Interface Devices and Public Participation[1]

Lewis D. Hopkins, Michael Twidale, Varkki George Pallathucheril
University of Illinois at Urbana-Champaign

Research on public-participation geo-spatial technologies is largely directed at taking advantage of the potential broad reach of the Internet. In particular, Web-based GIS applications support asynchronous participation by individuals in different locations. Public involvement is, however, facilitated to a significant extent at community meetings and charettes where people meet face-to-face, review spatial information, and collectively arrive at inferences that inform decisions and choices. In this paper, we describe ongoing work on how a collection of digital interface devices, intelligent software agents, and conventional paper-based tools can facilitate face-to-face collaboration among members of small groups. We also present some preliminary observations about incorporating this approach and an agenda for future research.

Public participation GIS (PPGIS) is concerned with a range of issues raised by the intersection of community interests and geo-spatial information technologies. The objective is to discover and address the limitations and potentials of using these technologies to facilitate and enhance broad participation in public policy and decision-making. Issues that have been raised in the literature on PPGIS, as captured in Craig, Harris, and Weiner (2002) for instance, can be broadly organized into three categories: societal issues, data issues, and technological issues.

The work on public-participation geo-spatial technologies is largely directed at taking advantage of the potential broad reach of the Internet and developing Web-based GIS applications to support public participation. With the exception of public access to GIS technology in university laboratories, much of this work has to do with asynchronous participation by individuals in different locations (e.g., Alkodmany 2000). Public involvement is, however, facilitated to a significant extent at community meetings and charettes where people meet face-to-face to review spatial information and to collectively arrive at inferences that inform decisions and choices.

Web-based GIS applications can be used to support deliberations in these face-to-face settings but the devices people use to interface with these applications do not support collaborative work in very fundamental ways. Hopkins et. al. (in press) argue that these devices are configured for an individual user rather than a group: they have small display screens oriented vertically; users manipulate content on the screen indirectly through a keyboard and a pointing device, such as a mouse, rather than directly as when working with pen on paper. The Design Workbench is an alternative to the vertical screen, keyboard, and mouse (Hopkins et. al. *in press*); it is a horizontal 36” by 48” touch-sensitive surface onto which the contents of the computer screen are projected from below. People stand on all four sides, and the touch-sensitive surface allows the content of the screen to be manipulated by any user who points or draws with a finger or a stylus. The horizontal surface encourages interaction among persons and computers in contrast to vertical surfaces, which invite one person to present to or record for others. The Design Workbench has two benefits relevant to PPGIS: first, working with this device can be very intuitive and software

[1] Paper presented at the 3rd Annual Public Participation GIS Conference, Madison, Wisconsin (July 2004)

tools and analysis can be more accessible; second, this device facilitates real-time collaboration within small groups.

In this paper, we describe ongoing work on how a collection of digital interface devices (including the Design Workbench, intelligent software agents), and conventional paper-based tools can facilitate face-to-face collaboration among members of small groups. We also present some preliminary observations about incorporating this approach: for instance, difficulties created by the ambiguities of gestures and benefits afforded by novices learning by watching others in the collaborative setting. We propose a research agenda on enhancing the technology of such interface devices.

Context

In the urban planning literature, as in the PPGIS literature, collaboration with stakeholders is particularly pertinent (Forester 1989; Innes 1996; Healey 1997; Innes 1998; Forester 1999), and this increases the importance of interfaces for collaboration. Shiffer (1992b; 1992a) devised a planning support system that projects computer screen images for shared viewing and identifies the possibility of multiple keyboards or mice to control the screen. Such wall projection does not yield collaborative behaviors equivalent to what happens around a conference table spread with maps. Projection on the wall tends to focus attention on one person presenting ideas to others, not on collaboration among persons to create new ideas. Shiffer's work builds in part on the collaborative decision support systems aimed at corporate decision making (Stefik, Foster, Bobrow et al. 1987; Nunamaker, Dennis, Valacich et al. 1991). Armstrong and colleagues developed similar systems for geographic location problems (Armstrong, Rushton, Honey et al. 1991; Armstrong 1994). This interface mode has not won wide acceptance, perhaps because it forces participants to interact either with people or with a computer, rather than interacting simultaneously with both computers and people. As long as input is through keyboard and mouse, however, it is difficult to develop ideas, talk to people, and interact with a computer all at the same time.

Commercial geographic information systems (GIS) software is readily available to work with and display well-defined spatial data. Freehand drawing software can be used for diagrams and collaborative work on site plans or infrastructure planning, but again, there is no meaning beyond the graphics themselves. We have proposed a general framework for planning support systems (Hopkins 1999), but most such software focuses on specific tasks without addressing the larger interface question of how to bring combinations of such tools to hand for collaborative use (Brail and Klosterman 2001). More recently we have initiated development of a planning data model to encompass the tasks of making plans, using plans, and modeling urban development processes (Hopkins, Kaza, and Pallathucheril 2003a; Hopkins, Kaza, and Pallathucheril 2003b).

Sketching software is also commercially available, but these are primarily drawing tools and the sketches communicate no meaning to the computer. Also, software that enables sketch input and elaboration to allow analysis and visualization is still in the research and development realm. Gross and his collaborators (Gross and Do 2000; Gross, Do, and Johnson 2000) are focusing on making this link. Research on design and sketching considers the cognitive processes occurring (e.g., Schon and Wiggins 1992; Suwa, Gero, and Purcell 1998) and the relationship to physical activities of sketching (Kavakli, Scrivener, and Ball 1998). Sketching—rapid expression of ideas in spatial form as the ideas are being created—is a crucial aspect of working on and collaborating on design problems. Sketches imply rapid description in a style that invites reconsideration and rapid modification. Most work on sketching focuses on supporting individual work (e.g.,Bailey, Konstan, and Carlis 2001). We focus instead on collaboration because we can observe the collaborative communication as an additional way of understanding what is going on and because collaboration is a valuable and common practice in PPGIS.

In computer-supported cooperative work (CSCW) research, considerable attention has been devoted to the issue of awareness (e.g. Dourish et al. 1996). Large displays offer various mechanisms for facilitating awareness; providing a larger space to enable greater context for the work at hand (MacIntyre et al 2001), as well as making it easier for people in the same room to work in short bursts individually, fluidly leaving and rejoining ongoing group work around a large shared display or worksurface. The latter is a case where new technology can afford a particular kind of work activity that then becomes more prevalent as a result, leading to evolving workspace requirements (Carroll & Rosson 1991). Work on single display groupware (Stewart et al. 1999) raises many of the issues that are of concern when multiple devices are involved, including how to enable easy interaction both with the system and with other participants.

Much of the early research on collaboration systems provided a way for individuals to enter ideas or ratings and for a computer to aggregate and communicate these ideas or ratings to others. More recent work has focused on collaboration in which all interaction is mediated through computing networks. In both cases, the primary contribution of computing is representation and communication. The computer is not really included in the collaboration. Further, in these systems the computer comes between humans, interfering with any parallel, direct communication between humans. Computing capabilities can contribute more by participating in the problem solving task as a collaborator rather than just a communicator (Woods 1986; Brill, Flach, Hopkins et al. 1990; Grosz and Kraus 1999). The focus ought to be on interfaces that enable humans to communicate with each other and with computers simultaneously. Such interfaces should increase capacity for true collaboration of humans and computers.

Scaife et al. (2002) consider the issue of asymmetrical collaboration and its implications for design. In their case it is the asymmetry of customer and sales assistant. In our context, it is a planner and a stakeholder, or a facilitator and a member of the public. In all cases, external representations can serve to powerfully support gaps of vocabulary or communication. Less expert users may lack the specialist vocabulary yet be quite capable of communicating their concerns by gesturing with and around accessible representations of the problem, particularly when supported by the more expert interlocutor.

The involvement of a variety of perspectives in public deliberation is a key justification for participation, which is one way individuals constitute themselves as citizens (see e.g. Hopkins 2001). In addition to bringing in different kinds of expertise to form a multidisciplinary team, there has been substantial work in participatory design, particularly with respect to the involvement of end user representatives in the development of computer systems (Kyng and Mathiassen 1997). This has many parallels with activity in urban planning involving community members in public deliberation.

Facilitating Public Participation

Our approach builds on the observation that human collaboration involves sketching, talking, and thinking simultaneously. Individuals gather around tables or whiteboards and sketch while talking and reacting to each other's words and sketches. Henderson (1999) suggests that such "talking sketches" serve as "boundary objects" (Star 1989) in that they allow different specific interpretations of reality embedded within a more general and universal interpretation. Thus, they are more than merely devices for recording ideas; they can serve as "conscription devices" that enlist group participation and organize networks of collaborators.

In public meetings, traditionally, large displays are attached to or projected on walls and used for presenting information. One person stands up at the front and operates the display using either a mouse or a touch screen (see Figure 1). Other participants may ask questions or make suggestions to be recorded, but rarely directly interact with the display. To do so requires walking over to the privileged position of control. What would happen if a large display were taken off the wall and used as a horizontal or slightly inclined sketching table? Would it encourage more participatory interaction? We have built and worked with a physical prototype of a sketching table and interface elements that would enhance its use (Hopkins et. al. *in press*).

Figure 1: Conventional Workshop Configuration

Figure 2: Design Workbench in Use

Figure 3: Top View of Collaboration with Design Workbench

(More information can also be found at http://www.rehearsal.uiuc.edu/DesignWorkSpace/; see Figures 2 and 3.) We have also developed a second device that converts easily from horizontal to vertical. We have developed elements of a sketch-based computer interface. These devices minimize use of a keyboard or mouse and use Smart Technology's touch-sensitive surfaces for both display and for communicating with the computer. We use conventional GUI, sketching, and "procedural graffiti"—graphic gestures on the surface.

Rather than a single such device in the context of a public meeting, we see a collection of these and other direct-manipulation devices networked together with intelligent software agents that facilitate dialog and collaboration among meeting participants. Among these devices would be those, such as the Design Workbench, that engage groups of participants as well as tablet PCs and PDAs used by individual participants. Since these devices are networked, the screen of any one device can be displayed on another device using remote desktop viewing technologies such as the open source, platform-independent Virtual Network Computing software (Richardson, et. al., 1998). (More information is at http://www.realvnc.com/). Seamless integration among these devices, and the work being done on them, can be effected through intelligent software agents such as those being developed for the GAIA project (Román, et. al., 2002). (More information is at http://choices.cs.uiuc.edu/gaia/.) Based on experience with computing interfaces in other situations, we expect that conventional paper will also be used in these forums, both as previously printed information and as blanks for recording and sketching.

Use cases

Urban planning deliberations involve at least four types of participants: experts (professional planners), citizen planners (members of planning commissions, city councils), petitioners (people triggering a particular decision or design situation), and "neighbors" (persons who become participants because of interest in a particular case). These participants are most obvious in conventional development review situations, but the basic distinctions can also be adapted to consider neighborhood-based initiatives, such as the action research approach of the East St. Louis Action Research Project (http://www.eslarp.uiuc.edu/). This paper focuses on four related types of collaborative deliberation situations in which these four types of participants engage each other.

Public meeting collaboration. In a public hearing, study session, plan commission meeting, or city council meeting, each type of participant takes on particular roles. Collaboration in "meeting time" is very difficult and most discussion is debate focused on advocating an a priori point of view rather than collaboration focused on creating new ideas, options, or insights. This use case implies equipping a real council chamber with devices such as a large horizontal work surface accessible to all four types of participants, simultaneous wall projection for the constantly changing portion of the participants who are temporarily peripheral, and tablet PCs for continuing participants such as professional staff and planning commissioners.

Public participation collaboration event. Planners are constantly trying to find better ways to engage the public as participants in making plans, resolving conflicts, and developing new solutions. The currently conventional ways of organizing such events include

- public hearings in which presentations by experts are followed by open microphones at which citizens can say their piece,

- open houses in which information is arrayed around a room with experts available to help explain it if asked and forms soliciting feedback from participants,
- large public meetings in which proposals are presented and participants have handheld voting devices to express preferences among them but no ability to modify the proposals,
- and focus groups.

None of these forms is particularly effective at supporting collaborative participation in generating, elaborating, or refining ideas about what to do or relationships among implications of particular proposals. One scenario is to equip a large room with several horizontal digital surfaces, each with linked projected wall images. Participants can then enter the space and see from a distance what kinds of collaborations about what issues are currently occurring and move to a particular worksurface to join in. Each worksurface would have a staff person also equipped with a tablet PC who could assist the rapid learning process of how to interact with the worksurface and facilitate recording and annotating of ideas as they are generated and accessing additional data and tools as the need for them emerges.

Collaboration of experts with client or petitioner. Small group work with a client or petitioner is one of the most important opportunities for collaboration among expert planners and persons proposing or opposing actions to change the built environment. This kind of small group collaboration is highly focused among highly motivated participants. Computer enhanced workspaces must still have rapid learning curves because, in each case, key participants will be new to the tools and particular procedures. Some neighborhood initiatives will have this form if the number of participants is small.

Collaborative design among experts. In collaboration among expert planners and designers, it is likely that participants will be experienced in using the technologies to do design work and in working with substantive aspects of particular design problems even if they represent different interests, as when designers working for a developer meet with planners working for a city.

Interface development approach

Our approach to developing interfaces involves rapid, iterative prototyping and formative evaluation. Rather than developing completely new interfaces, we deploy and analyze a series of more modest, easier to prototype features in order to get a richer understanding of users requirements and how these co-evolve (Carroll et al. 1991) with the functionality that users experience. Formative evaluations enable us to identify both breakdowns in the fluidity of the interaction that need to be addressed and spontaneous appropriations of the technology for new kinds of working that can be exploited and enhanced.

This approach follows a model in CSCW research of ‘lived evaluation’ (e.g. Dourish et al. 1996) where the researchers themselves, colleagues, and students attempt to apply the technologies to their own real world needs over an extended period of time. This serves as a test of the generality of the claims as new use scenarios, not initially envisaged in the earlier stages of prototyping, precipitate ongoing iterative development. It also uncovers interacting issues of use that need to be considered in systems design. New kinds of interaction and new design requirements will likely emerge as a result of making appropriately designed computational resources available – as our pilot studies already indicate.

To speed up the iterative design cycle, a high frequency of collaboration activities must be observed, such as bimonthly plan commission meetings and continuing planning classes. Rather than work for a year creating a radically new piece of software, then test it and revise it over another 6 months, we work on relatively small changes in increments of a couple of weeks. These changes can be:

- small refinements of an interface or functionality of a tool in the light of analyzing earlier use;
- introduction of a new functionality or program as an additional resource for use, and then assessment of its use over time from being a novelty to just being a familiar option;
- introduction of a new program or piece of hardware, relying if necessary on 'human middleware' to minimize the effort required for systems integration so as to more quickly assess issues of use in practice

Given the nature of rapid prototyping, there are times when versions need to be 'wrapped' in some support in order to evaluate attributes of interest. Examples of wrapping include:

- Less authentic situations, such as testing in the lab with students working on assignments in order to remain in the lab where setup and error recovery are easier: Although the situation is authentic for student learning, it is not quite like actual collaborative design.
- Design team acting as 'human middleware', such as by manually transferring files created by different applications: This approach saves on prototype development time because need not have completely integrated applications and observation can still focus on attributes of interest.
- Variants on the Wizard of Oz style of experimental evaluation, such as research staff simulating: some part of the system in real time: Traditionally this technique presents users with an interface and then manually but in real time computes the results of user actions, but it can be used more broadly to emulate proposed systems attributes with human capabilities.

As versions of prototypes become more robust, observations occur in more authentic settings such as community meetings. When elements are separable, more reliable elements of systems are deployed without waiting for complete systems. Formative evaluations are used in multiple ways:

- To fix (immediately after the session) clearly evident problems with usability, learnability, usefulness, and support for collaboration;
- To develop (over a longer time period) a better understanding of the nature of collaboration around devices, a classification scheme, and an evaluation archive with which to examine attributes in the light of evolving understanding;.
- To compare within and among cases, such as examining within a case why device A was used more than device B, or why learning to use option C seemed so much harder than learning to use option D or examining across cases commonalities in how device A gets used over a wide range of work contexts and in combinations with other devices.

Similar contexts are useful for understanding when and why we get different effects, a kind of sensitivity analysis. Different contexts are useful for understanding effects that recur in very different contexts, and so are likely to be encountered with other technologies.

All of these observations are part of an iterative system development and evaluation approach for investigating fundamental interface issues in very realistic situations. The interface devices and software are continually modified and refined in response to operational feedback as well as to focus on evolving fundamental questions. For example, if collaboration engaged a larger portion of group members when there is shared workspace and private workspace, we would focus on trying to understand how to support this effectively. If graffiti driven interfaces increased use of computing tools compared to conventional GUI, we would focus on enhancing these capabilities.

Findings from pilot studies

Here we outline some inferences drawn from pilot studies of these kinds of interface devices. These ideas are necessarily tentative, but point to issues that should be investigated further because they seem to be key to the development of successful systems.

We have observed users of these devices in several different situations, modified devices or software, and then observed again. Our approach has been qualitative and iterative rather than based on formal experiments, because this enables more rapid development of interface ideas at this early stage. Students have used some devices for public presentations and for in-class exercises. The Design Workbench was used in Madison, Wisconsin, by a community group from Verona, Wisconsin, working on a township plan using Place-It software developed at the Land Information and Computer Graphics Facility at the University of Wisconsin (http://www.lic.wisc.edu/placeit/). The Workbench has been used to present simulation results for the St. Louis metropolitan region developed using LEAM (http://www.leam.uiuc.edu/)

We have also been participant observers in several recent community charettes. In Spring 2001, a charette in Champaign, Illinois, considered proposals for a West Campus Traffic Plan. Approximately 100 people attended and worked in breakout groups of 8 to 10 for about two hours relying on paper maps and documents. We observed this charette but did not provide computing support. Participant observation in this event further confirmed, however, the feasibility of providing prototype systems for real cases and the importance of horizontal work surfaces and easily enabled use and movement of paper.

We now discuss four key inferences drawn from our observations:

Pointing for the computer and pointing for people. One of the most frequently observed tasks was identifying unambiguously for the group a location, entity, or relationship that a participant wanted to comment on or change. The interface is not merely a means of interacting with the computer, giving input and getting output. It is also a rhetorical tool supporting the conversation among people, analogous to the way that sheets of paper, a flipchart or a whiteboard may be incorporated into a conversation to help clarify a point or reconcile different interpretations. As a result the interface should ideally be easy to use while simultaneously talking. We have observed that the input device, whether finger or stylus, is both a drawing and pointing device and can serve the two purposes simultaneously or separately. That is, people may point to draw something, or to move elements around in order to modify a design, but they may also point and move elements not so much to have an effect on the computer but as a rhetorical device to emphasize the point that they are making in their simultaneous verbal interaction with the other participants. This can also cause confusion if a dramatic gesture for the benefit of fellow humans is interpreted by the computer as a request for it to do one or several actions. This dual use of human-computer interaction devices in support of human-human interaction must occur fluidly. People are very adept at using pens as dual purpose drawing tools, annotators and (non-touching) pointers on whiteboards and paper, but it can be much more clumsy to do the same kind of explaining with a computer application – not surprisingly because such use is rarely explicitly supported.

Learning by watching. Direct interaction with a touch sensitive screen appears to facilitate social learning and to invite participation by non-experts in the design process. With any new technology, users have to overcome the barrier of learning how to use it. In the case of a rapid-fire activity such as collaborative planning and design, the learning barriers may be so great that users just give up and revert to the low tech but easy to use technologies of paper. In the case of design that involves people with a range of backgrounds, including those with far less exposure to advanced technologies, the learn curve is even more important. One particularly interesting observation from the videotaped Verona group was the speed with which participants got involved with the use of the system to support their planning decisions. Our understanding of this is only preliminary, but the following potential factors are being considered in subsequent versions of the interfaces.

- It is easier for a group of 5 to 10 to stand around a horizontal than a vertical surface, observe, and progressively increase their level of interaction.
- Although we did not see all 10 interact at once, we did observe interesting transitions, from passive observing to active manipulation, supported by the physical and software capabilities of the system. This is an example of legitimate peripheral participation (Lave & Wenger 1991).
- Although a tentative finding from a pilot , it is interesting that progressions of interaction included older lay people, not normally considered the first adopters of new technologies.
- It is quite possible to just stand and watch what is going on, without having to make a major commitment to interact. People gradually moved around, getting closer and became more 'active observers', then asked questions, suggested interactions to do, helped out in the interaction doing simple tasks (like scrolling because they were close to the scroll bar) and finally took more active roles in using the interface to suggest ideas.

With a large, horizontal, direct interaction interface, it is not only the results of interactionswith the computer that are easy to see, but also what was done to effect those interactions. Rather than moving a hand over a mouse while watching the results on a screen, you directly touch the screen. This is likely to have advantages of immediacy and involvement for the user doing the actions. It appears to have even greater impact on a second person who is unfamiliar with the technology and is standing by observing. Research in a project on over-the-shoulder learning (Twidale 2002) has investigated informal learning of computer applications from colleagues using conventional computing interfaces. However this is not without its problems—just watching is insufficient to understand what has been done and why. It is much easier to follow and understand what the user is doing when using a large horizontal surface, because a second learner can focus just on where the hand is and see the rhetorical effect of pointing and touching,rather than having to shift attention between the hand on a mouse and the cursor and content on the screen.

'Direct Manipulation' Isn't. Describing graphical user interfaces as involving direct manipulation is something of an approximation. We move our hand over a mouse while looking at the consequences of that action on the screen. With touch screen interaction, the manipulation becomes much more direct and hence easier for others to see and learn from. Coupled with the large screen, this means that actions are both more direct and more exaggerated than on a conventional screen.

'Interface Aerobics' Although there are many advantages to using a large screen, there are certain problems, and some that are exacerbated by using interface styles developed for conventional mouse and PC use. Using drop down menus from the top of the screen is now potentially difficult because of the reach, involving whole arm and body movements. Doing multiple menu selections starts to resemble an exercise workout. Shorter people have to stretch even further to reach the areas of the screen a long way from them. In our pilot studies, people standing at the side of the screen claim to be quite happy in following the interaction even if the usual form of interaction is rotated 90°, but interaction with a standard GUI is more difficult in this orientation. An interesting and potential positive side effect of this greater effort is that we have seen greater sharing of the interaction, with the person near to the scrollbar, for example, anticipating the scrolling needs, and the person near the graphic mode selector choosing modes as asked by someone else doing the drawing. These roles, in several instances, served as steps into more active participation in interacting with the interface devices.

Conclusion

Our experience thus far indicates that a combination of interface devices, intelligent software agents, and conventional paper-based tools can enhance participation and true collaboration in face-to-face public deliberations. The iterative interface development approach enables rapid modification and enhancement of systems in operational settings. None of our interface versions have yet, however, progressed beyond the stage of novelty in real collaborative settings. In part, this may be due to relatively few instances of true collaboration—devising new ideas or understandings jointly in the course of a meeting or charette—with or without computing interface tools as enhancements. Rather than focusing primarily on unusual community charette events, we are now focusing on more routine situations such as plan commission meetings and planning presentations, in which some aspects of collaboration do occur and could occur more frequently with additional interface capabilities.

References

Al-Kodmany, K. (2000). Extending geographic information systems to meet neighborhood planning needs: The case of three Chicago communities. *URISA Journal* 12, 3: 19-37.

Arias, E., Eden, H., Fischer, G., Gorman, A. & Scharff, E. (2000). "Transcending the Individual Human Mind--Creating Shared Understanding through Collaborative Design." *ACM Transactions Computer-Human Interactions* 7(1), 84-113.

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

Armstrong, M. P., Rushton, G., Honey, R., Dalziel, B. T., Lolonis, P., De, S. & Densham, P. J. (1991). "A Decision Support System for Regionalizing Service Delivery Systems." *Computers, Environment and Urban Systems* 15(1), 37-53.

Bailey, B. P., Konstan, J. A. & Carlis, J. V. (2001). Supporting Multimedia Designers: Towards More Effective Design Tools. Proceedings of Multimedia Modeling.

Brail, R. K. & Klosterman, R. E., Eds. (2001). *Planning Support Systems*. Redlands, CA, ESRI Press.

Brill, E. D., Jr., Flach, J. M., Hopkins, L. D. & Ranjithan, S. (1990). "MGA: A Decision Support System for Complex, Incompletely Defined Problems." *IEEE Transactions on Systems, Man, and Cybernetics* 20(4), 745-757.

Craig W., T. Harris and D. Weiner (eds.). (2002). *Community Participation and Geographic Information Systems*. London: Taylor and Francis.

Deal, B. & George, R. V. (2003). The Land Evolution and impact Assessment Model (LEAM): Will It Play in Peoria? 8th International Conference on Computers in Urban Planning and Urban

Forester, J. (1989). *Planning in the Face of Power*. Berkeley, Calif, University of California Press.

Forester, J. (1999). *The Deliberative Practitioner*. Cambridge, MA, MIT Press.

Gross, M. D. & Do, E. Y.-L. (2000). "Calligraphic Interfaces: Drawing on the Back of an Envelope: A Framework for Interacting with Application Programs by Freehand Drawing." *Computers and Graphics* 24, 835-849.

Gross, M. D., Do, E. Y.-L. & Johnson, B. R. (2000). Beyond the Low-Hanging Fruit: Information Technology in Architectural Design: Past, Present, and Future. Association of Collegiate Schools of Architecture Technology Conference, Cambridge, MA.

Grosz, B. J. & Kraus, S. (1999). The Evolution of SharedPlans. In A. Rao &M. Wooldridge (Ed.), *Foundations and Theories of Rational Agencies***:** 227-262.

Healey, P. (1997). *Collaborative Planning: Making Frameworks in Fragmented Societies*. London, Macmillan.

Henderson, K. (1999). *On Line and On Paper: Visual Represenation, Visual Culture, and Computer Graphics in Design Engineering*. Cambridge, MA, The MIT Press.

Hollands, J. & Wickens, C. (1999). *Engineering Psychology and Human Performance*. Englewood Cliffs, NJ, Prentice-Hall.

Hopkins, L. D. (1999). "Structure of a Planning Support System for Urban Development." *Environment and Planning B: Planning and Design* 26(3), 333-343.

Hopkins, L. D. (2001). *Urban development: The logic of making plans*. Washington, DC, Island Press.

Hopkins, L. D., Johnston, D. & George, R. V. (1999). Computer Support for Sketch Planning. Computers in Urban Planning and Urban Management, Venice, Italy.

Hopkins, L. D., Kaza, N. & Pallathucheril, V. G. (2003a). Planning Markup Language: Representing the Meanings of Plans and Regulations. Association of Collegiate Schools of Planning/Association of European Schools of Planning, Leuven, Belgium.

Hopkins, L. D., Kaza, N. & Pallathucheril, V. G. (2003b). Shared Data Model for Describing Plans and Regulations as Inputs to Simulation Models of Urban Development. Regional Science Association, Philadelphia, PA.

Hopkins, L. D., Ramanathan, R. & Pallathucheril, V. G. (in press). Interface for a Sketch Planning Workbench. *Computers, Environment and Urban Systems*.

Innes, J. E. (1996). "Planning through Consensus Building: A New View of the Comprehensive Planning Ideal." *Journal of the American Planning Association* 62(4), 460-472.

Innes, J. E. (1998). "Information in Communicative Planning." *Journal of the American Planning Association* 64(1), 52-63.

Kavakli, M., Scrivener, S. A. R. & Ball, L. J. (1998). " The Structure of Sketching Behaviour." *Design Studies* 19(4), 485-518.

Kyng, M. & Mathiassen, L., Eds. (1997). *Computers and Design in Context*. Cambridge, MA, MIT Press.

MacIntyre, B., Mynatt, E. D., Voida, S., Hansen, K. M., Tullio, J. & Corso, G. M. (2001). Support for Multitasking and Background Awareness Using Interactive Peripheral Displays. ACM Symposium on User Interface Software and Technology, Orlando, FL, Association of Computing Machinery.

Nunamaker, J. F., Dennis, A. R., Valacich, J. S., Vogel, D. R. & George, J. F. (1991). "Electronic Meeting Systems to Support Group Work." *Communications of the ACM* 34(7), 25-32.

Richardson, T., Q. Stafford-Fraser, K. R. Wood, and A. Hopper. (1998). Virtual Network Computing. *IEEE Internet Computing*. 2, 1: 33-38.

Román, M., C. K. Hess, R. Cerqueira, A. Ranganathan, R. H. Campbell, and K. Nahrstedt. 2002. Gaia: A Middleware Infrastructure to Enable Active Spaces. *IEEE Pervasive Computing*, pp. 74-83, Oct-Dec 2002

Schon, D. A. & Wiggins, G. (1992). "Kinds of Seeing and Their Functions in Designing." *Design Studies* 13(2), 135-156.

Shiffer, M. J. (1992a). A Hypermedia Implementation of a Collaborative Planning System. *Urban and Regional Planning*. Urbana, IL, University of Illinois at Urbana-Champaign**,** 185.

Shiffer, M. J. (1992b). "Towards a Collaborative Planning System." *Environment and Planning B: Planning and Design* 19, 709-722.

Star, S. L. (1989). The Structure of Ill-Structured Solutions: Heterogenous Problem-Solving, Boundary Objects and Distributed Artificial Intelligence. In M. Huhns &L. Gasser (Ed.), *Distributed Artificial Intelligence 2*. Menlo Park, CA, Morgan Kauffmann**:** 37-54.

Stefik, M., Foster, G., Bobrow, D., Kahn, K., Lanning, S. & Suchman, L. (1987). "Beyond the Chalkboard: Computer Support for Collaboration and Problem Solving in Meetings." *Communications of the ACM* 30(1), 32-47.

Streitz, N. A. (2001) ambiente: Workspaces of the Future. May, 2001 (http://www.darmstadt.gmd.de/ambiente/

Streitz, N. A., Geißler, J., Holmer, T., Konomi, S., Müller-Tomfelde, C., Reischl, W., Rexroth, P., Seitz, P. & Steinmetz, R. (1999). i-LAND: An interactive Landscape for Creativity and Innovation. ACM Conference on Human Factors in Computing Systems (CHI'99), Pittsburgh, Pennsylvania, USA.

Suwa, M., Gero, J. S. & Purcell, T. (1998). "Macroscopic Analysis of Design Processes Based on a Scheme for Coding Designer's Cognitive Actions." *Design Studies* 19(4).

Twidale, M.B. (2002). Over the shoulder learning: supporting brief informal learning. Submitted to Computer Supported Cooperative Work: The Journal of Collaborative Computing

Scaife, M., Halloran, J., and Rogers, Y. (2002) 'Lets work together: Supporting two-party collaborations with new forms of shared interactive representatons'. Proceedings of COOP '02, International Conference on Cooperative Systems Design, 123-138.

Pinelle, D., Gutwin, C., and Greenberg, S. (2003) Task Analysis for Groupware Usability Evaluation: Modeling Shared-Workspace Tasks with the Mechanics of Collaboration. *To appear*, *Transactions on Computer Human Interaction (TOCHI)*

Woods, D. D. (1986). Paradigms for Intelligent Decision Support. In E. Hollnagel, G. Mancini &D. D. Woods (Ed.), *Intelligent Decision Support in Process Environments*. New York, NY, Springer-Verlag, 1986.