“Geocollaborafrankenstein”: A Novice’s Walkthrough of Geocollaboration

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Abstract

This whitepaper offers a preliminary overview of designing collaborative Geographic Information System (GIS) applications, specifically within the context of synchronous, distributed Computer Supported Cooperative Work (CSCW) environments. We consider the group work setting of remote users in a distributed network engaged in same-time collaboration. Topics discussed in this paper include: what kinds of group work call for synchronous GIS map applications, synchronous CSCW architectures that can support distributed GIS work, and the user-interface issues that need to be considered in making such applications more effective.

1 INTRODUCTION

The field of Geographic Information Systems presents a fertile problem space for CSCW research because of its potential for group collaboration. Insights in GIS arise from the dynamic integration of diverse data types from a variety of sources and domains. Very often this involves harnessing the brainpower of specialists in an interdisciplinary setting. Also numerous are the mundane range of situations in which maps are used or *could be* used constructively in group work to contextualize, visualize and negotiate multifaceted problems. This applies to fields as diverse as real-estate and urban planning, environmental studies, ecology, communications, transportation, political geography, nautical sciences, energy studies, law enforcement, disease control and crisis management, and many more.

On the other hand is the study of computer supported group collaboration, which is a rich theoretical discipline informed by Human-Computer Interaction that researchers have only begun to apply to GIS production. In this context, how can we apply the broad range of classic CSCW issues such as response time, information structures, sharing control, workflow, activity awareness, and asynchronicity vs. synchronicity, to real-world GIS contexts, environments, sociality and principles? What are the salient issues in spatial cognition that need to be considered in collaborative geoprocessing? Can we generalize how application design can be shaped by a longer-term community of practice for collaborative GIS-based work?

As a point of departure in answering these questions we will use an a priori geoprocessing scenario as an approach to exploring geocollaboration intuitively. A fictional but conceivable scenario in which information-sharing and decision-making are interdependent offers concrete requirements for effective group collaboration. This scenario will provide a real-world context from which we can begin to consider the range of requirements for a synchronous map tool.

Our scenario is a short narrative of issues exploration with GIS data. This approach limits the potentially gargantuan scope of geocollaboration while making room for some abstract requirements such as tool modularity and flexibility. The design rationale here is that since GIS work is fundamentally multifaceted, diverse and variable, an effective tool must be adaptable to many situations while also being lightweight and minimalistic. But the salient question that will be addressed in our scenario design is why certain group tasks must be synchronous and what the requirements of such tasks are.

This paper discusses how to think about collaborative, geographic visualization tool design: from 1) exploring interactivity issues in geocollaboration that relate to our scenario, to 2) a multi-disciplinary geography problem scenario, along with 3) a preliminary discussion of usability issues, followed by 4) a discussion of architectural considerations in tool design, and finally 5) some discussion of future infrastructures for geocollaboration.

2 BACKGROUND

As part of an undergraduate summer research project, this whitepaper offers a perusal of CSCW architecture and design issues in geocollaboration, which we base on MacEachren and Brewer’s definition to mean “visually-enabled collaboration with geospatial information through geospatial technologies.”[1] Their framework for geocollaboration was developed “to delineate important technological, social, and cognitive parameters that must by considered as we extend or reinvent geoinformation technologies to support work by groups.” This paper attempts to do a walkthough of geocollaboration alongside this framework by providing a naïve user’s intuitive inspection of this emergent sphere.

Issues in Geocollaboration

Geocollaboration is an activity influenced by spatial cognition, geography education, and classic group work issues such as activity awareness, workflow, distributed cognition, intrusiveness, and so on. Before presenting our imagined scenario we would like to touch upon some of these topics that were considered the design of the scenario.

Spatial Cognition Considerations

An important research topic in geography is to understand how people construct, comprehend and remember maps. Insofar as geography is "understanding and explaining spatial behavior," this cognitive process involves acquiring spatial information, representing it as knowledge, and then using this knowledge to direct and explain our attention and behavior.[2] Can this process be applied to computer-supported cognition by a group? To answer this we can look at what happens first at the individual level and then see if this influences applications to distributed group work.

In *Spatial Cognition*, Robert Lloyd describes how theorists break down stages in spatial cognition in the human mind. These include: perception and the parsing of sensory input by the brain; mental imagery and the encoding and decoding of internal spatial representations and their semantic relationships (cognitive maps); associative memory and the storage of visual information; information lookup, neural networks and cognitive map searches; and the importance of orientation in map comprehension.

Models of how these processes are enacted in individual cognition can inform the design of a useful distributed tool to help group cognition processes. Spatial cognition precepts, applied to group collaboration prototypes, could enhance distributed cognition in geocollaboration. This would be helpful for computer-aided user-to-user interactions via shared maps as boundary objects or with helper applications that enable computational modeling between users trying to merge their discrete cognitive maps.

Knowledge not in common. Cognitive maps among different users can be divergent, but the process of finding out how they are different can be difficult. Ideally, an intelligent CSCW system could help sieve what knowledge is required for a group task and how to present it. If one were to design a CSCW system that highlighted differences and allowed for multiple representations at the same time, then collaboration could be more creative. It could move beyond the continual need for consensus to be achieved in group work and allow users to spend less time on knowledge in common. The importance of knowledge *not* in common in enhancing group learning and productivity is highlighted in the theory of activity awareness as espoused by Carroll, Rosson, Convertino and Ganoe.[2]

Change Blindness. When designing awareness of changes for distributed users, it is important to consider that differences in individual visual perceptions of changes have been found in spatial cognition research. Rensink found that subjects who were originally shown a map with a particular arrangement and shading of icons would have a harder time noticing large changes to the display when the activity was coupled with eye movements or a blinking screen. Changes that occur outside of a user's attention often go unnoticed.[3] Spatial memory tends to stick, and sometimes can override the mind's ability to create fresh visual perceptions. An effective awareness tool for collaborative map editing would need to aid users in noticing new changes or by animating the before-after changes that have taken place.

Spatial Motives. The acquisition, representation and use of spatial knowledge are also guided by spatial behavior motivations. Spatial knowledge of the environment is traditionally divided into three hierarchical levels of information: landmark—visual details, procedural/route—connecting landmarks into sequential relationships, and survey—landmarks and routes become synthesized into topological interrelationships. Different users may rely on different different combinations of these hierarchies in learning about space: a map user may choose to use just landmarks to become familiar with a map, then plan a route by linking landmarks, and then try to understand the layout of a city based on the route they just demarcated through it. A user may also be able to navigate a space by wayfinding cues on a route, forming knowledge of a city by learning how other major routes intersect with the one they know.

The encoding and decoding processes of each strategy differ: for procedural navigation, landmarks may need to be sequenced in a particular way to make sense. A linguistic index of street names could be how a person organizes space internally. Both verbal and visual cues are important, as are timeframes, perhaps even forming an animation of a route in the user's mind. Landmark knowledge can be encoded as discrete, static mental images, and survey knowledge might be encoded holistically, as a collection of memories of routes taken, and previously discrete trajectories may start to form an awareness of larger swaths of space.

If we consider the implications these cognitive hierarchies and strategies have for computer-aided visualizations, we can already begin to see individual difference implications. Thus multi-user investigations require an array of flexible visualization tools.

Assorted Sources and Representations. Another distinction suggested by Lloyd is between primary knowledge directly acquired from the environment, and secondary knowledge, indirectly acquired from a secondary source such as a map. Perceptually the two differ, and so the internal cognition of users relying on different sources to comprehend a space will differ. Lloyd goes on to note that computer-generated map displays can provide users with multiple perspectives and dimensions, heightening simulated navigation possibilities through animations, pans and zooms, and meshing. But this has varying implications for spatial cognition and perception. For example, 3D terrain visualizations alter perceptions drastically in lieu of 2D maps. Objects are realized differently in different dimensions, and a GIS group work application could be capable of allowing distributed users to navigate the same terrain from different angles at the same time. There are also cognitive differences for environments that users have only experienced virtually, and yet need to use for negotiation.

Spatial data can also be organized into varying scale categories and political geography hierarchies such as countries, states, cities, townships, or school districts, with further associations within layers such as street names, roads, interstates, powergrids and transportation nodes. Hierarchical classifications can translate well to the layer structure of most GIS application data but it is often harder to merge subsets of different layers into more complicated groupings. A versatile application should enable this for users.

Cognitive Maps. Yet another aspect of spatial knowledge is its internalization as cognitive maps. The internal structures users hold in memory are a key component of what collaborative work with maps attempts to bridge. Thus cognitive maps are a important topic for group work in visualization and joint geographic analysis. Lloyd notes that spatial information is thought to be encoded along with object characteristics (something a system that links objects in a map to other workspace objects can take advantage of), and that cognitive maps differ in their encodings in short-term or long-term memory, such as with respect to how they become incorporated with other bodies of knowledge in our memory stores.

Encodings in memory may be incomplete and inaccurate, and sometimes spatial distortions are shared systematically among different users because of shared distorted maps. The hope of collaborative map work would be to decrease distortions and expand perspectives to generate new insights as well as to verify each other's assessments. Frames of reference among users can often differ, but these differences may also lead to insights later on—the adjudication of differences can highlight salient points for discussion, and maintaining separate, individual reference frames can be conducive to this process.[4]

Geography Education Perspectives

Aside from spatial cognition, another relevant issue in modeling geocollaboration is how people learn to use maps. Geography skills are appropriated within a certain socio-cultural context. Apart from aptitude in spatial intelligence is the issue of how people learn to use and apply it to real-world situations within this context. What questions have they been taught to ask about space and how do these questions relate to their goals?

Reference Strategies. There are numerous strategies in geography, such as whether someone learning about a space should focus attention on landmark details, or more on exploration and layout. Other issues include how to understand orientation and scale, identifying constraints of a current representation, and picking uniform reference systems that minimize distortions. Also significant are navigation schemes, and making geographic cause-and-effect inferences. Such issues affect how people learn to use maps, manipulate spatial data, and then relate them to space. Here we present a cursory discussion of some ways geography education tries to frame these processes.

Verbal and Non-verbal Encodings. Just as spatial information is encoded as verbal and non-verbal data in spatial cognition, learning geography also involves learning verbal and non-verbal decoding techniques. Geography teaches us how to talk about spatial data as well as how to comprehend its external representation. Moreover, specialists from divergent disciplines who rely heavily on these representations also have their own rhetoric and operandi for the management of spatial relationships. A useful approach is to consider geography education models as a way to build a CSCW tool for interdisciplinary use since group geoprocessing naturally requires specialists to teach each other. At the application level, the presentation of material in a GIS CSCW system must therefore be educational, i.e., it should provide scaffolding and transparency, and the tools should be intuitive.

Geography Improvisation and Dual Processing. In "Modifying Our View of Geography," Castner proposes mapping as an improvisational activity which can involve many sources of spatial information. The process of mapping can be expansive and include numerical data, field photos and measurements, paths and routes, virtual images, printed images, verbal descriptions and narratives, viewed scenes, photographs including aerial views, landscape paintings, other existing maps, and so on. The repetition of information in many forms allows for students with individual differences to digest the information in their preferred way. It also emphasizes salient relationships in the information because these relationships are repeatedly revealed in different formats. This reinforces dual processing, which is a process that calls upon multiple memory stores and the activation of better cues to enable propositional thinking and visualization.[5]

Spatial Hierarchies. The varied mediums that Castner presents above also have model implications for the kinds of space they represent and how these relate with each other.

Spatial cognition can happen at a variety of levels: space within an individual's grasp, space larger than humans but visible in one look, socio-geographic space such as a neighborhood or city which we can experience through continuous travel, symbolic geographic space such as metropolises, states, regions, countries and the universe that for the most part require mental models that must be patched together from episodes of experience or from other sociological or theoretical models, panoramic space—views that do not require locomotion such as views in a room, field or scenic overlook, a spatial node, pictoral space, or vista, and map space—products of cartographic generalizations. These differences in scale and object-field relationships and other cognitive dependencies are important to GIS processing and demonstrate the breadth of information involved, from physical to sensorimotor, to perceptual, cognitive, and symbolic, as well as locomotive, temporal and inductive.

Our understanding of space is essentially tied to our understanding of the world. In the educational guide *Geography for Life,* Boehm et al. lay out two fundamental perspectives in geography: spatial and ecological, which has complementary perspectives such as historical, economic, biological, meteorological etc., all of which impose other kinds of hierarchies on space as well. Thus geoprocessing is not solely spatial and is a discipline that predicates collaboration with other disciplines.[6]

Geography Acts. Insofar as the kind of space in question determines the kind of queries formed based on these models, it is important to have some outline of basic investigative steps in geoprocessing. *Geography for Life* also outlines some basic skills fundamental to all geography education: 1. asking geographic questions 2. acquiring geographic information 3. organizing geographic information 4. analyzing geographic information 5. answering geographic questions. An adequate CSCW would support all of these types of questions and provide a good means to document and chronicle their integration into a coherent case.

Considering the socratic nature of these steps and the importance of spatial motivations such as navigation or surveying to guide geography learning, we can see that geography is essentially grounded in activities. A geocollaboration task is therefore very much like a geography education activity where even specialists learn from each other as well as from their own explorations of data. Therefore an understanding of computer-supported, same-time human dynamics is also necessary.

What we mean by synchronous group work

Synchronous, distributed group work is predicated by interdependent actions and interactions among individuals. For Schmidt and Rodden, "being mutually dependent in work means that 'A' relies positively on the quality and timeliness of 'B''s work and vice versa and should primarily be conceived of as a positive, though by no means necessarily harmonious, interdependence . . . Because of this interdependence, cooperating workers have to articulate (divide, allocate, coordinate, schedule, mesh, interrelate, etc.) their distributed individual activities."[7] Geocollaboration fits very well into the model of synchronous work they describe here because of the vast range of activities, cognitive styles, motivations, resources, individual differences and perspectives that are involved in group geography tasks.

The Activity, not the Medium. Schmidt and Rodden go on to argue that the traditional two-dimensional taxonomy of CSCW systems as a synchronous-asynchronous vs. same-place or different-place grid is not very helpful in requirements analysis because it conceives of "CSCW facilities in terms of the characteristics of the medium as opposed to the characteristics and requirements of the cooperative effort." They go on to characterize key requirements of synchronous group work instead:

- the degree and nature of interdependence as determined by the field of work
- the extent to which the field of work requires instantaneous reactions to events and hence rapid articulation of activities
- the extent to which the work is characterized by incomplete, ambiguous, erroneous and contradictory information, criteria, or a conceptual world of rich and varied semantics
- the extent to which tasks involve discretionary decision-making and concomitant negotiations

What we mean by synchronous geocollaboration thus takes into account all of these possibilities and focuses more on requirements of the activity, not the nature of the CSCW medium. [6]

Changing Dynamics. However Schmidt and Rodden also note that groups change and applications need to adapt to new dynamics. If a group is transient, time and short-term task completion is critical. If a group is more stable, then group features like long-term memory among members, greater habituation between them, and the likelihood of stable but elaborate views can be factored in to the process.

Different groups or members may have different organizational allegiances which may require work to overlap or be discrete and portable. In general, patterns of interactions can change with different situations, relationships, organizations, constraints, and varying spectrums of participant autonomy can be deployed, from autonomous to highly interdependent, requiring different degrees of synchronicity. Formal and informal organizational structures may need to be built in to the system, ranging from tacit understandings that can remain unseen vs. the need to make translucent exchanges and rules that need to be legally enforceable. Also important are divergent conceptual schemes, and methods to make them transparent and accessible to all users.

Individual Work Mixed with Group Work. There is an inherent relationship between cooperative work and individual work and both permeate each other in complex ways. A sophisticated CSCW should support what Schmidt and Rodden call "fluid meshing": since cooperative work is punctuated by individual work and vice versa, such that "over time, people shift between individual and cooperative activities." [6] Since much GIS processing happens in individual workspaces, individual work should be easy to incorporate and evaluate in cooperative work, and a CSCW application should provide an environment for going back and forth easily between the two.

Human-computer-human Interaction. In some situations a CSCW collaboration might prove to be a better medium than a face-to-face meeting among scientists or specialists who have work that is heavily computer-dependent or for whom in-person collaboration would be difficult, either due to time and travel constraints or because egalitarian, harmonious interactions might prove more difficult in face-to-face settings among fields without clear cooperative norms. The collaborative medium should be customizable to moderate social dynamics in a flexible structure that can be adapted to specific situations.

A geocollaborative CSCW system for synchronous group work is therefore best designed to accommodate various kinds of interdependent geocollaboration activities. It should incorporate into its structure different tools for changing dynamics, meshing individual and group work, and should build upon affordances of the human-computer-human triangle that may not exist outside of such a system. We will now discuss a multi-disciplinary geography problem scenario that will help us envision such a tool.

3 THE SCENARIO

This paper presents an insurance task force GIS scenario. It involves policy-makers, non-experts and experts who must share their knowledge and opinions in assessing risk using GIS processing. Specialists are inherently naïve about each other's complementary fields and may have conflicting assumptions, attitudes and goals, especially in the area of financial risk assessment, an extremely complicated and often eclectic task. Based on this scenario we will later present some issues in synchronous CSCW system design for geocollaboration.

Insurance in Florida following Hurricane Charley. In the wake of Hurricane Charley in August of 2004, the news reported that in addition to relief workers, search teams, infrastructure repair and clean-up crews and various other groups that descended upon Florida at that time, a multitude of insurance claims adjusters also made their way there to assess the estimated $11 billion in damages. After the shock of the immediate calamity, looming in the aftermath of such a disaster are the dire repercussions for insurers, consumers, households, communities, the state, the region and national economy. According to NPR, some people even spray-painted their insurer's name on the remains of their houses in hopes of ensuring reimbursement. Given the extent of the devastation, there is a high degree of uncertainty in the insurance market in Florida following the storm, in addition to uncertainty over how to rebuild communities.

The insurance industry is notorious for having a carpetbagger persona in the wake of tragedy. Claims adjustment can be a mystifying and often frustrating process for most, despite the fact that at best the industry's intentions are to ensure the financial stability and buoyancy of its consumers, albeit at a profit. As a result the insurance market is heavily legislated at the state and federal levels, and consumer advocacy groups keep a close watch on the industry.

After Hurricane Andrew in 1992 which caused $26.5 billion in damages in the United States[8], many insurers went under and the insurance market in Florida raised its rates by 200%. The State Legislature had to regulate a state insurer of last resort for consumers unable to obtain coverage from private companies, and also initiated the Florida Hurricane Catastrophe Fund of $11 billion to provide provisions for the state's insurance market in case an industry bailout was ever needed again.

With insurance, "regulators are also deeply involved in monitoring insurer insolvency and market conduct… Aside from regulation, there are a host of government programs that closely interact with private insurance. On the federal level, these include Social Security, Medicare, federal crop insurance, and the federal flood program. On the state level, there are scores of residual market pools, Fair Access to Insurance Requirements plans, and catastrophe facilities."[9] Thus there are many agencies and groups who would like to have greater access to the arbitration process of insurance regulation.

An Insurance Assessment Task Force. In this context, imagine that several months after the hurricane, the state calls for a commission in which state and federal regulators from various agencies including legislators, insurance claims adjusters, actuaries, consumer advocacy representatives, real estate developers and lawyers, economists, and journalists, will all meet to collaboratively decide how to best distribute disaster aid, and to assess damage and future risk while maintaining a viable insurance industry in Florida.

In order to prepare for the introductory plenary meeting, a special task force is called together to gather a body of evidence. The use of a synchronous CSCW is suggested to collectively explore relevant materials, lay the groundwork, and figure out the scope of some issues that need to be addressed. One of the ultimate goals of the commission is to eventually spread the cost of risk fairly among all parties in the insurance market, with implications for making the regulation of capitalism a more public process, targeting citizen involvement and empowerment. Everyone involved would like to overcome the prisoner's dilemmas between insurers, consumers, legislators/regulators, and investors, in terms of the issues they face, the evidence they use to make decisions, and how they expect to achieve their goals.

Issues Exploration and Evidence Gathering. The immediate objective of this initial collaboration is to agree on some shared evidence and issues to discuss, or at least to learn where the other constituencies stand, so that the introductory plenary session of the commission can be more productive with better supporting materials.

One goal could be a collection of informative data similar to the New York Times' topical web graphics, such as their election coverage guides that include an educational array of demographic charts, maps, polls and figures.[10] However our scenario is not geared towards any cohesive end product, instead the focus is the joint exploration process.[11]

What we are primarily concerned with includes an exploration of Brewer and MacEachren's geocollaborative requirements: what GIS metaphors would reduce the cognitive and communicative load of the participants? What virtual gestures should be incorporated into the system? How can dynamic visual displays be mediators for group work?

Benefits of a CSCW System

In a real-world setting this scenario would most likely take place in a series of in-person meetings. However, such meetings are not likely to be easily accessible to the public and difficult to stage informally in the introductory stages. We propose a CSCW environment that can augment collaborative exploration and that would allow participants to get to know where the others stand so that they can better prepare for the commission.

Goals of the CSCW System. Our early discussion of spatial cognition and geography education precepts outlines several general prescriptions for a tool. These are that a CSCW system can help sieve useful information for users, highlight differences among perspectives and increase awareness of edits, minimize distortions including shared ones, and that the process in this work can be about teaching each other from diverse sources with different spatial hierarchies, all along the lines of universal yet salient geography questions.

Accessibility. By removing the constraint of travel, computer-supported collaboration would be more convenient and informal, so that representatives from remote areas of the state as well as other regions could be more involved in the process. In cases where participants must travel large distances for extended periods, work is often delegated to proxies with less decision-making prowess. The convenience of remote collaboration might get higher-ups or sought-after authorities with time constraints more directly involved, enabling greater executive involvement and therefore more efficient decision-making.

However in the case where users might prefer to meet face-to-face as well, co-located collaboration could also be possible and yet still be enhanced by our CSCW environment, for the reasons discussed below.

The deliberation process can be recorded and made public immediately (even in real-time) as a primary artifact such as an animation of participants directly exploring data together. A secondary artifact such as a video or report on proceedings entails greater delay and a live, public broadcast might upset the informality of this online meeting. Considering the far-reaching repercussions for statewide insurance at stake, it is crucial that all interactions and proceedings during this process be transparent and recorded for public reference.

Transparency. This is duly important because users are regulating each other while also trying to collaborate on consensual risk assessments. In a task where conflicts are likely to be frequent, fact-based, and unpredictable, transparency among participants and for the public could prove indispensable. This is especially true in the face of consumers or regulators trying to argue with the highly analytical and bottom-line-oriented actuarial process.

Proximity to Individual Work Environments. Such a system could be closer to each party's personal desktop systems, and therefore closer to what they already use to process geospatial data with their single-user programs, along with their preferred resources for obtaining supporting evidence quickly. Each party's desktops would be within orbit of the shared space, allowing further geoprocessing to be accessible and individual. Supporting data and computational resources can then be better utilized during the conversation. The desired effect would be that the proceedings have greater potential to involve fair collaboration and improvisation in selecting relevant evidence from the ground up, rather than having only prepared presentations where different sides showcase evidence that was probably chosen on partisan grounds.

Evidence-based Argumentation. We envision a tool that allows decision-making and evidence exploration close to the facts and based on visualization and distributed cognition, rather than in the style of public hearings where persuasion and rhetoric can often sway prevailing arguments. This might increase trust among participants, which confers important connotations on what comes of the meeting and task force.

The likelihood of frequent and ambiguous conflict is also why this task is best suited to a real-time, synchronous application. Although many of the gestures and cues that are perceived in face-to-face interactions would be lost, the conversational props could become extremely sophisticated visual and conceptual arguments in themselves: rich interactive visualization that is collaborative distills cognitive group work that can be externalized, and puts more emphasis on thoughtful argumentation, not the ability of participants to be persuasive interpersonally. Dispassionate interactions such as joint fact exploration and argumentation would be spotlighted. This might reduce the emotional and political fraying of deliberations that commonly erupt at public hearings among parties inherently in opposition.

The Task Force. A hypothetical task force might include the following members:

Figure 1: List of collaborators and their motivations in our risk assessment scenario

User	Goal
Insurance Actuary	Maximizing insurance profits and hedging losses
Consumer Advocate	Lowering insurance premiums while maximizing benefits
State Legislator	Shaping policy to boost the state economy by enticing insurance companies to provide affordable insurance for his/her constituency
Meteorologist/ Geographer	Hurricane expert, ensuring environmental conservation and enabling proper GIS utilization
Federal Emergency Management Agent	Preventing development in unsafe locations with unsound materials and answering disaster-related questions and predicting relief needs
Real Estate Developer	Maximizing development opportunity, raising property values, enticing people to move to Florida

Interdependent Group Goals. In this scenario, the group goals: distributing aid, assessing damage and future risk, and spreading the cost of risk fairly among all parties, is by essence a collaborative, interdependent task because every member has a partisan stake that may compete with those of other members. For negotiations to be fluid, conflict resolution typically requires rapid articulation of what is at stake and their pros and cons. Timely reactions among concomitant parties are key to policy and decision-making and could speed up negotiations in what tends to be a drawn-out process. Interdependence is also a requisite because this work is characterized by incomplete, contradictory information from fields with different semantics, which fits into Schmidt and Rodden's model for requirements for synchronous collaboration. We can see that real-time group work is important in picking which geographic evidence to use in planning since what is used can greatly affect the weight of arguments and create bias, which we are trying to prevent through collaboration.

Since risk assessment is a very involved process with many stages, here we shall focus on some initial discussions that may come about from collaborative GIS map and data exploration.

Setting: A task force on the state of insurance in Florida has been assembled, calling together the participants listed in Figure 1 with the aforementioned goals of laying the groundwork for damage and risk assessment and policy planning in the aftermath of Hurricane Charley. Prior to a formal public meeting, the participants have agreed to collaborate using a synchronous CSCW system to build a library of collaborative data, maps, and to hammer out some of the core issues that need to be addressed. For the sake of argument, we assume that every member has received training in the use of the CSCW application and can use it effectively. Their initial work will be recorded and shared with the public.

Positions: The participants have divergent issues they support. The consumer advocacy representative is concerned that low-income counties in high risk areas may not have access to equitable insurance. On the other hand, the insurance actuary must follow strict protocols for assessing risk and is liable to state and federal regulations on top of his insurance company's fiscal targets. The areas in question in this setting are high-risk counties that are likely to prove unprofitable insurance markets given Florida's recent history. Many property owners in these areas were forced to go uninsured following Hurricane Andrew and as a result suffered irreparable blows to their life savings during Charley. Many are now homeless and facing bankruptcy, thus the state has a vested interest in facilitating accessible insurance. Since the state regulations they legislate can control insurance practices, the actuary has a huge stake in presenting a clear case for high insurance rates in this commission.

The meteorologist is a hurricane expert as well as a geographer and present to help in discussing Florida's historical weather patterns. Although the meteorologist is prone to being passed around as an expert-on-call to back up partisan arguments, as an academic geographer he secretly has his own agenda of environmental conservation planning, something that has been neglected among all the other participants.

The FEMA coordinator is involved to assess emergency response deployment in the state and to portray what rebuilding infrastructure has actually been like. The real estate developer is appraising whether the locales in question might be more profitable and less risky as farmland or golf courses, but this depends on the initial insurance estimates and property value projections that will be assessed in the process.

Meanwhile the state legislator would like to fairly shape insurance policy while maximizing revenues for the state. She is trying to figure out what the issues are from the point of view of consumers as well as insurers. The disaster has left the state in a fiscal crisis. Some relief funding has been provided by the federal government and needs to be properly used or invested, and a major concern is also the future of the state's economy which cannot function smoothly without viable insurance providers.

Diverse Goals. The diversity of goals among users already raises the issue that their geography motivations are mismatched, and much effort must be spent in merging reference systems and perceptions in order to have lucid discussions. But note that this is an exploratory stage for the group. Also, the approaches to geography presented are multi-faceted, including political, economic, demographic, geomorphic, meteorological, regional and urban planning geography issues, thus the semantics of individuals will be divergent, requiring real-time, synchronous work.

Implicit Roles. Since the state legislator is a policy-maker and a member of the commission who called for a task force, it is understood that she will be the presider during this endeavor—her goal is to understand what kinds of legislation would fairly regulate the insurance industry.

The primary opposing arguments are from the insurance actuary, who is trying to protect industry interests, and the consumer advocate, who is concerned with individual consumer rights and represents the legislator's political constituency. The meteorologist and emergency response coordinator function as expert witnesses in discussing the disaster. The real estate developer is also affected by the insurer-consumer conflict although it is unclear what his plans are as of yet.

Thus the main cohorts are the legislator, actuary and consumer advocate, while the meteorologist, real estate developer and FEMA coordinator are helpful bystanders who will either join the discussion when prompted or ask for permission to chime in at an opportune moment with questions or concerns.

The Group at Work

Now consider a CSCW that might be able to manage all of these interests in a useful collaborative exploration.

Hurricane History. The meteorologist presents the history of the area's hurricane patterns with a brief PowerPoint that all other users can save to their local desktops. He explains that since 1950-2004 there have been 556 tropical storms in Florida and 375 of them hurricanes. Of those, 18 have had a Category 5 intensity, which is the highest level that incurs serious damage. There is a high degree of uncertainty in hurricane prediction that makes them very difficult to track. He explains the current satellite tracking mechanisms storm watch centers use and their forecast error rates, which reflects how many hurricanes often veer off the Florida coast without landfall. The FEMA coordinator adds to this his estimated costs of emergency evacuation and preparation when these false alarms do happen.

The FEMA coordinator also has a related presentation on the state's history of hurricane damage and describes the three biggest prior to Hurricane Charley. In 1935, the Labor Day Hurricane had winds up to 155 mph and 400 people died, although most casualties were related to a train wreck which occurred as people were being evacuated. The second was in 1969, Hurricane Camille, causing extensive flooding damage with a 20-25 foot rise in the water line, particularly in the Appalachian areas, with 250 deaths recorded in the state. Finally, in 1992, Hurricane Andrew had winds of 115 mph, with occasional gusts up to 160 mph, 125,000 homes destroyed and 41 fatalities. Financially, at a little under $26 billion it was the most costly natural disaster the U.S. has ever seen. [12]

The state legislator notes how safety precautions have improved in response to hurricanes over the last 70 years. The real estate developer adds in that building materials and structures that defy high winds have improved a great deal, although the consumer advocate notes that for low-income housing it's been variable. She suggests that the state should revise their policies to regulate better construction and building materials for affordable housing.

Clearer Maps. In the meantime the meteorologist has some quick maps of the paths of Hurricane Camille, Andrew and Charley through Florida based on past data of wind speeds. A chronology of maps are laid side by side for each hurricane, with each map displaying isogons as short vector lines of varying length and aggregate density. These are confusing to most of the non-experts present.

The state legislator requests that the maps be made more clear using different colored swaths and asks that they be animated. The meteorologist brings up a map example using isotachs which they agree is easier to look at, so the meteorologist plans to redo his maps this way later on. The actuary also requests that flood damage over all three hurricanes be plotted in overlapping transparency. The FEMA coordinator says he has maps on flood damage, which he will send to the meteorologist. The meteorologist makes a note to go back through his maps to review flood devastation.

Land Use Exploration. The real estate developer wonders whether the devastated land in question might be better utilized as farmland with crops that end before the hurricane season. He asks for meteorologist-geographer for information about the land quality. The geographer queries a database service he has access to from his local desktop, pulling into the space information on soil surveys and acid rain rates for these areas. He wonders to himself whether phosphorous runoff would cause greater environmental devastation. He points out that droughts are common right before hurricane season because the urban areas use up so much of the water, creating sustainability issues for agriculture.

The developer suggests the possibility of re-zoning these areas for resorts such as golf courses instead. He says that property taxes would have to be very low. The consumer advocate considers the tradeoff of the land being used for housing or for resort use, which could create more jobs, albeit in the lower-paying service sector. A low-density housing sector could also be a good plan. Both the geographer and FEMA coordinator prefer the idea of golf courses to housing sprawl, but the legislator considers the reduction in tax revenues might be disagreeable to the local counties. However, they note this suggestion as a topic for later discussion.

FEMA Briefing. At this point there is a lull so the FEMA coordinator offers to recap the current extent of destruction after Hurricane Charley, which several members agree would be useful. He has compiled briefing slides with photos of the most outstanding devastation, a review of hurricane evacuation efforts, a review of types of hurricane-related casualties from hospital ER reports, situation reports from declared disaster areas, figures on the number of homes destroyed by county, and maps of the flood-devastated areas.[13]

Finally, he reviews the effectiveness of emergency response task force's efforts during the recent hurricane with previously compiled GPS tracking records of large emergency response team movements. This is synchronized with and layered on top of the previous animation of the course of the hurricane winds through the state. He also presents information on the distribution and use of shelters, roads damaged and traffic patterns during and after the storm, information on the accessibility of food and water and how they were provided in the aftermath, and finally, before and after maps of the state power grid.

Cost Assessment. Also in their shared information library is the actuary's report on historical precedents related to insurance, such as damages and risks assessed following the previous hurricanes and long-term studies of the insurance policies affected by them. Along with this, the state legislator gives a quick review of hurricane-related state spending, federal aid received, the economic recovery strategies that were established, and what kinds of policies are up for consideration now. The main one being negotiated in this session is how to regulate property insurance premiums in high risk counties. Quick resolution is needed to rebuild homes in Florida while making the insurance infrastructure in the state viable. The state will again need to regulate an insurer of last resort, but how should the premiums be regulated so that both insurers and consumers can persevere?

Conflicting Interpolations. Already there are discrepancies among users in how they would like to interpolate the data and its implications. For example, the actuary predicts that the population will migrate out of the affected areas, lowering demand for real estate and hurting local economies. He cites regions of Louisiana that were never able to re-establish themselves in the aftermath of such a disaster and underwent major economic depression. He also brings up charts displaying how the insurance industry was set upset by previous hurricanes and current estimates for Hurricane Charley.

The consumer advocate cites the importance of affordable insurance premiums as key to helping to rebuild any region. She pulls up a map of counties devastated by the previous hurricane as well as bivariate chloropleth maps (maps which show areas that have the same characteristics) based on 1990 and 2000 census data of average per capita income and populations by county, overlaying this one over the disaster areas map. She argues that the maps from 1990 and 2000 do not show distinct economic or population declines in devastated counties despite a 1992 hurricane. She believes this implies that these areas were buoyant.

However the actuary argues that the span of a decade is too nonspecific to make such an assumption. At this point a clear conflict of interpretations arises and the others try to step in to explore the incongruity. The real estate developer points out that Florida had a real estate boom due to rapid development and will continue to do so as a popular destination for vacationers and retirees from the coming boomer generation.

The state representative concurs, citing an influx that eventually replaced those who migrated out of the disaster areas after 1992 and noting the basic fact that unlike Louisiana, Florida has the fourth largest population in the U.S. Although concentrated in the urban areas, there is a big push for federal assistance in developing the "New South," which includes some of the devastated rural areas towards the West. She would like to support continued growth.

Following the consumer advocate's previous example of exploring census data, the legislator digs further into the existing census data's name registries with a scatter plot of households that stayed the same between 1990 and 2000, showing high degrees of change in the affected areas. Thus migration occurred, both out of and into the areas in question. The real estate developer adds data on enterprise zones that reflects high retail growth sectors from 1994 and on, arguing that it implies the growth of surrounding threshold populations that are required to support them.

However the actuary isn't convinced that the real estate boom in the '90s is a trend that will be repeated, since some projections have suggested that Florida real estate growth has begun to plateau with increasing congestion and a slower economy. He tries to explore some data to do this but only has figures on regional insurance sales. He asks others in the group for potential data to back his view.

Asynchronous Tangents. This gives the consumer advocate the insight that the growth may have more to do with the interstate that was built during that time, right through some low-income neighborhoods in most counties, bringing with it the mass of strip malls and jiffy-built communities common to Florida. However since she is just considering an idea, she is not ready to share it formally but would rather poke around first. She begins exploring this line of thought on her own desktop. It may be useful in a tangential discussion she could start with the state representative later on in the session on how to spur economic growth in these areas. She begins pulling out the affected counties by enlarging them on a map of Florida and looks for interstate and road layers. She also adds the topic to the list of questions for eventual discussion.

The developer who happens to be looking at that panel of questions sees the topic title 'development surrounding interstates" and its author. He checks the page of thumbnails of participants' views and sees that she is exploring roads in the affected counties. He makes a note to relate this topic to his earlier resort development scheme.

The consumer advocate also notices that the developer is checking out her view. She makes a note to instant message him a feeler as to what he is thinking about it later on at the upcoming 10-minute intermission. The intermission was the legislator's idea at the beginning of the session.

Overlapping Incentives. Meanwhile others have supporting evidence for the actuary's argument against future growth that they do choose to contribute directly. As an environmentalist, the meteorologist-geographer would like to see some of the areas in question reverted back to natural conservation trusts. He already has a lot of evidence on his local desktop to support changes in ecological quality rankings of state land covers and watersheds done by the EPA, which he begins to bring into the collaborative space. The FEMA coordinator has maps of areas susceptible to heavy flooding that show many of the hardest hit areas as problem areas in previous hurricanes—low-income areas with many trailer home communities. The meteorologist notes that many of these areas should have been left alone as swampland in the 80's.

The state legislator has unemployment figures by county for that time period and adds that in, and the developer has information on changes in county property value averages after Hurricane Andrew as well. The FEMA coordinator has data on the cost and duration of reconstructing the overground power grid in those areas, which the consumer advocate records because it relates to her interest in growth surrounding the interstate.

At this point there is a wealth of data in the shared space so the legislator suggests some joint adjudication of what they have seen.

In this session, some shared questions and territories have been explored among diverse participants with contrasting data and representations. Differences in how participants interpolate data have also been exposed, with new insights generated. Even if little consensus is reached, at least the participants have engaged in some initial discussion of what kinds of supporting evidence to look for in their research, and are likely to be better prepared when the commission meets formally. The session would also be recorded as an animation of the workspace, so that members of the commission can later review what ensued, as well as all the evidence.

4 GEOCOLLABORATIVE APPLICATION USABILITY

In order to envision an efficient tool that would support our hypothetical scenario, we would like to posit some features of a distributed application that would enable collaborators to best apply their skills in a timely manner to remote group work. Ideally users should be able to decide for themselves when in the session to contribute their knowledge, raise a concern, or ask for help. This allows for coordination of the exploration to be informal and flexible. To be able to do this fluidly, there must be a high degree of awareness of what is going on built into the system and interface.

Carroll lays out questions that are essential for awareness in computer-supported collaboration. "In order to collaborate effectively, one needs to know many things about one's collaborators. Who are they? What are they doing? What do they expect? What do they want to do? What are they doing now? What tools are they using? To what other resources do they have access? What are they thinking about? What are they planning to do in the near future? What criteria will they use to evaluate joint outcomes?"[14] In designing a tool with high degrees of social awareness and action awareness we shall try to provide for these questions while allowing for the flexible interleaving with individual work that our scenario calls for.

Enabling Reciprocity in Exploration and Argumentation

Awareness and transparency in collaborative exploration of GIS data sources may affect a greater degree of trust between users, especially between experts and non-experts. Conflicts of interpretation can arise even in the early stages of gathering evidence to make decisions. If users can teach each other in the process of making their arguments, there can be much more reciprocity in exploration. Moreover, collective adjudication of conflicts enables complementary reasoning and feedback, and this is precisely the kind of use case in which group work in a synchronous CSCW system can effect productive distributed cognition. Thus we would like to facilitate an interchange of ideas and opinions from the get-go, when the participants are asking themselves, "what are we going to use to talk about our issues?"

Meshed Synchrony and Asynchrony. Because building a body of evidence with which to discuss risk assessment can be a biased process, collaborative exploration that allows for both independent and interdependent processing would be useful. In our depiction work can be synchronous and asynchronous, and the two modes can mesh.

During our scenario several contrasting queries of the census data were made, as a way to probe correlations. At times an individual preferred to do solo queries, while at other points an inquiry was better considered with several users with complementary expertise probing together, such as when census data was queried in various ways to argue for both migration and population stasis. Such an interchange should be synchronous as a more efficient interaction so that the consumer advocate can contest the actuary's point transparently in front of everyone, so that other participants can counter or support either one's argument. In the meantime, the actuary and consumer advocate can ensure their points were taken correctly by everyone who responds.

However, the consumer advocate, inspired by an insight, can also explore a perpendicular argument on her own, one that might end up being a useful topic for discussion later on. The asynchronous aspect allows for users to have independence interleaved with interdependence. This allows for some activity modularity when one issue or subset of users dominates the synchronous collaboration while other users have alternative embryonic ideas they would prefer to consider apart from the group[15]. Perhaps they would simply prefer to wait to bring the idea into the collaborative space after some individual exploration, or when the issue becomes more relevant to the discussion.

Meanwhile, the questions and evidence users share synchronously become meaningful boundary objects in the moment and potential evidence for the commission for which they are preparing. Being able to discuss possibilities as a group allows for arguments to be built up into more sophisticated points of view, especially since there is a faster exchange of affirmative-negative points.

Also convenient asynchrony prevents the domination of one way of looking at data. But private asynchrony has the potential to centrifuge users away from the goals of collaborative work. In our scenario however, there was still some public awareness of what the consumer advocate was looking at on her own, that allowed the real estate developer to pick up on it. There was also some tacit awareness recognition between them, and this is one way that asynchrony can be implicitly meshed with synchrony.

Asynchronous collaboration could also be applied to a later scenario. During playback of the entire session, a viewer who becomes interested in one issue could use the CSCW system itself to go back to the system's state at that point in time. They could probe that area or follow a query with other related queries, with all the databases, maps and related documents from that point in time made accessible.

Floor Control. In multi-person telephone conference calls, the number of remote users is usually kept small because it becomes difficult to manage the conversation without awareness cues. A method of floor control for the distributed tête-à-tête is necessary among the larger group in our scenario, assuming they are all distributed. We propose a system of token-passing (or baton-passing) that also allows other users to interrupt each other.

To begin with, we imagine the CSCW system to support a written chat format of conversation coupled with phone use, which can be enabled with commercial speech-to-text translators. Both written and spoken versions of the conversation are recorded for playback and transcript. The speaker who has the floor is highlighted in a separate window.

We also propose that participants directly indicate through a release button when they have finished their turn in speaking and having control of the floor. Control of the floor would entail control of the lead pointer: perhaps a big red arrow whereas other pointers (if other users should choose to have them be visible) are small and multi-colored arrows with username labels. The speaker could also choose to pass the pointer to another participant while they speak, for example, if the other user were better at navigating an area.

A special window would spotlight the speaker (highlight the speaker's name or brighten/enlarge the speaker's avatar) along with a chat window and audio from the speaker. If others would like to speak, a floor-control model could allow for group members to select an option indicating to others that they have something to say. If there are several who wish to speak at the same time, a FIFO queue can be generated for turn-taking/token-passing and role awareness.

For the conversation to be fully interactive, participants should be able to interrupt or interleave their points with the main speaker's. A secondary interrupt queue could be started in a new panel, which would raise a semaphore for everyone including the current speaker, so that the speaker knows to head to a pause in his/her argument and relinquish control to the secondary queue at an opportune moment. When the interjector is finished, the floor would revert back to the original speaker, who can decide whether to continue or let the others in the secondary queue speak first.

This allows for arguments and interjections to be made in a timely fashion, and is a flexible structure in which users can break out of the restrictions of strict turn-by-turn baton-passing. Otherwise, if users prefer, they could also have the option to enable a free-interrupt-style of discussion in which two users can talk at the same time without having to use the control mechanism, so that more naturally interleaved conversation patterns can also occur for smaller groups.

In the case a speaker takes too long of a turn, the group could perhaps opt to override him collectively through a "kick the soap box" mechanism made possible through a group vote (potentially necessary in conflict resolution-style work). Voting to shut a speaker down would relinquish control to the next speaker in the queue.

At the beginning of the session no participant would yet have control, and participants could also opt to go back to this state if all queues were empty. This could be a state in which users just converse using a simple chat window without any one person taking control, i.e., with no individual pointer movements or selection tools in dominance. This would be also useful when no one wants to take the floor.

In terms of self-monitoring awareness aids, a timeline would be helpful for users to see how long they are spending on one topic (which could be labeled by the user or based on how long they have held the baton), how long each user has taken the floor and who has been taking the floor disproportionately, and a history of what the used tools, maps and documents were.

Elbow Room for Personal Views. Sometimes shared control is also necessary. Queues are not always the most efficient way to manage a conversation or exploration. Sometimes it is helpful for two or more participants to explore with two or more pointers concurrently, or for the WYSIWIS to be more relaxed, such as a more flexible WYSIWYTIS (What you see is what you think I see)[16] in which users have slightly different scales, angles or lenses open, or two users could explore different views placed side by side in the interface. In this case thumbnails somewhere in the interface can give more awareness information on what other users are doing and looking at so that a plurality of views can be explored, enabling user preferences for specific visualization styles and data sets.

Ideally a flexible CSCW environment should enable Dourish's paradigm of separating the shared data and the user interface, which should not be coupled for collaborative work to be multi-faceted. However since a tool with a multitude of buttons, options and utensils typical to advanced GIS processing might be overwhelming, the interface should also be scaffolded to user-selected preferences.

If a user would like to use their personal visualizations when taking control of the floor, then there could be a broadcasting option to make their view central in the collaborative space. Because any user can take the floor and other users can also have secondary pointers synchronously, inquiries and browsing strategies are likely to be varied and multifaceted, and participants can help each other browse and elaborate their queries with their expertise and visualizations entwined or in contrast. Since, as Dourish suggests, representation can *cause* the behavior, it is important to allow maximum flexibility in this process for exploration to be truly collaborative.

Themescapes, Concept Maps and Argumentation Maps. We can use maps for storing objects and create themescapes of issues that have arisen as a form of complexity control. Since typically only several things can be held in immediate human awareness at a given time, maps can help to manage arguments and their often branch-like details through innovative spatial views and flexible navigation of arguments. Ideally an intelligent system would be able to keep track of a discussion while participants had natural interactions, but how a system keeps track of topics can have bias.

Perhaps a more effective means would be to have this process built into the way that users interact with the system, so that what participants *choose* to pay attention to becomes the material with which the system outlines their arguments and themes. Key to this process would be the ability to make arguments modular, so that useful pieces can later be incorporated into other arguments, as well as to hide details unless appropriate, as with object-oriented programming. Collaborative work is not necessarily chronological nor is it strictly logical, but can be associative and sometimes disjoint depending on what the participant goals are.

Argumentation Maps. One possible example is given by Claus Rinner who makes the case for Argumentation Maps[17] as useful tools in spatial planning. These maps link GIS maps to geo-referenced objects such as discussion forum threads related to a specific map area. This presents a combined visual and linguistic argument with instinctive connections based on how the maps are used. Another useful tool would support basic whiteboarding on maps, as well as the option to save certain versions of maps and related data to a tree-like concept maps or chronologies (and to possibly automate this process based on awareness cues of what is being looked at) so that the group can quickly backtrack in the conversation history. This way they would have a useful summary of their collaborative session, including divergent and convergent arguments.

Themescapes. A themescape would allow users to navigate topics spatially and allow them to see a gestalt view of what they have covered. A themescape is a "'thematic terrain' that communicates the primary themes of a collection of documents and the relative prevalence of those themes. Elevation in a themescape is a measure of theme strength."[18] Documents, maps or data sets would be represented by points and those that are related placed near each other. Close points in a themescape raise that area's elevation. Well documented topics with a high concentration of evidence would form a terrain peak, so that the participants can see what areas of evidence are well covered and what other areas need more research.

Colors, flags, symbols, contours, and various methods of annotation can be used to make multivarious connections among themes and documents and create alternative patterns among themes. Since users would be accustomed to map viewpoints, a themescape might fit well into their existing perception habits. During adjudication and review, participants could group documents according to topic on their own or as a group, using a folder explorer view or by creating demarcations in the time line that can be isolated as themes.

The relationship of themescapes and related concept maps to personal user preferences would be important. Participants could rate issues and evidence, affecting different personal views if they should choose, or collaboratively creating a shared themescape in which certain things are elevated or included based on an aggregate of opinions. This allows for user feedback to shape the themescapes through a flexible survey mechanism, such as a "decision meter" which Fonseca and Egenhofer suggest would be very useful in their description of an "ontology-driven GIS" for groupwork.[19]

Themescapes also bring up the possibility of more complicated relationships between maps and objects linked to them, since such a tool would already be quantifying and qualifying objects in order to calculate a spatial representation. Also possible within a map that contains many objects would be networked objects, perhaps related to various layers of the map or to a more complicated database with greater relational algebra capabilities for nodes, as well as for how nodes are integrated into spatial representations. This suggests greater possibilities for visualizing more complicated data relationships, which as a collaborative task can be a very powerful way to control complexity, as different users can have different ways of looking and should share their views.

Concept Maps. However for mundane purposes a simple concept mapping tool linked to maps and map objects could suffice. It would also be interesting if a CSCW system could intelligently automate the process of creating fluid concept maps based on discussions. Even a simple timeline tool that either lists documents by title, thumbnails of maps, or by queries made would be helpful to record. Sometimes participants will want to backtrack or merge various sources and points into a new problem space, which they can do if the thumbnails are also flexible objects on a concept map/whiteboard tool that can be copied, pasted, indexed and grouped easily.

Another useful feature might be a way for users to pose looming questions that they would like to address at some point but not immediately. This would increase the awareness of what participants are thinking about, aiding others in taking up their topics and planning the flow of the session's future, providing something new to move on to in case the group becomes stymied. Looming questions should not have a high level of awareness since they may affect the flow of the current argument being staged, but could be on a deprecated panel, say a tabbed pane, that lists the question and user who posed it, along with a possible priority ranking. Perhaps in an alternative scenario users could opt to post more controversial questions anonymously, although in our scenario accountability in our system has to be transparent for public record.

Adjudication. Finally, an important feature in concept mapping, argumentation mapping and themescaping would be the ability to collaboratively adjudicate what evidence to include for future discussion. How will they evaluate joint outcomes? To achieve this, participants can opt to look over the themescape or concept maps or timelines that have been created, making additional links or removing others as they cull what has accumulated. One participant could lead the navigation of this harvesting process while the others watch and help adjudicate based on a voting system or through discussion and consensus. If participants disagree on what should be included, they can maintain personal copies, or create alternative copies in the shared space. For cases where thumbnail views are not sufficient to display complicated maps or analyses, animation-replays could be used to capture and revisit these animations of arguments, multi-layered queries and map white-boarding.

User Identities and Other Awareness. Carroll, Rosson, Convertino and Ganoe have argued that activity awareness, i.e., the ability to contextualize and understand the activity and process at hand, is essential to effective collaboration, and can be a substitute for the rigidity of workflow systems.[2] Geoprocessing is often such a complicated process that some have argued for the need for some workflow structure. Here we argue that activity awareness is a more useful a tool, at least in our scenario. Because the focus is open-ended exploration and not definitive geoprocessing among experts, the lack of a clear production cycle makes a workflow structure unnecessary.

In terms of the implementation of awareness, it would be redundant for one or two users to be controlling a whole session while the other four watch without any input. A sense of presence is important for users to feel co-located and accountable for their own attendance at an online meeting, as is an understanding of what people are currently gazing at.

At the same time privacy may also be important. In our scenario we allow for users to go off on their own digressions if they have an alternative perspective from the dominant one being explored on the floor. The natural flows of conversations and thought processes are often multi-threaded, and sometimes users need the freedom of privacy, which should be an option users can select.

However privacy might foster the balkanization of group work. Gaze and activity awareness of what other participants are doing and looking at could help to prevent this. Awareness could be enabled with thumbnails of user views or thin, colored frames covering portions of a map that users are focusing on. If a user chooses a different visualization the thumbnails would instead display this information and clicking on them would bring up that view. To increase awareness of changes that users make, a side panel logging changes, different colored whiteboarding markers, edits on a map labeled by number and user, and animated replays of edits could also be potential aids.

Another possibility is how the Groove collaborative map tool, Toucan Navigate (to be discussed later in this paper), accomplishes awareness with a number in parentheses next to an object's title. This number indicates how many users are looking at that window. Right-clicking on the window tab offers a list of options, one of which identifies who else is in the space. This is very effective for clearly separated tool spaces and could apply to tool bar widgets as well.

Also key are cues for long-term identity awareness: who users are, who they represent and a general overview of their platforms. We could offer some self-identified user info associated with names as hyperlinks. More complicated would be how to place people in terms of where they stand on issues. We propose an optional overlay on top of concept maps and themescapes displayed in a new layer, relating users to the concepts they advocate in contrasting colors. These could be listed by author, editors, self-described supporters and dissenters, and created by means of a voting or rating panel offered during group adjudication or during the initial discussion.

Another possibility would be radar views of user activity, which could be hyperlinked to the various other tools mentioned. MacEachren suggests the possibility of using social proxy diagrams such as IBM's Babble's.[20]

Data Mining Tools. GeoVISTA Studio is a sophisticated GIS visualization tool developed at the GeoVISTA Center at Penn State. One of its impressive features is its ability to visualize multivariate GIS data mining, which is the kind of exploration that our scenario portrays.[21] Although Studio does not currently support distributed collaboration, the Center's hope is that eventually it will. For now, complicated data mining and map manipulation can be done on locally, with existing single-user GIS tools such as Studio, then uploaded to the collaborative space in supported formats. The problem is that users would not be collaborating during that key stage of the process, which our scenario presents as ideally, a group effort.

Perhaps, given the resources, a special non-partisan GIS application expert could be assigned the role of pulling up what collaborator request, as often happens in the military and in NASA control room settings where specialized assistants aid in computation. For maximum flexibility in high-priority collaborations, perhaps several GIS software experts could be on hand (also remotely 'on-call' in the space) to do data mining for the collaborators so that discussion participants can focus more on issues and not be limited by a lack of skill in GIS use.

GIS databases such as the census data used in our scenario also need to be made accessible. GIS consists of many varieties of data, from disparate sources such as satellites, mobile devices, complicated spatial and non-spatial databases, data from different disciplines, in addition to a large variety of GIS formats. The distributed aspect of CSCW systems suggests that GIS databases can also be networked interactive nodes.

5 GIS APPLICATION ARCHITECTURES

The Current State of Geocollaboration

Researchers at the GeoVISTA Center at Penn State University are also developing a body of work on collaborative geographic visualization. Theirs is an approach highly informed by activity and user-centered design with the goal of developing computer applications that support diverse scenarios. These range from same-place, same-time collaboration to remote, distributed group work, and for specialists ranging from GIS experts to crisis management teams. Some of their current research involves interfaces such as speech-controlled command centers to mobile devices to a synchronized, remote, event-sharing demo for Studio.

Next door to the GeoVISTA Center at Penn State's School of Information Sciences & Technologies are several labs involved in CSCW development and evaluation. HCI researchers at the Computer Supported Cooperative Learning Lab have developed a synchronous, collaborative computing environment called BRIDGE (Basic Resources for Integrated Distributed Group Environments). This Java-based CSCW environment enables users to interact synchronously in real-time on the same object, thus enhancing the collaborative experience. Currently they are building a GIS map editing tool within BRIDGE, which is able to link to other BRIDGE objects. These Penn State groups are planning to assist each other in geocollaboration.

Furthermore, there is one commercially available collaborative GIS application of note: Toucan Navigate, developed by Infopatterns for the Groove collaborative environment. Groove is a commercial, Windows-only, .NET-based collaborative environment for which many independent satellite companies build plug-in tools. It is currently among the more popular CSCW environments in use today because of its ease of use and the wide array of tools that extend it.

The projects from the aforementioned three groups constitute the current state of real-time geocollaboration presented in this paper. Although there are many single-user GIS applications and a few asynchronous GIS CSCW systems, currently these are the only ones of which we know that support real-time, synchronous collaboration for distributed groups working with GIS data. Here we offer a brief discussion of their architectures with respect to our scenario in hopes of highlighting a few salient design issues in developing a CSCW system for same-time, different-place geocollaboration.

Groupware Toolkits that Support Geocollaboration

Currently there are no tools that could fully support our proposed scenario, although in tandem with an advanced single-user desktop GIS tool the ones mentioned here could be used. Because distributed synchronization in software applications tends to be an expensive and complicated process, it is important to consider what the specific circumstances of its use are in addition to how to enable it via the internet. At what level should things be shared, for example, data, events or screens? How compact can application data units be made to optimize transmissions and how do we couple them for synchronous behavior? How are the geospatial and linguistic components of the task interpreted and encapsulated in the CSCW system? Different methodologies have different constraints as well as benefits.

We will examine the geocollaborative tools of two groupware toolkits, Groove and BRIDGE. They contrast architecturally because Groove is a peer-to-peer, synchronous CSCW system whereas BRIDGE follows a client-server model with a central server. Since distributed GIS processing requires the strategic architectural management of large amounts of data, the differences in their architectures are informative. They highlight issues in performance bottlenecks and bandwidth, data distribution, consistency control, awareness mechanisms, flexibility and scalability, and the fluidity of synchrony and asynchrony.

Groove and Toucan Navigate

Toucan Navigate is a synchronous, collaborative map tool built for the Groove platform. Groove is a commercial, Windows-only, .NET-based collaborative environment with semi-open implementation: since Groove supports outside companies who are interested in developing plug-in tools (like Toucan Navigate) to their platform, the Groove API is publicly available.

Controlled Decentralized Framework. Groove is structured as a peer-to-peer network that Chen et al. describe as a 'controlled decentralization framework'. "There is no point that contains the whole resource information in the network. However, there is a central admission server. This server can control which peer can join the network."[22] A user logs into a central Groove server to be cleared for authorization, which directs them to the peers in their shared workspace, to whom they connect directly as peer nodes. Thus different stages of the process have different architectures: authentication uses a central server, then the actual synchronous, collaborative workspace is peer-to-peer.

Having a server control workspace permissions but then maintaining direct connections only between peers provides greater security, a very important issue in online group work in business. Moreover, Groove's transactions are 192-bit encrypted.[23] The peer-to-peer aspect minimizes server dependence and data is kept local to the nodes that use it, preventing the performance bottlenecks that a system as popular as Groove would have if it were centralized and again providing greater data security than a central server would. Bandwidth, computational resources, and storage are optimized between directly connected peers without the redundancy of a server which can be more efficient for the heavy loads of geoprocessing,.

Only Deltas are Transmitted. To reduce bandwidth, the Groove framework turns user gestures into "a transactional unit of change called a delta, which … indicates that something has changed in the shared space." Deltas are transmitted as XML elements, and can be files or the series of actions necessary to change data, which is sent synchronously although receipt by remote users is asynchronous. A local node transmits the delta and then moves on to other processes, so that local application responsiveness is optimized. However, this means that applications are actually only 'near real-time': this can lead to some latency for the remote nodes. If synchronous editing conflicts arise, applications may use locks or automatically create another version of the edited file to resolve them.[24]

Mediated MVC Architecture. Considering the Model-View-Controller interactive application paradigm, Groove has a "mediated Model-View-Control" layered architecture: the Controller components in Groove are the "'glue' that binds the Model and the View, and in essence contain the business logic of the application."[19] Groove adds new parts to the MVC structure to maintain synchronicity among nodes. There is a command processor, virtual message queue and XML object routing between the controller and model layers, and an XML object store below the model layer to enable multiple users to interact with the same application synchronously. Updates and queries in a tool are passed to the what is called the engine level, which resolves conflicts and as mentioned "packages gestures to deltas," that are then sent to the dynamic services level, which ensures consistency among peers. The XML object store also allows users to continue to work asynchronously when disconnected.

Relay Server for Asynchronous Work. Also, asynchronous work is enabled through a relay server on Groove.net that is used to manage connections between peers and with offline users. This feature can also be used when a collaborator has a slow connection and is sending large amounts of data. "In this scenario, the sender would send the large file over their slow link to a Groove relay, which would then 'fan out' distribution over its fast link to all other shared space members. The relay acts as a multicast router and maximizes the efficiency of each communications link." The relay server can also maintain a backlog of deltas while users are offline.

PopG. However, since Groove is .NET-based, currently only Windows operating systems support Toucan Navigate, unless a system such as PopG's browser-based Groove service is used.[25] PopG supports Groove and Toucan Navigate use on Macs and handhelds, which adds to GIS portability. This reflects the architectural flexibility of these tools: since handhelds can only hold a limited amount of data locally, the ability of PopG to load Groove and Toucan Navigate from a server is more efficient than strict peer-to-peer networking. This solves bandwidth, latency and data distribution issues for mobile devices. However, with respect to more complicated GIS processing, GIS-specific architectural customization would be necessary for truly efficient communication costs. But for now, PopG provides a great deal of breadth for different work styles.

Toucan Navigate is the first commercial-grade collaborative GIS tool in existence. Since Groove already supports a bevy of collaborative tools it is situated in a useful, popular environment. As only deltas are disseminated, the synchronous geoprocessing workload can be very fleet after an initial download of the workspace. That it also includes GPS location-finding reflects its ability to be synced with a larger GIS databases. GPS tracking also highlights that Toucan Navigate has been designed with some GPS-based collaboration in mind with participants who cold potentially be in the field.

Toucan Navigate. In the Toucan Navigate tool, users can be assigned varying roles as managers, participants or guests, with varying permissions with respect to inviting others to the space and tool use. Groove "supports unicasting, multicasting or broadcasting to other members, so that some communications can be hidden." User presence is maintained as users are online and as they enter and leave shared spaces. Activity awareness is reflected by an awareness icon next to the member's name in a side panel, as well as a number next to a tool's title indicating the number of users currently viewing that tool.

Toucan Navigate gives users the choice to navigate, co-navigate, or follow in a session. Other Groove objects can be linked to items on a map, including forms and tables. A thumbnail view is included to allow users to keep track of where they are in different contexts of the larger map for dual levels of awareness. Toucan Navigate also currently offers GPS lookup for geo-referencing locations on a map, and supports XML which allows for a wealth of features and customizable symbols to be added to maps.

BRIDGE and Architectural Comparisons

A synchronous GIS map tool exists in BRIDGE (Basic Resources for Integrated Distributed Group Environments), a synchronous, Java-based, CSCW environment that enables users to interact with and edit the same objects in real-time. BRIDGE was developed at Virginia Tech's HCI Lab and Penn State's CSCL Lab as a research tool for CSCW and community computing projects, and earlier versions of the system have been used in community, educational and military settings such as MOOsburg, LiNC, Navciiti and TeacherBridge.[26]

Central Server. BRIDGE is built upon the Content Object Replication Kit (CORK) which supports the replication of Java objects across Java Virtual Machines on different hosts, all managed by a central server via TCP/HTTP (Groove has its own Simple Symmetrical Transmission Protocol[27]). Unlike Groove in which peers share data directly, it is the central server in BRIDGE that manages real-time updates. "CORK uses a central server for authentication, access control, and persistence, as well as for serialization of messages describing modification."[28]

Centralized Synchronization Management. In his taxonomy of synchronous groupware architectures, Roth points out that centralized servers "are a cost factor…they must be fail proof and perform with high throughput."[29]

Server dependence is therefore a huge factor in using BRIDGE. However because the components that control synchronization are centralized, persistence and event logging are easier to manage among collaborating users.

Here is an overview or how it is managed: listeners in CORK detect local changes, then a change object is created, which "implements the logic for reproducing the modification on another replica of the object."[30] The server in BRIDGE first ensures that the user has permission to make changes to that object, then updates the master replica and broadcasts the change object to other local replicas. This server-based management is in contrast to the peer-to-peer model of Groove in which synchronicity ceases the minute deltas are broadcast to other peers.

However like Groove, individual changes made locally are immediately updated, increasing the user responsiveness of the local client but causing some latency for remote clients. Both systems only transmit changes, which minimizes the amount of data necessary to support synchronous collaboration. Despite the fact that the central server in BRIDGE maintains a master replica of the data and logs annotations made on remote nodes, it does not need to understand application semantics. The server only manages the object replication services needed for remote applications to be synchronized.

Asynchrony is also trivial because of the central server, and BRIDGE was designed with overlapping, 'late-joiner' users in educational settings in mind.[30] BRIDGE supports fluidity between synchronous and asynchronous modes, like Groove, in that users can continue to work on objects with or without others. The benefits of this model are that users do not have to learn different interfaces nor interrupt their process to switch applications and late-joiners do not upset ongoing collaborations.

Finally, a central server can also ration communication costs by not disseminating all data to local machines, but rather only what is local to a task, which can be useful for mobile devices and low bandwidth considerations. In Groove this would be enabled with PopG.

Multi-level MVC Sharing. BRIDGE also extends the MVC architecture but unlike Groove, it does not share data at just one layer: Isenhour et al. note that programming with CORK allows for various layers to be used in replication, allowing for more flexible design in the adaptation of single-user application source code. CORK is unique in its flexibility to adapt applications to collaborative use without having to re-engineer the actual application logic or layers of single-user programs. "CORK supports attachment of collaborative functionality to otherwise unmodified classes. The ability to add collaboration support through composition rather than replacement or extension simplifies reuse of existing software and supports collaborative use of classes whose implementations evolve over time."[30]

Thus CORK supports replication at different layers so that it can be engineered to match the granularity of the Java objects that need to be shared. This enables a great deal of programming flexibility in deciding what is needed at the time vis-à-vis bandwidth, application state, resolution of synchronous conflicts, or data abstraction. Previous synchronous CSCW systems have attempted to implement whole classes of synchronous widgets or synchronized views which puts more strain on rewriting large chunks of code. "CORK takes a different approach, providing infrastructure for attaching collaborative capabilities to collaboration-unaware objects in the model, view, or widget layers of an application." In this sense CORK is compelling in its flexibility to adapt applications for synchronous, collaborative use without having to rewrite single-user programs from scratch.

Both are Hybrid Systems. Then again, if we use Roth's taxonomy of architectures, BRIDGE built on CORK is actually closer to the replication strategy of Groove than it is to a centralized server. In Roth's archetypes, the taxonomy of an synchronous architecture is determined by where the functional application core lies. In BRIDGE, since application semantics reside within the local client and not on the central server, the functional core of applications are on local Java virtual machines. BRIDGE is a therefore more of a hybrid system. Aside from the master replica, a minimal amount of data and logic are kept on the central server. But both Groove and BRIDGE maintain replicated states by broadcasting changes only.

Adaptability. A Java-based collaborative environment like BRIDGE and toolkit such as CORK are more adaptable through Java interfaces to changing API's of single-user application source code. Also, varying degrees of bandwidth consumption can be implemented depending on needs: writing code that consumes less bandwidth typically increases programming complexity because higher layers must be modified to achieve this, which also creates the need for more involved conflict resolution strategies when things are modified at the same time. Since CORK can apply collaboration semantics to collaboration-unaware objects at various layers, application data unit and conflict considerations can be decided at the time of implementation, not based on the overall CSCW environment's architecture.

Development. Groove is interesting because it has an "semi-open" implementation, in which third parties can develop for the environment but must first obtain a license from Groove Networks, Inc. Its commercial use makes it and tools like Toucan Navigate much more deliverable-oriented and the products are very user-friendly, streamlined and visually pleasing, whereas BRIDGE is an experimental academic tool that must therefore be developed with specific research grants in mind. One of Groove's main criticisms is that it only works on Windows platforms, but .NET is a currently a widely-used framework augmented by a very extensive array of libraries and resource management tools that are attractive for their convenience.

Since BRIDGE is built in Java it is meant to be a robust, portable, research-oriented CSCW system. Current extensions in development include incorporating the latest version of GeoTools[31], a very advanced, open-source GIS

Java toolkit, as well as development of BRIDGE and CORK with federated servers and mobile device-based applications, which would strengthen its robustness and applicability to many real-world GIS scenarios. BRIDGE will be made open-source soon.

Future Infrastructures

One potential architectural innovation might be a more asymmetrical architecture in which other nodes can be highly sophisticated GIS databases that are linked through a central server to the systems discussed. A central server structure would be more efficient in the same way that Groove uses a relay server for large deltas, but the asymmetry in node type may require extra programming and interface overhead.

File format discrepancies are often contested and problematic in GIS data processing. There are many formats, some of which are proprietary, such as ESRI's shapefiles or MapInfo files. It is common practice to design tools to support the most popular formats, but for true GIS interoperability more formats should be supported. For now alternative formats can be converted to the more popular ones using ArcGIS and other advanced single-user GIS tools. Currently GML (Geography Markup Language) is also in development with the hope that it will make GIS map processing and web services much more robust, adaptable, compact and searchable, with wider implications for incorporating this data into the emergent semantic web.

Also relevant are the range of web services being developed. Web services allow for very lightweight information exchange through protocols such as SOAP (Simple Object Access Protocol), WSDL (Web Services Description Language) and Web Map Server (WMS) and Web Feature Server (WFS) protocols,[32] which moves distributed transmissions beyond the need for specialized architectures, operating systems and other incompatible system technologies to more universal and lightweight implementations on the web.

Furthermore, various prototypes of online, synchronous applications are being developed such as those used in online, multi-player gaming, which have the potential to inform geocollaboration.

6 Conclusion

GIS processing can be very demanding. Networking GIS is already an essential component given the many sources and databases available. Adding to the already complex issue of GIS usability the prospect of designing a system for distributed human-human collaboration is both daunting and compelling. There are many possible strategies. We have done one possible walkthrough of geocollaboration by means of a hypothetical, same-time, group work scenario, a discussion of usability issues, and a rough outline of synchronous GIS tool architectures.

However our discussion does not take into account how real, practicable GIS integration with synchronous, collaborative architectures would actually work, which is a critical topic for future research. Because it falls short of what we meant to accomplish, and because the anatomy of this paper is somewhat experimental with respect to standard HCI, CSCW, Architecture and Geography writing, we have titled our walkthrough "Geocollaborafrankenstein," a hodgepodge with some (hopefully) promising sentience.

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