Cartography and GIS: Facilitating collaboration I

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Maps and geographic information systems (GISystems) both encode spatial relationships in structured formal representations. These representations enable shared understanding of geographic phenomena and their interdependencies. This formal encoding makes maps and GIS well suited inherently to facilitating collaboration among human participants in thinking and decision making about the geographic scale environment. Recent conceptual and technical developments in geographic information science (GIScience), and in information technology more generally, suggest we are on the cusp of a substantial increase in the role of maps and GISystems as mediators of collaboration – in a range of contexts that include urban planning, resource management, scientific inquiry, and education (see, for example, the NCGIA Initiative 17 Specialist Report on collaborative spatial decision making, Densham, et al, (1995) and the rapidly expanding literature on Computer Supported Collaborative Work (CSCW) -- e.g., (Prates et al., 1997, Shum et al., 1997).

Collaboration can take many forms and research focused on collaboration about geographic phenomena and problems can be approached from many perspectives. Here, emphasis is on basic and applied research directed to maps and GISystems as mediators of human-human collaboration. From that perspective, the most useful categorization of collaborative situations (and the role of maps and GISystems in those situations) is one that emphasizes spatial and temporal differences in the collaborative setting.

Spatially, the key distinction is between collaborators who are co-located (same place collaboration – e.g., standing around a map and talking about a new zoning plan) and those located remotely (different place collaboration – e.g., talking on the telephone about a map, with each participant having a copy in front of them). Temporally, collaboration can be categorized as synchronous (same time, as in the above examples) or asynchronous (different time). A typical asynchronous (and different place) map-based collaboration might occur between a property owner and a planning agency faxing a proposed subdivision map back and forth as approval for the subdivision is negotiated.

Research dealing with *same place* collaboration has focused on the social and organizational issues involved in group decision making and on development and application of synchronous methods and tools to support that decision making. Much of the initial work on *different place* collaboration has been directed to asynchronous sharing of access to information and tools (topics considered in detail in my report last year). However, specific attention has also been directed to methods and tools that support different place synchronous collaboration in task performance. Collaborative tasks given attention include data base construction, information retrieval, decision making, and scientific exploration of large data sets.

Discussion below focuses on *same place* collaboration. Part two in this report, to appear next year, will consider the complementary issues associated with different place collaboration facilitated by geoinformation technologies.

Research dealing with the extension of cartographic and GISystem methods to facilitate same place collaboration can be further partitioned into four partially overlapping components. Two of these deal with the decision making context in which collaboration might occur. One topic involves research directed to group decision making by experts – Group-Spatial Decision Support Systems (Group-SDSS). The second is directed to group decision making that involves public participation – Public Participation GIS (PPGIS). Neither of these research foci must be same place -- and related different place developments will be considered in Part II of this report next year. These efforts are complemented by a third research component directed to the design and implementation of methods and tools supporting group work and a fourth directed to understanding how groups work and the impact of these new technologies on that work.

I. Design, implementation, and theoretical basis of Group-SDDS

One of the key arguments behind development and implementation of GIS over the years has been its potential to integrate information representing multiple perspectives and disciplines, thus its potential to support complex location-based decision making. In spite of this expected application, early GISystems were not well suited to support of decision making for at least three reasons. GISystems were (and often still are) designed for application to well structured problems (Armstrong, 1994), it lacks tools that support decision making directly (Copas, 1993), and it does not contain tools that support group work (Armstrong, 1993). Spatial decision support systems (SDSS) address these issue by extending GISystems with tools designed to overcome these limitations, individually in most initial effots (e.g., (Carver, 1991, Lesser et al., 1991, Densham, 1991, Copas, 1993, Armstrong, 1993, Heywood et al., 1995)). The NCGIA Initiative 17 on Collaborative Spatial Decision-Making served as an important stimulus for research directed to addressing the issues collectively (Densham et al., 1995).

Armstrong (1993, 1994), in a pair of papers, identifies important links to ongoing research in CSCW (e.g., (Greif, 1988, Grudin, 1990, Ishii and Mryake, 1991) and outlines a set of core objectives for Group-SDSS. These objectives involve supporting three stages in the decision making process: strategizing (formulating an initial solution strategy), exploration (generating and evaluating alternative solutions), and convergence (narrowing the focus of analysis to consider a subset of competing viable alternatives). A parallel three-step typology (initial screening, refined evaluation, and selection) is used by Nyerges and colleagues (1997b) to develop a detailed task model of the decision making process involved in deciding among competing transportation improvement site selection projects. Their task model is then used to summarize the influence of various aspects of group-based GISystems technology on decision making in this context. Related work in decision support systems that incorporate environmental process models (but not GISystems) suggests that breaking an apparently ill-structured environmental decision making process into a series of structural components makes the process tractable. Appropriate information management tools and techniques can then be matched to each component (Reitsma, 1996).
Attention has been directed, in several studies, to identifying the components of a software environment considered essential for effective Group-SDSS and to matching these components with stages in the decision making process (e.g., (Jankowski et al., 1997, Armstrong, 1993, Armstrong, 1994, Grimshaw and Howes, 1995)). The techniques can be grouped into those for basic information handling, decision analysis support, and group process consistency (Nyerges et al., 1997b). The latter are particularly important in the context of government decision making where there is a mandate to document the decision making process (Faber et al., 1997). Among the more interesting of the specific tools proposed are "trace and reset" and WYSIWIS (what you see is what I see) techniques (Armstrong, 1993, Armstrong, 1994). The first involves recording a sequence of actions (the trace) so that a scenario can be revised from a key decision point rather than requiring the entire scenario to be rebuilt. This capability has generic applicability to interacting with models of any kind, not just those used in comparing implications of planning decisions (Armstrong's target appication).

In addition to the focus on extending technology to groups (characteristic of research cited above) Nyerges and Jankowski (1997) have proposed a theoretical framework for considering the human components of GIS-supported collaborative decision making. Their framework, an extension of adaptive structuration theory, is derived from a comprehensive assessment of research dealing with GISystems use, collaboration, group decision making, and information technology more generally. This assessment yielded 21 "aspects" of the group decision making problem that the framework attempts to take into account. The framework has been applied to identifying research questions related to use of Group-SDSS (Nyerges and Jankowski, 1997, Nyerges, 1999).

Overall, most of the research directed to Group-SDSS, has pursued an explicit or implicit goal of making better decision support tools. A typical approach has been to develop a conceptual framework and associated methods that will extend existing GISystems and SDSS environments to support group work. This effort has been undertaken primarily by individuals with a research focus that includes geographic information technology development. It draws upon a combination of theoretical perspectives from the information and decision sciences, with particular emphasis on work in spatial analysis, location theory, decision support, CSCW, structuration theory.

II. PPGIS – empowering people through access to mapping/GISystem tools

Some of the research directed to PPGIS, as with that directed to Group-SDSS, has considered method and tool development. More emphasis, however, has been given to the social and political processes that determine who has access to geospatial data and GISsystems and to the role of geographic information technologies in empowering or disenfranchising participants in public policy decisions. As Obermeyer (1998) points out, PPGIS is a direct outgrowth of research on societal implications of GISystems (see (Sheppard, 1995) for an overview). Researchers who are developing PPGIS or studying its use are as likely to be GIScience "outsiders" as "insiders." Their work often draws upon theoretical perspectives provided by critical social theory, social cartography, policy studies, library science, or urban and regional planning. A key distinction in PPGIS research, thus, exists between those who focus on public participation as a social-political issue, and those who focus on development and implementation of technology to facilitate that participation.

Among the social-political issues considered within the context of PPGIS are: access to information and its complement of information confidentiality (e.g., (Barndt, 1998, Harris and Weiner, 1998)), power and control exerted through information access (e.g., (Elwood and Leitner, 1998, Harris and Weiner, 1998)), the failure of traditional GIS to encode what matters to many of the stakeholders affected by decisions, such as information about “place” and values (e.g., (Schroeder, 1997)), the limiting map-based metaphor that underlies GIS and makes it difficult to encode non-metric information (e.g., (Harris and Weiner, 1998)), and the lack of access to GIS technology due to its cost and complexity (e.g., (Barndt, 1998)). A somewhat more pragmatic stance is offered by Monmonier (1998), who proposes a set of “guerrilla tactics” (derived from Alinsky (1971)) that public participants might use to counter the “power” of GIS-derived solutions that they do not agree with. These issues and others are considered in detail in a report from the NCGIA Initiative 19 Workshop on PPGIS (Schroeder, 1996), in a recent special issue of *Cartography and Geographic Information Systems* (Obermeyer, 1998), and in a report from the NCGIA Varenius Workshop on PPGIS (Craig et al., 1999).

One issue that cuts across most of the social-political research directed to PPGIS is the importance of making PPGIS a community-based activity. Harris and Weiner (1998) discuss the various tensions that exist when GISystems are introduced into local communities, particularly ones that have traditionally been marginalized. They advocate “community-integrated” GISystem that is managed by government agencies who have the resources and expertise to build data bases and apply analytical tools. At the same time, community-integrated GISystem should treat local knowledge as valuable and expert, incorporate multiple perspectives, and work from the understanding that spatial decision making is conflict ridden and embedded in local politics. To achieve the goal of community-based application of GISystems to facilitate public participation requires attention to how maps and geographic information are actually used by local groups, an issue addressed recently by Craig and Elwood (1998) (see section 4 for details).

Collaboration as a specific issues in PPGIS has been considered primarily from a practical rather than a theoretical perspective (e.g., (Roche and Humeau, 1999)). The general conceptual approach taken, however, matches Healey’s (1996), contention that urban planing, as a “place-making” activity, should be approached using collaborative interaction among stakeholders. She outlines a trend in planning theory more generally that is characterized as “inclusionary argumentation.” This is a perspective that advocates a decision making environment in which all members of a political community are contributors and that recognizes the range of ways participants have of knowing, valuing, and giving meaning to relevant issues.

As noted above, the socio-political component of PPGIS research is balanced by research designed to create GIS-based technologies that facilitate public participation in decision making. Developments in group decision support are considered below and in Part II of this report. Here, relevant conceptual issues that underlie the technologies are highlighted.

To support development and implementation of successful PPGIS technology requires a conceptual framework from which to approach both design of these technologies and assessment of their use (e.g., (Nyerges et al., 1997a, Howard, 1998, Craig and Elwood, 1998)). Following a strategy similar to that noted for Group-SDSS, several authors have delineated stages in public group decision making (e.g., (Nyerges et al., 1997a)) as well as factors in success (e.g., (Faber, 1995)). PPGIS, in comparison to Group-SDSS, puts more focus on helping users learn about the problem context (at the early stages) and on follow up (due to legal mandates associated with public policy decisions. A four stage partitioning of the collaborative public decision making process seems most appropriate: preliminary assessment (understanding factors involved in a decision, exploring data, and supplementing those data), problem definition (identifying/agreeing upon issues, priorities and decision criteria), decision making (assess options, apply criteria, narrow alternatives, and judge their relative implications), and decision follow up (preserve rationale for decision making in order to justify the process when required and monitor results in order to determine whether expectations are fulfilled). It is likely that different technologies or combinations of them will be appropriate for facilitating collaboration at each stage. As Craig (1998) notes, in his report on a recent PPGISoriented conference in France, it is also likely that public participation will take a very different in form in Europe than in North America, due to both legal and cultural differences.

III. New software and display forms to facilitate group work

Several investigators have directed attention to creating or adapting technology that can facilitate collaboration using geospatial data and models. Specific problems considered include: (a) representing multiple forms of information in group settings and allowing group members to interact with, and change, the representations; (b) adapting and applying electronic meeting software designed to facilitate both individual and collective decision making; and (c) facilitating efficient use of expert knowledge to assist non-experts in information retrieval.

Within the same time - same place category of collaboration, Shiffer (1992, 1993, 1995a), has developed some of the most innovative tools to facilitate both public understanding of planning proposals and public involvement in planning meetings. The ideas have been implemented in his Collaborative Planning System (CPS). The CPS links GIS with multimedia methods to increase the breadth of information forms and perspectives incorporated in decision making. In particular, Shiffer's CPS makes use of formal geographic representations (e.g., map, air photos, etc.) linked to images, video, sound, and animation to give non-specialists a better understanding of the context for planning decisions and their potential implications. The overall goal of the system is to enable an integration of gestural, visual, and verbal discourse.

The importance of facilitating direct user interaction with representations has been noted by several authors (e.g., (Faber et al., 1997, Shiffer, 1998, Florence et al., 1996)). Direct interaction can help users to understand various alternatives (by making it possible for them to pose specific questions and try specific alternatives) and can result in the users feeling that they have a real voice in the decision because they were able to present their perspective. With this goal in mind, Faber and her colleagues (1997) have developed tools that allow users to graphically evaluate differences between alternative plans and to leave both verbal and graphical comments. Although direct manipulation interfaces that rely on a point-and-click metaphor are quite common for individual desktop computing environments, both technical and conceptual issues must be addressed in order to extend the potential of direct manipulation to group settings.

Technical issues include those associated with generating a large display that can be seen from a distance and with methods and devices that allow interaction from beyond arms reach. Since very large, high resolution displays will probably not be affordable in the near future (at least for local public meeting spaces), projection-based large format displays may be the answer. Interacting with these large displays, whatever technology they are based upon, will require remote pointing devices and ways to negotiate conflicts in attempts to simultaneously control the display. Large collaborative displays can make use of virtual reality methods to facilitate understanding (by making proposed structures appear more like the real world, see: (Verbree et al., 1999, MacEachren et al., in press)). With such displays, it is becoming possible to present separate images keyed to each user's viewpoint (Agrawala et al., 1997), making it possible for each participant to consider only those sets of information relevant to their role in the process.

Beyond the technical hurdles, it is important to develop a conceptual understanding of interaction with representations at various distances, thus of the metaphors for interaction that may be effective, plus an understanding of styles of interaction suited to group versus individual settings. In relation to these issues Florence and colleagues (1996) propose using a "wallboard" as a possible metaphor for a group meeting display. They then consider the nature of likely interactions with such a device and variations in those interactions with distance from it. Key categories identified are interactions that can involve direct contact (drawing on the display), those that can use natural gestures, and those that must rely upon a remote pointing device. For an overview of work on interfaces that would support the gestural form of interaction and application of this work to map-based interfaces, see respectively (Pavlovic et al., 1997, Kettebekov and Sharma, 1999).

In addition to research focused on display and interaction forms for group use of geospatial information, research has also addressed integration of methods for facilitating group negotiation and consensus-building with geospatial information retrieval, display, and modeling tools. One approach has been to incorporate GISystems analysis into an electronic meeting system (EMS) architecture (Faber et al., 1995, Faber et al., 1997). Goals here are to allow multiple individuals to state an opinion at once, support anonymous input (to stimulate open exchange of ideas), summarize input for group review, and automatically generate meeting documentation (to meet public disclosure rules and enable later justification of decisions). These goals are similar to those articulated by Jankowski and colleagues (1997) for their Spatial Group Choice software. In that system, multi-criteria decision making tools are integrated with a modified commercial GIS and a module to support "voting" on options. Recent ideas concerning "argumentation mapping"(Horn, 1998) and "knowledge maps" (Hewitt and Scardamalia, 1998), not considered in either system, seem to have substantial potential to provide information visualization methods that help make complex conflicting perspectives understandable. Similarly, work in distributed cognition (Boland et al., 1994, Derry et al., 1998) has a potential to provide a theoretical perspective from which to approach both design of group decision support systems that facilitate a "sense-making dialog among organization members" (Golay, 1995) and assessment of system effectiveness and implications for decision outcomes.

The third area of development, for which there has been much less progress, involves how to efficiently share expertise with non-experts in an information retrieval context. Tools for making expertise available to help non-experts in information retrieval can involve those that facilitate direct collaboration between experts and non-experts (Twidale and Nichols, 1998) and those that encapsulate expertise in a knowledge base (Cartwright, 1999), or in intelligent agents (Ferrand, 1996).

IV. Understanding group decisions and groupware use

Research associated with design and implementation of geospatial technologies for group use is still at an early stage of development. Thus far, there have been only a few empirical studies addressing the process of group spatial decision making and the role in that decision making of representations and technologies designed to facilitate group work. A basis for designing such studies, however, is provided by the long history of work in cartography associated with empirical testing of map and mapping system effectiveness (e.g., (DeLucia, 1979, Olson, 1981, Slocum et al., 1990, Monmonier and Gluck, 1994, MacEachren et al., 1998)) and a growing emphasis in GIScience as a whole with human factors (e.g., (Medyckyj-Scott and Hearnshaw, 1993, Turk, 1993, Davies and Medyckyj-Scott, 1996)), human-computer interaction (e.g., (Mark and Gold, 1991, Densham and Armstrong, 1994, Edsall et al., 1997)) and cognitive issues more generally (e.g., (McGuinness et al., 1993, Mark and Freundschuh, 1995, MacEachren, 1995, Lloyd, 1997)).

Several informal analyses of prototype systems for group decision making have been reported, together with guidelines on system design based on these experiences (e.g., (Shiffer, 1995b, Shiffer, 1998, Godschalk et al., 1992)). In addition, the nature of map use by community groups in the context of PPGIS has been assessed by Craig and Elwood (1998) using in depth individual interviews. Based on analysis of these interviews, they identify four somewhat overlapping categories of application for maps in the PPGIS context: administrative (to support activities of staff members, such as facilitating property purchases or planning door-to-door surveys), strategic (investigating conditions and planning for provision of services), tactical (to plan specific actions in response to particular issues), and organizing people (to generate interest and participation in activities). These uses are matched with two primary categories of audience: internal (the community organization itself plus people and businesses in the community) and external (institutions and organizations with resources and power, individuals and other organizations seeking coalitions, the general public).

Nyerges and colleagues (1998) adopt a different methodology for exploring group performance with their prototype Spatial Group Choice software. Their dual goals are to improve understanding of group process dynamics and to develop requirements for information technology. The general approach taken is an implementation of protocol analysis. They document, in considerable detail, the processes involved in developing coding schemes for videotape analysis of group performance. The paper will provide a valuable source of information for anyone considering similar analysis of individual or group use of interactive software.

An alternative to the largely qualitative interview and protocol analysis methods involves controlled experiments focused on the role of geospatial information technology in a group decision making context. Reitsma and colleagues (1996) conducted one of the first such experiments. Specifically, their study investigated the effects of various kinds of access to a simulation model on water resources negotiation outcomes and processes. They characterize access to a shared model as having three dimensions: control (ability to initiate model runs), visibility (the authority to see results), and schedule (when and how often model runs can be made). Matching individual and group control, individual and group visibility, and free and restricted scheduling results in eight categories that could be tested. The study looks at 4 of them – as they compare to decision making without access to a model. Assessment methods used by Reitsma and colleagues emphasized ability of teams of participants to arrive at a consensus that was physically viable and self assessment by participants of the decision making process and outcomes. Results suggest that model availability encouraged negotiators to consider more policies and helped to identify policies that meet specific task constraints but did not help in understanding the environmental system itself.

As should be clear from the limited literature cited here, the study of group geospatial decision making and tools to facilitate it is not well developed. There is no clearly specified set of methods appropriate to this task. The complexity of both the group problem solving context and of the integrated tool environments being developed makes study of group work with geospatial tools a challenging task and one that deserves a concerted effort. The approaches taken by Reitsma and colleagues as well as those by Nyerges and colleagues provide a good start toward developing rigorous methods for study of group work in a geospatial information context and toward development of standards for the application of these methods and for interpretation of results.

V. Conclusions

The length of this report required a limited focus on human-human same-place collaboration. However, understanding and facilitating different-place collaboration and that between humans and intelligent objects/agents are also important areas of research for the next decade. That decade will bring dramatic improvements in digital communications technologies. Currently separate developments in mapping/GISystems development, the Internet and WWW, teleconferencing, immersive virtual reality, mobile communications systems, and others are likely to merge and evolve in ways that we cannot anticipate. We can, however, anticipate dramatic improvements in our potential to interact remotely, in meaningful ways, about geographic problems. The changes that occur will bring with them an exciting array of research questions for geographers generally and geographic information scientists specifically. My report next year will highlight a selection of these questions, with particular attention to those design, use, and implications of different place map/GISystem-facilitated collaboration in decision making, education, and science.

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