationInfo {
    type "EXAMINE"
    headlight TRUE
}

Viewpoint {
    position 0 -20 30
    orientation 1 0 0 0.5
    description "Entry"
}
```

Figure B.1.: Cosmo Player 2.0 navigation control panel

The following lines describe a geometric shape, a thin box with x and y sizes adjusted to the JPEG image that is attached to it as a texture. The *url* field of the texture loads the map image from a local file, but it could load any valid URL that points to an image on a remote server.

```
Shape {
    appearance Appearance {
        texture ImageTexture { url "argumap.jpg" }
    }
    geometry Box { size 64 89 0.05 }
}
```

The *EXTERNPROTO* keyword initiates a kind of type definition, the contents of which are stored in an external file. The statement announces the interface of the prototype to the VRML viewer. The Flag prototype defined here is stored in “flagproto.wrl” that is described below.

```
EXTERNPROTO Flag [
    field SFColor color
    field SFVec3f position
    field SFInt32 level
    exposedField MFString label
]
"flagproto.wrl"
```

The last statement in “argumap.wrl” introduces an empty group that is intended to incorporate the flag symbols that will be added to the scene by the Java applet described in section B.3. The *DEF* keyword gives a name to the *Group* object so that the VRML viewer can provide a handle for the object to the Java applet.

```
DEF Flags Group{}
```

The remainder of this section describes the external prototype definition for the flag symbols. The file starts with the VRML header line and the prototype’s interface which must be an exact copy of the external prototype definition in the main file. The *color* parameter and the *label* string define the appearance of the flag symbol. The *position* field is its position on the map surface. Finally, *level* is a key for the rank in the IBIS argument hierarchy, influencing the size of the symbol and its visibility (see below). The values specified at the end of each field definition are the default values.

```
#VRML V2.0 utf8

PROTO Flag[
    field SFColor color 0 0 0
    field SFVec3f position 0.0 0.0 0.0
    field SFInt32 level 1
    exposedField MFString label "type"
]
```

A Flag object consists of a cylinder as staff, a thin box as corpus, and a text that shows the label property, indicating the type of argument represented by the flag. These components are grouped together as the *children* nodes of a *Transform* node. Its initial translation is set to the value of the position parameter. The flag is slightly rotated in order to keep it visible for those who look at the map from a bird's perspective.

```
{
    DEF tr Transform{
        translation IS position
        rotation 1 0 0 1.41
        children[
```

The *Transform* node has an effect on a single node, a level-of-detail (*LOD*) definition. A *LOD* defines ranges for differently generalized displays for a scene. In this case, there are two ranges, $[0..40]$ and $[40..\infty]$. The *level* array contains the descriptions of the two alternative visualizations, one after the other. The VRML viewer selects the level that corresponds to the current distance of the user from the center of the scene.

The first level-of-detail is a *Billboard* node, i.e. an object that turns around a default axis to re-orient itself to the viewpoint of the user. *Billboards* are grouping nodes (like *Group*, *Transform*, and *LOD*) that enclose different children nodes.

```
            DEF lod LOD{
                range[ 40 ]
                level[
                    Billboard{
                        children [
```

The first part of the billboard is a narrow, white cylinder, the flag staff. The cylinder must be translated by half its height in order to have its foot at height zero, on the map surface. The transformation node also comprises a *PlaneSensor*, that is a node that registers dragging events by the user in two dimensions. The plane sensor is calibrated to the starting position of this flag instance.

```
Transform{
    translation 0 1.5 0 #move foot to origin
    children [
        Shape{ #cylinder
            appearance Appearance{
                material Material{ diffuseColor 1 1 1 }
            }
            geometry Cylinder{
                radius 0.1
                height 3
            }
        }
        DEF ps PlaneSensor{
            offset IS position
        }
    ]
}
```

The second child of the billboard is the flag corpus, the last child is the label text. The corpus is a thin box of the colour determined by the prototype parameter. The text was defined as a *Text* geometry; alternatively, it could have been mapped onto the corpus as a texture. Both objects have to be transformed in order to shift them to the appropriate position with respect to the flag staff.

```
Transform{
    translation 0.75 2.625 0
    children[
        Shape{ #flag
            appearance Appearance{
                material Material{ diffuseColor IS color }
            }
            geometry Box{ size 1.5 0.75 0.1 }
        }
    ]
```

```
        }

        Transform{
            translation 0.75 2.25 0.1
            children[
                Shape{
                    geometry Text{
                        string IS label
                        fontStyle FontStyle {
                            size 1
                            justify "MIDDLE"
                        }
                    }
                }
            ]
        }
```

The second level-of-detail is an empty group, which means that in a distance higher than the *LOD* range limit, the flag will disappear.

```
                        ] # children
                    } # Billboard
                    ,
                    Group{} # empty group

                ]   # level
            }       # LOD

        ] # children
    } # Transform
```

The following script performs an initialization when a flag object is instantiated. The *level* parameter is set to the level of the flag. Depending on the *level* value, the outgoing *scale* parameter of the script is set to a scaling vector.

Through the following *ROUTE* statement, the changed scale is transferred to the *translation* field of the named, top-level *Transform* node. That is, the complete flag is scaled according to the script result, meaning that high-level arguments (issues) are represented by larger flags than low-level arguments. The second event routing statement was an attempt to adjust the *LOD* range to the level parameter. But as the VRML node reference does not specify the range field of *LOD*s as an *eventIn* type field, the field cannot be the destination of an event routing mechanism. Thus, the *LOD* range is equal for all levels of flags.

```
    DEF scr Script{
        field SFInt32 level IS level
        eventOut SFVec3f scale
        eventOut MFFloat range
        url "javascript:
            function initialize(){
                range = new MFFloat( 1 );
                if( level == 1 ) scale = new SFVec3f( 4, 4, 4 );
                else if( level == 2 ) scale = new SFVec3f( 3, 3, 3 );
                else if( level == 3 ) scale = new SFVec3f( 2, 2, 2 );
                if( level == 1 ) range[0] = 50;
                else if( level == 2 ) range[0] = 30;
                else if( level == 3 ) range[0] = 20;
            }
        "
    }
    ROUTE scr.scale TO tr.scale
#   ROUTE scr.range TO lod.set_range        # not an enventIn !
```

The final routing statement transmits the translation of the plane sensor object, caused by the user, to the top-level group node of the flag. That is to say that the flag moves together with the dragging mouse cursor.

```
    ROUTE ps.translation TO tr.translation
}
```

B.3. Java applet

The ArguMap Java class creates an applet that provides the graphical user interface below the VRML viewer in figure 6.4 on page 83. In order to communicate with the VRML viewer, the Java applet imports different Java classes of the “vrml.external” package that is delivered with Cosmo Player 2.0 for using the External Authoring Interface (see section 6.2.3).

```
/*
 * ArguMap.java
 *
```

```
 * applet to control VRML Argumentation Map
 *
 * 08/98 by Claus Rinner
 */

import java.awt.*;
import java.awt.event.*;
import java.applet.*;

import java.net.*;

import vrml.external.Node;
import vrml.external.Browser;
import vrml.external.exception.*;
import vrml.external.field.EventInMFNode;
```

The applet consists of a text field for the URL to be linked to the annotation symbol, a choice menu to select an argument type, a button to create a new symbol, and a text area for status messages of the applet execution. The *browser*, *flags*, and *childs* variables are handles to the VRML browser, the encompassing *Group* node of the VRML main file, and the *children* array of that group.

```
public class ArguMap extends Applet{

    TextField tf_url;       // URL of Zeno document
    Choice ch_type;         // type of Zeno document
    Button bn_create;       // button
    TextArea ta_status;     // status field for user info and debugging
    Browser browser;        // the VRML browser
    Node flags;             // the flags
    EventInMFNode childs;   // flags' add_children event in
```

The applet's *init* method is run once, when the WWW browser loads the applet. It sets the background of the Java area on the HTML page to the same light grey as was used as background on the HTML page and in the VRML scene. The GUI elements are created and added to the applet.

```
    // initializations run once
    public void init(){
        setBackground( new Color( 204, 204, 204 ) );
```

```
        add( new Label( "Document URL: " ) );
        tf_url = new TextField( "http://", 40 );
        add( tf_url );

        add( new Label( "Argument type: " ) );
        ch_type = new Choice();
        ch_type.addItem( "Issue" );
        ch_type.addItem( "Position" );
        ch_type.addItem( "Pro-Argument" );
        ch_type.addItem( "Contra-Argument" );
        ch_type.addItem( "Comment" );
        add( ch_type );

        bn_create = new Button( "Create flag" );
        add( bn_create );

        ta_status = new TextArea( 3, 56 );
        add( ta_status );

        ta_status.appendText( "Initialization finished.\n" );
    }
```

The applet's *start* method is run whenever the WWW browser gets the window focus. First, the Java thread is paused for a few seconds to permit the WWW browser to restart the VRML plugin. The EAI requires that on every reappearance of the window, Java gets a new reference to the VRML viewer (called “browser” in the code).

```
    // initializations run on every re-appearance of applet window
    public void start(){
        try{
            java.lang.Thread.sleep( 2000 );
        }
        catch( InterruptedException e ){}

        browser = (Browser) vrml.external.Browser.getBrowser( this );
        if( browser == null ){
            ta_status.appendText( "Browser not found!\n" );
        }
        else{
```

```
            ta_status.appendText( "Browser = " + browser + ".\n" );
        }

        try{
            flags = browser.getNode( "Flags" );
            childs = (EventInMFNode) flags.getEventIn( "addChildren" );
        }
        catch( NullPointerException e ){
            ta_status.appendText( "Failed to address browser!\n" );
        }
        catch( InvalidNodeException e ){
            ta_status.appendText( "Failed to get node: " + e );
        }
        catch( InvalidEventInException e ){
            ta_status.appendText( "Failed to get eventIn: " + e );
        }
    }
```

The events of the Java GUI are processed through the *action* method of the applet, using Java 1.0 event handling technique. On clicking the "create" button, the applet checks whether the URL text field contains a valid URL. If so, it writes a status message and begins composing the new VRML symbol.

```
    // handle GUI event: create button pressed
    public boolean action( Event e, Object obj ){

        if( e.target instanceof Button ){

            String argurl = tf_url.getText();
            try{
                URL tmp = new URL(argurl);
            }
            catch( MalformedURLException mue ){
                ta_status.appendText( "Please enter valid URL!\n" );
                return true;
            }

            ta_status.appendText( "Create new flag ...\n" );
```

The new flag is composed in a string variable. The string must contain a complete, valid VRML file, and therefore starts with the VRML header line, seen before. It also must contain the *EXTERNPROTO* definition for the flag symbol to allow the VRML classes to check the syntax of the subsequent flag instance.

```
Node[] newflag = null;
String newflagstring =
"#VRML V2.0 utf8\n" +
"EXTERNPROTO Flag [\n" +
" field SFColor color\n" +
" field SFInt32 level\n" +
" field SFVec3f position\n" +
" exposedField MFString label\n" +
"]\n" +
"\"flagproto.wrl\"\n\n" +
```

The flag symbol is defined as an *Anchor* node that provides a hyperlink to the URL given by the user, to be opened in a named browser frame. The *description* parameter is a text that appears when the user moves the mouse cursor over the anchored VRML object.

```
"Anchor{\n" +
" url \"" + argurl + "\"\n" +
" description \"View Zeno document\"\n" +
" parameter \"target=viewerFrame\"\n" +
" children[\n" +
"  Flag{\n";
```

The flag parameters for level (influencing the symbol's size), colour, and label string are then filled with values that depend on the selection in the argument type choice menu.

```
switch( ch_type.getSelectedIndex() ){
    case 0: newflagstring +=
        "level 1\n" +
        "color 0 0 1\n" +
        "label \"?\"\n";
    break;
    case 1: newflagstring +=
        "level 2\n" +
        "color 1 1 0\n" +
        "label \"<>\"\n";
    break;
    case 2: newflagstring +=
```

```
                "level 3\n" +
                "color 0 1 0\n" +
                "label \"+\"\n";
            break;
            case 3: newflagstring +=
                "level 3\n" +
                "color 1 0 0\n" +
                "label \"-\"\n";
            break;
            default: newflagstring +=
                "level 3\n" +
                "color 0.4 0.4 0.4\n" +
                "label \"...\"\n";
        }

        newflagstring +=
        "  }\n" +
        " ]\n" +
        "}\n";
```

The VRML viewer is then instructed to *try* to create a VRML object from the composed string. An *InvalidVrmlException* is thrown if the definition of the new flag contains a VRML syntax error.

```
        try{
            newflag = browser.createVrmlFromString( newflagstring );
        }
        catch( InvalidVrmlException ex ){
            ta_status.appendText( "Invalid VRML string in applet!\n" );
        }

        try{
            childs.setValue( newflag );
        }
        catch( NullPointerException ex ){
            ta_status.appendText( "Failed to add children!\n" );
        }
    }
```

Finally, the new VRML object is added to the *children* field of the top-level VRML group and the *action* method is terminated.

```
        if( e.target instanceof Checkbox ){
            ta_status.appendText( "Change mode ...\n" );
        }
        return true;
    }
}
```

Bibliography

Abecker, A., Decker, S., Matta, N., Maurer, F., and Reimer, U. (1998). Call for Papers Workshop on Building, Maintaining, and Using Organizational Memories (OM-98), in Conjunction with the 13th Biennial European Conference on Artificial Intelligence (ECAI-98). Available: `http://www.aifb.uni-karlsruhe.de/WBS/ECAI98OM/CFP.html` [August 17, 1999].

Albrecht, J. (1992). Objektorientierung und Wissensbasierung in GIS - einige erläuternde Bemerkungen. In *Salzburger Geographische Materialien, Heft 18*, pages 43–47, Salzburg, Austria.

Andrienko, G. L. and Andrienko, N. V. (1998). Interactive maps for visual data exploration. Paper presented at the ICA Commission on Visualization meeting. Available: `http://borneo.gmd.de/and/icavis/` [August 17, 1999].

Andrienko, G. L. and Andrienko, N. V. (1999a). Interactive maps for visual data exploration. *Int. J. Geographical Information Science*, 13(4):355–374. WWW supplement available: `http://borneo.gmd.de/and/IcaVisApplet` [August 17, 1999].

Andrienko, G. L. and Andrienko, N. V. (1999b). Knowledge engineering for automated map design in Descartes. In *Proceedings of 7th ACM Symposium on Advances in Geographic Information Systems (ACM GIS'99)*, Kansas City, USA. Accepted for publication.

Armstrong, M. P. (1994). Requirements for the development of GIS-based group decision-support systems. *Journal of the American Society for Information Science*, 45(9):669–677.

Augstein, B. and Greve, K. (1994). Umweltanwendungen Geographischer Informationssysteme - Bausteine für einen Referenzrahmen. In Dollinger, F. and Strobl, J., editors, *Angewandte Geographische Informationsverarbeitung VI. Beiträge zur AGIT'94*, Salzburg, Austria. Institut für Geographie der Universität Salzburg.

Averdung, C. (1994). Lösungsmodell zur Unterstützung raumbezogener Planungen durch wissensbasierte Informationsverarbeitung. Technical Report 21, Institut für Kartographie und Topographie der Rheinischen Friedrich-Wilhelms-Universität Bonn, Germany.

Bartelme, N. (1995). *Geoinformatik: Modelle, Strukturen, Funktionen.* Springer, Berlin, Heidelberg, Germany.

Beck, C. H., editor (1996). *Baugesetzbuch.* dtv, München, Germany, 27th edition.

Bentley, R., Horstmann, T., Sikkel, K., and Trevor, J. (1995). Supporting collaborative information sharing with the World Wide Web: The BSCW shared workspace system. In *Proceedings of the 4th International WWW Conference*, pages 63–74. O'Reilly.

Bodum, L., Afman, I., and Smith, J. (1998). Visualisation of spatial planning with the use of new media. In *Proceedings of GIS PlaNET'98 International Conference on Geographic Information*, Lisbon, Portugal.

Brewka, G. and Gordon, T. F. (1994). How to buy a Porsche: An approach to defeasible decision making. In *Working Notes of the AAAI-94 Workshop on Computational Dialectics*, pages 28–38, Seattle, Washington, USA.

Brunsdon, C., Openshaw, S., Macgill, J., Turner, A., and Turton, I. (1999). Testing space-time and more complex hyperspace geographical analysis tools. In *Proceedings of GIS Research UK (GISRUK'99)*, Southampton, UK. Available: `http://www.ccg.leeds.ac.uk/smart/data/gisruk99.html` [September 8, 1999].

Buckingham Shum, S. (1996). Design argumentation as design rationale. In *The Encyclopedia of Computer Science and Technology, Vol. 35*, pages 95–128. Marcel Dekker, New York, USA.

Buehler, K. and McKee, L. (1998). *The OpenGIS Guide. Introduction to Interoperable Geo-processing and the OpenGIS Specification.* OpenGIS Consortium Technical Committee, 3rd edition.

Bundy, A., Du Boulay, B., Howe, J., and Plotkin, G. (1984). How to get a Ph.D. in AI. In O'Shea, T. and Eisenstadt, M., editors, *Artificial Intelligence: Tools, Techniques, and Applications.* Harper and Row, New York, USA.

Burg, A. (1999). Der Einfluß des Internets auf die Öffentlichkeitsbeteiligung in der Bauleitplanung am Beispiel Deutschlands, Großbritanniens und Schwedens. In Schrenk, M., editor, *Computergestützte Raumplanung. Beiträge zur CORP'99*, Austria. Selbstverlag des IEMAR der TU Wien.

Buziek, G. and Hatger, C. (1998). Interactive animation and digital cartometry by VRML 2.0 and JAVA within a temporal environmental model on the basis of a DTM of the Elbe estuary and a 12 hour tide period. Available: `http://visart.ifk.uni-hannover.de/~buziek/COMVIS/COMVIS98/buziek/comvis%98.html` [July 26, 1999].

Car, A. (1998). Hierarchical spatial reasoning: Theoretical consideration and its application to modeling wayfinding. Technical Report 10, TU Wien, Austria.

Conklin, E. J. (1991). A process-oriented approach to design rationale. *Human-Computer Interaction*, 6:357–391.

Conklin, E. J. and Weil, W. (1999). Wicked poblems: Naming the pain in organizations. Available: `http://www.gdss.com/wicked.htm` [June 8, 1999].

Conklin, J. (1989). Design rationale and maintainability. In *Proceedings of the 22nd HICCS*. IEEE Computer Society Press.

Conklin, J. (1996). Designing organizational memory: Preserving intellectual assets in a knowledge economy. Technical report, Group Decision Support Systems, Inc.

Conklin, J. and Begeman, M. L. (1988). gIBIS: A hypertext tool for exploratory policy discussion. In *Proceedings of the Conference on Computer-Supported Cooperative Work (CSCW '88)*, pages 140–152.

Conklin, J. and Begeman, M. L. (1989). gIBIS: A tool for all reasons. *Journal of the American Society for Information Science*, 40(3):200–213.

Coors, V. and Flick, S. (1998). Integrating levels of detail in a Web-based 3D-GIS. In Laurini, R., Makki, K., and Pissinou, N., editors, *ACM-GIS'98, Proceedings of 6th International Symposium on Advances in Geographic Information Systems*, pages 40–45, Washington, D.C., USA.

Couclelis, H. (1992). People manipulate objects (but cultivate fields): Beyond the raster-vector debate in GIS. In Frank, A. U., editor, *Theories and Methods of Spatio-Temporal Reasoning in Geographic Space*, pages 65–77. Springer, Berlin, Heidelberg, Germany.

Couclelis, H. and Gottsegen, J. (1997). What maps mean to people: Denotation, connotation, and geographic visualization in land-use debates. In Hirtle, S. and Frank, A., editors, *Spatial Information Theory. A Theoretical Basis for GIS. Proceedings of the International Conference on Spatial Information Theory (COSIT'97)*, pages 151–162, Laurel Highlands, Pennsylvania, USA.

Cowen, D. J. (1988). GIS versus CAD versus DBMS: What are the differences. *Photogrammetric Engineering and Remote Sensing*, 54(11):1551–1555.

Cowen, D. J., Shirley, W. L., and Jensen, J. (1999). GIS design for video-conferencing. In Laurini, R., editor, *Proceedings of First International Workshop on Telegeoprocessing*, pages 86–91, Lyon, France.

Czeranka, M. (1997). GIS-basierte Entscheidungsunterstützung in der naturschutzorientierten Raumplanung. Technical Report 1, Institut für Umweltwissenschaften, Hochschule Vechta, Germany.

Czeranka, M. and Trapletti, A. (1998). Statistische Modellierung mit Neuronalen Netzen und Anwendungen in der Geographischen Informationsverarbeitung. In Strobl, J. and Dollinger, F., editors, *Angewandte Geographische Informationsverarbeitung. Beiträge zum AGIT-Symposium Salzburg '98*, pages 39–50, Heidelberg, Germany. Wichmann.

Däßler, R. and Palm, H. (1998). *Virtuelle Informationsräume mit VRML*. dpunkt-Verlag, Heidelberg, Germany.

Densham, P. J. (1991). Spatial decision support systems. In Maguire, D., Goodchild, M., and Rhind, D., editors, *Geographical Information Systems: Principles and Applications*, pages 403–412. Longman, Harlow, Essex, UK.

Densham, P. J., Armstrong, M. P., and Kemp, K. K. (1995). Collaborative Spatial Decision-Making. Scientific report for the initiative 17 specialist meeting. Technical Report 95-14, National Center for Geographic Information and Analysis (NCGIA).

Doyle, J. and Dean, T. (1996). Strategic directions in Artificial Intelligence. *ACM Computing Surveys*, 28(4):653–670.

Egenhofer, M. J. and Mark, D. M. (1995). Naive Geography. In Frank, A. U. and Kuhn, W., editors, *Spatial Information Theory. A Theoretical Basis for GIS. Proceedings of the International Conference on Spatial Information Theory (COSIT'95)*, pages 1–15, Semmering, Austria. Springer.

ESRI (1996). *ArcView GIS. The Geographic Information System for Everyone*. Environmental System Research Institute (ESRI).

Fairbairn, D. and Parsley, S. (1997). The use of VRML for cartographic presentation. *Computers and Geosciences*, 23(4):475–481.

Fitzke, J., Rinner, C., and Schmidt, D. (1997). GIS-Anwendungen im Internet. *Geo-Informations-Systeme*, 6:25–31.

Fleischhauer, D., Märker, O., Pipek, V., and Schmidt, D. (1998). http://buerger.beteiligung.de? *Standort*, 4:19–25.

Franck, G. (1997). Folgt der Raumordnung die Zeitordnung? Zur technischen Relativierung von Raum und Zeit. In Schrenk, M., editor, *Computergestützte Raumplanung. Beiträge zur CORP97*, Austria. Selbstverlag des IEMAR der TU Wien.

Frank, A. U. (1993). The use of geographical information system: The user interface is the system. In Medyckyj-Scott, D. and Hearnshaw, H. M., editors, *Human Factors in Geographical Information Systems*, pages 3–14. Belhaven Press, London, UK.

Fuhrmann, S. and Kuhn, W. (1998). The design of everyday maps. Paper presented at the ICA Commission on Visualization meeting. Available: `http://ifgi.uni-muenster.de/~fuhrman/publ/ica_polen/design1.htm` [October 5, 1999].

Gahegan, M. (1996). Specifying the transformations within and between geographic data models. *Transactions in GIS*, 1(2):137–152.

GeoMed-F (1995). Geographical mediation systems, feasability project no 174, final report. Technical report, Commission of the European Communities, DG XIII.

Gibson, J. (1979). *The Ecological Approach to Visual Perception.* Houghton Mufflin, Boston, USA.

Göbel, E. O. (1998). Begrüßung und Ansprache. In *Werner-Von-Siemens-Ring. Verleihung an Carl Adam Petri 1996*, pages 11–23. Stiftung Werner-von-Siemens-Ring, Berlin, Germany.

Goodchild, M. F. (1997). Towards a geography of geographic information in a digital world. *Computers, Environment, and Urban Systems*, 21(6):377–391.

Gordon, T. F. (1994). Computational dialectics. In *Workshop Kooperative Juristische Informationssysteme*, pages 25–36. GMD Studien Nr. 241.

Gordon, T. F. and Karacapilidis, N. (1996). The Zeno argumentation framework. In *Proceedings of the Workshop on Computational Dialectics: Models of Argumentation, Negotiation and Decision Making, International Conference on Formal and Applied Practical Reasoning (FAPR '96)*, Bonn, Germany.

Gordon, T. F., Karacapilidis, N., Voß, H., and Zauke, A. (1997). Computer-mediated cooperative spatial planning. In Timmermans, H., editor, *Decision Support Systems in Urban Planning*, pages 299–309. E & FN SPON.

Görz, G., editor (1993). *Einführung in die Künstliche Intelligenz.* Addison-Wesley, Bonn, Germany.

Gottsegen, J. (1995). Modeling human conceptions of regions and boundaries in land use debates. Position Paper for NCGIA Intiative 21: Formal Models of Commonsense Geographic Worlds. Available: `http://pollux.geog.ucsb.edu/~jgotts/i21/position.html` [June 8, 1999].

Gottsegen, J. (1998). Assessing the interests and perceptions of stakeholders in environmental debates through argumentation analysis. In Laurini, R., editor, *Proceedings of the Int. Workshop on Groupware for Urban Planning*, Lyon, France.

Greve, K. and Rinner, C. (1999). Argumentationskarten - GIS-basiertes Planungswerkzeug im WWW. In Strobl, J. and Blaschke, T., editors, *Angewandte Geographische Informationsverarbeitung XI. Proceedings of AGIT Symposium, July, 7-9, 1999, Salzburg, Austria*, pages 237–244, Heidelberg, Germany. Wichmann.

Hake, G. and Grünreich, D. (1994). *Kartographie.* Walter de Gruyter, Berlin, Germany, and New York, USA, 7th edition.

Harmon, P. and Watson, M. (1998). *Understanding UML: The Developer's Guide.* Morgan Kaufmann, San Francisco, CA, USA.

Hendricksen, C. (1999). Asynchronous collaboration by document review. Available: `http://students.washington.edu/veritas/papers/DRpaper/basedoc.html` [September 22, 1999].

Hertzberg, J. (1989). *Planen: Einführung in die Planerstellungsmethoden der Künstlichen Intelligenz*. BI-Wissenschaftsverlag, Mannheim, Germany.

Isenmann, S. and Reuter, W. D. (1996). Ist IBIS in der Praxis anwendbar? - Einige Erfahrungen und Folgerungen. In Krcmar, H., Lewe, H., and Schwabe, G., editors, *Fachtagung Deutsche Computer Supported Cooperative Work (DCSCW'96)*, pages 173–187, Stuttgart-Hohenheim, Germany.

Jankowski, P. and Stasik, M. (1997a). Design considerations for space and time distributed collaborative spatial decision making. *Journal of Geographic Information and Decision Analysis*, 1(1):1–8.

Jankowski, P. and Stasik, M. (1997b). Spatial understanding and decision support system: A prototype for public GIS. *Transactions in GIS*, 2(1):73–84.

Kingston, R., Carver, S., Evans, A., and Turton, I. (1999). A GIS for the public: Enhancing participation in local decision making. In *GIS Research UK (GISRUK'99)*.

Kraak, M. J. and Driel, R. V. (1997). Principles of hypermaps. *Computers and Geosciences*, 23(4):457–464.

Kunz, W. and Rittel, H. W. J. (1970). Issues as elements of information systems. Technical Report 0131, Universität Stuttgart, Institut für Grundlagen der Planung.

Langran, G. (1992). *Time in Geographic Information Systems*. Taylor and Francis, London, UK.

Laurini, R. and Milleret-Raffort, F. (1990). Principles of geomatic hypermaps. In *Proceedings of the 4th International Symposium on Spatial Data Handling (SDH '91)*, pages 642–651, Zurich, Switzerland.

Laurini, R. and Thompson, D. (1992). *Fundamentals of Spatial Information Systems*. Academic Press, London, UK.

Lee, H. D. P. (1967). *Zeno of Elea. A Text, with Translation and Notes*. Adolf M. Hakkert, Amsterdam, Netherlands.

Lehmkühler, S. (1998). Virtual Reality Modeling Language - 3D-Standard des World Wide Web / Chance für die Raumplanung. In Schrenk, M., editor, *Computergestützte Raumplanung. Beiträge zur CORP98*, Austria. Selbstverlag des IEMAR der TU Wien.

Lochter, F.-A., Däßler, R., and Morin, P. (1996). Interaktive Exploration. *iX*, 10:76–82.

MacEachren, A. M. (1994). Visualization in modern cartography: Setting the agenda. In MacEachren, A. M. and Taylor, D. R. F., editors, *Visualization in Modern Cartography*, pages 1–12. Elsevier Science, Oxford, UK.

Maguire, D. and Dangermond, J. (1991). The functionality of GIS. In Maguire, D., Goodchild, M., and Rhind, D., editors, *Geographical Information Systems. Principles and Applications.*, volume 1: Principles, pages 319–335. Wiley, New York, USA.

Malczewski, J. (1999). *GIS and Multicriteria Decision Analysis.* Wiley, New York, USA, Toronto, Canada.

Malone, T. W., Grant, K. R., Lai, K.-Y., Rao, R., and Rosenblitt, D. (1986). Semi-structured messages are surprisingly useful for computer-supported coordination. In *Proceedings of the Conference on Computer-Supported Cooperative Work (CSCW'86)*, pages 102–114.

Mann, T. (1999). Personal communication. Visit to GMD - German National Research Center for Information Technology, Mediation Systems team, July 14, 1999.

Märker, O. (1999). Computervermittelte Kommunikation in der Stadtplanung. Unterstützung formaler Beteiligungsverfahren durch Issue Based Information Systems. Technical Report 10/1999, GMD - German National Research Center for Information Technology, Sankt Augustin, Germany. Also: Master's Thesis University of Bonn, Germany (1998). Available: `http://www.gmd.de/publications/research/1999/010/` [October 6, 1999].

Marrin, C., Kent, J., Immel, D., and Aktihanoglu, M. (1999). Using VRML prototypes to encapsulate functionality for an external Java applet. Available: `http://www.marrin.com/vrml/papers/InternalExternal/Chris_Marrin_1.html` [July 21, 1999].

Maurer, F. and Pews, G. (1995). Ein Knowledge-Engineering-Ansatz für kooperatives Design am Beispiel der Bebauungsplanung. *KI*, 1:28–34.

McCall, R. J., Bennett, P., D'Oronzio, P., Ostwald, J., Shipman, F., and Wallace, N. (1990). PHIDIAS: Integrating CAD graphics into dynamic hypertext. In Streitz, N., Rizk, A., and André, J., editors, *Hypertext: Concepts, Systems and Applications*, pages 153–165. Cambridge University Press.

McKee, L. (1996). Digital maps: An essential part of every citizen's interface to the NII. OGC's position paper for the NRC Computer Science and Telecommunication Board's workshop "Toward an Every-Citizen Interface to the NII". Available: `http://www.opengis.org/techno/articles/citizen.htm` [September 6, 1999].

Norman, D. A. (1988). *The Design of Everyday Things.* Currency and Doubleday, New York, USA.

Nyerges, T. and Jankowski, P. (1997). Enhanced adaptive structuration theory: A theory of GIS-supported collaborative decision making. *Geographical Systems*, 4(3):225–259.

OGC (1998). *OpenGIS Simple Features Specification for SQL, Revision 1.0.* OpenGIS Consortium. Available: `http://www.opengis.org/techno/specs.htm` [September 8, 1999].

OGC (1999). *The OpenGIS Abstract Specification. Topic 5: Features.* OpenGIS Consortium. Available: `http://www.opengis.org/techno/specs.htm` [September 8, 1999].

Openshaw, S. and Openshaw, C. (1997). *Artificial Intelligence in Geography.* John Wiley, Chichester, UK.

Papadias, D. and Egenhofer, M. (1995). Qualitative collaborative planning in geographic space: Some computational issues. Position Paper for NCGIA Intiative 21: Formal Models of Commonsense Geographic Worlds.

Pipek, V., Märker, O., Rinner, C., and Schmidt-Belz, B. (2000). Discussions and decisions: Enabling participation in design in geographic communities. In Gurstein, M., editor, *Community Informatics: Enabling Communities with Information and Communications Technologies.* Idea Group Publishing, Hershey, PA, USA. Submitted for publication.

Plewe, B. (1997). *GIS Online: information retrieval, mapping, and the Internet.* OnWord Press, Santa Fe, NM, USA.

Poiker, T. K. (1997). From traditional cartography to GIS of the 21st century. In Dollinger, F. and Strobl, J., editors, *Beiträge zur Geographischen Informationswissenschaft*, pages 99–104, Salzburg, Austria.

Rational (1997). UML 1.1 notation guide. Available: `http://www.rational.com/uml/resources/documentation/notation` [June 10, 1999].

Reuter, W. (1997). Planning as argumentation and power-acting: Theory and methods. In Timmermanns, H., editor, *Decision Support Systems in Urban Planning*, pages 35–52. E & F N Spon.

Rhyne, T.-M. (1999). A commentary on GeoVRML: A tool for 3D representation of georeferenced data on the Web. *International Journal of Geographical Information Science*, 13(4):439–443.

Rinner, C. (1997a). Geographical mediation - discussing maps via the World-Wide Web. Presentation at ESF conference on Socio-Economic Research and Geographic Information Systems. Available: `http://ais.gmd.de/~crinner/pres/EURESCO97/slide0.html` [Ocober 5, 1999].

Rinner, C. (1997b). Using VRML for hypermapping in spatial planning. In Sellis, T. and Georgoulis, D., editors, *Proceedings of the International Conference on Urban, Regional, Environmental Planning, and Informatics to Planning in an Era of Transition*, pages 818–829, Athens, Greece.

Rinner, C. (1998a). ATKIS-Objekte in VRML? In Strobl, J. and Dollinger, F., editors, *Angewandte Geographische Informationsverarbeitung. Beiträge zum AGIT-Symposium Salzburg '98*, pages 289–297, Heidelberg, Germany. Wichmann.

Rinner, C. (1998b). ONLINE MAPS IN GEOMED - Internet mapping, online GIS and their application in Collaborative Spatial Decision-Making. In *Proceedings of International Conference on Geographic Information (GIS PlaNET'98)*, Lisbon, Portugal.

Rinner, C. (1999). Argumaps for spatial planning. In Laurini, R., editor, *Proceedings of the First International Conference on Telegeoprocessing*, pages 95–102, Lyon, France.

Rinner, C. and Schmidt, D. (1998). Dimensions of DSS application in urban planning. In Laurini, R., editor, *Proceedings of Int. Workshop on Groupware for Urban Planning*, Lyon, France.

Rittel, H. W. J. (1972). On the planning crisis – systems analysis of the first and second generations. *Bedriftsokonomen*, 8:390–396.

Robinson, A. H., Morrison, J. L., Muehrcke, P. C., Kimerling, A. J., and Guptill, S. C. (1995). *Elements of Cartography.* Wiley, New York, USA, 6th edition.

Schmidt-Belz, B., Märker, O., and Purtschert-Voss, C. (1997). Validierung einer WWW-basierten Unterstützung für die Stadt- und Raumplanung. In Dollinger, F. and Strobl, J., editors, *Angewandte Geographische Informationsverarbeitung IX = Salzburger Geographische Materialien, Heft 26*, pages 391–396, Austria. Institut für Geographie, Universität Salzburg.

Schmidt-Belz, B., Rinner, C., and Gordon, T. F. (1998). GeoMed for urban planning - first user experiences. In Laurini, R., Makki, K., and Pissinou, N., editors, *ACM-GIS'98, Proceedings of 6th International Symposium on Advances in Geographic Information Systems*, pages 82–87, Washington, D.C., USA.

Schrenk, M. (1996). Einbeziehung dynamischer Elemente in den Planungsprozeß – regelbasierte dynamische Planung. In Dollinger, F. and Strobl, J., editors, *Angewandte Geographische Informationsverarbeitung VIII*, Austria. Selbstverlag des Instituts für Geographie der Universität Salzburg.

Shiffer, M. J. (1997). Managing public discourse: Towards the augmentation of GIS with multimedia. In Longley, P., Goodchild, M., Maguire, D., and Rhind, D., editors, *Geographical Information Systems: Principles, Techniques, Management and Applications.* Wiley, New York, USA.

Smith, B. (1995). On drawing lines on a map. In Frank, A. U. and Kuhn, W., editors, *Spatial Information Theory (COSIT'95)*, pages 475–485, Berlin, Heidelberg, Germany, and New York, USA. Springer.

Sumner, T. and Buckingham Shum, S. (1998). From documents to discourse: Shifting conceptions of scholarly publishing. In *Proceedings of CHI 98: Human Factors in Computing Systems*, Los Angeles, CA. ACM Press: New York.

Timpf, S. (1998). Hierarchical structures in map series. Technical Report 13, GeoInfo, TU Wien, Austria.

Tobler, W. R. (1970). A computer movie simulating urban growth in the Detroit region. *Economic Geography*, 46(2):234–240.

Tweed, C. (1997). An information system to support environmental decision making and debate. In Brandon, P. S., editor, *Evaluation of the Built Environment for Sustainability*, pages 67–81. Spon, London, UK.

Tweed, C. (1998). Supporting argumentation practices in urban planning and design. In Laurini, R., editor, *Proceedings of the Int. Workshop on Groupware for Urban Planning*, Lyon, France.

Tweed, C. (1999). About CrossDoc. Available: `http://www.qub.ac.uk/tbe/arc/people/staff/chris/CDAbout.html` [June 8, 1999].

Voisard, A. (1998). Geologic hypermaps are more than clickable maps! In Laurini, R., Makki, K., and Pissinou, N., editors, *Proceedings of Int. Symposium on Advances in Geographic Information Systems (ACM-GIS'98)*, pages 14–19, Washington, D.C., USA.

Voß, H. (1996). Dimensions of KBS applications. In *Proceedings of the 2nd Knowledge Engineering Forum*, Karlsruhe, Germany.

Wegener, M. (1978). *Mensch-Maschine-Systeme für die Stadtplanung.* Birkhäuser, Basel, Switzerland, and Stuttgart, Germany.

Willems, S. (1994). Domänen- und Taskanalyse für die Standortwahl in der Stadtplanung. Master's thesis, Fachhochschule Rheinland-Pfalz, Abteilung Trier, Fachbereich Angewandte Informatik.

Wood, M. (1994). The traditional map as a visualization technique. In Hearnshaw, H. M. and Unwin, D. J., editors, *Visualization in Geographical Information Systems*, pages 9–17. John Wiley, Chichester, UK.

Worboys, M. F. (1994). Object-oriented approaches to geo-referenced information. *International Jounal of Geographic Information Systems*, 8(4):385–399.

Worboys, M. F. (1995). *GIS: A Computing Perspective.* Taylor and Francis, London, UK.

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Academic record

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1992-1993	Studies of Applied Mathematics and Geography (*Mathématiques Appliquées aux Sciences Sociales*), University of Montpellier III, France, as a fellow of the German Academic Exchange Service (*DAAD-Jahresstipendium*)
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Research interests

	Coupling GIS with Groupware tools
	Internet Map Servers, visualization of geographic data
	GIS and environmental simulation models
	GIS data models and exchange formats