Chapter 11

Groupware and Computer-Supported Cooperative Work

Computer-supported cooperative work or CSCW (Greif, 1988; Baecker, 1993) is computer-assisted coordinated activity carried out by groups of collaborating individuals. Examples of such activities include communication, problem solving, and coauthoring a document. CSCW seeks to become a scientific discipline guiding the thoughtful and appropriate design and development of *groupware*, the multiuser software that supports such activities. Groupware has been defined by Malone (cited in Coleman and Shapiro, 1992) as "information technology used to help people work together more effectively."

There is controversy over the definition of groupware. Some investigators include network file servers, some include data base software, some include electronic mail, and some include none of these. One view is that of Lynch, Snyder, and Vogel (1990, p. 160), who write:

> *Groupware is distinguished from normal software by the basic assumption it makes: groupware makes the user aware that he is part of a group, while most other software seeks to hide and protect users from each other. . . . Groupware . . . is software that accentuates the multiple user environment, coordinating and orchestrating things so that users can "see" each other, yet do not conflict with each other.*

The term *groupware* was coined by Peter and Trudy Johnson-Lenz (1982, p. 47), who defined it to be "intentional GROUP processes and procedures to achieve specific purposes" plus "softWARE tools designed to support and facilitate the group's work." Their early and insightful paper included discussions of structured communication forms such as messaging, conferencing, filtered exchanges, relational structures, voting, and decision support tools.

Today, groupware is a distinct product category and market, yet by the year 2000 many or most software tools will probably be "group aware," supporting coordinated group activity in addition to the use by individuals that is more conventional now.

The phrase "computer-supported cooperative work" was coined by Irene Greif and Paul Cashman in 1984 in the call for an invitation-only workshop on CSCW held in Cambridge, Massachusetts. The much-heralded "office automation" efforts of the 1970s and early 1980s were falling far short of expectations, and this was part of a recognition that it would be useful to bring together people from diverse disciplines—technical, social, economic—who shared an interest in issues of communication and coordination.

Thoughtful introductions to CSCW are found in Ellis, Gibbs, and Rein (1991), Bannon and Schmidt (1991), Robinson (1991), and Grudin (1994a). These papers debate the definition and nature of CSCW. They examine hardware and software technologies; design issues; lessons from experience; system descriptions; the nature of group work; core concepts and issues; differences in focus in Europe, America, and Asia; and analyses of the backgrounds and priorities of the diverse people who work in CSCW.

Greenberg (1991) notes that the term *computer-supported cooperative work* may be misleading: we study technologies *other than the computer*, the technology can *disrupt* activities of individuals while assisting the group overall, they support *competition* as well as cooperation, and they can assist *casual and social interactions* as well as those more typically thought of as work. Independent of what CSCW is or should be, we adopt in this chapter the pragmatism of Bannon, Bjorn-Andersen, and Due-Thomsen (1988):

> *We believe that for the moment the name CSCW simply serves as a useful forum for a variety of researchers with different backgrounds and techniques to discuss their work, and allows for the cross-fertilization of ideas, for the fostering of multi-disciplinary perspectives on the field that is essential if we are to produce applications that really are useful.*

"Forum" is indeed a nice metaphor: People come from different places with different priorities to examine the work of others with an eye to what might be useful, then return home. There is no expectation of a common goal or even a common language, and with participants from HCI, management information systems, software engineering, social science, and computer science backgrounds, to name a few, much diversity and some confusion are unavoidable.

A PARADIGM SHIFT FOR COMPUTING

Groupware and CSCW represent a paradigm shift in computer use. *Human-human* interaction rather than *human-machine* interaction is the primary focus; the computer facilitates human communication rather than acting as a purely computational device.

This paradigm shift results from several converging phenomena:

- Pervasive networking that enables widespread computer-based interpersonal and data communications
- The extension of personal computing technology to support small group productivity, sometimes known as *work-group* computing
- The maturing of technology developed by information systems researchers to support executive and managerial group decision making
- The merging of telecommunications and computing, as telecommunications companies seek new applications such as videoconferencing that exploit bandwidth
- The growing interest in telecommuting and work at a distance
- The introduction of new technologies and standards, such as ISDN (the Integrated Standard Digital Network)

Hence groupware use is now widespread and growing rapidly.

Electronic mail (e-mail), the most successful CSCW technology, is the topic of this chapter's first reading (Sproull and Kiesler, 1991a). Structured electronic mail, in which messages are often organized by topic and discussions sometimes mediated by a convenor, is called *computer conferencing* (Hiltz and Turoff, 1993). (Netnews, newsgroups, and electronic bulletin boards are other terms used for these increasingly popular forms of communication.) With the convergence of telecommunications and computation, CSCW can incorporate *teleconferencing*, the use of audio and video links while conferring at a distance.

The computer can also facilitate joint problem solving rather than communication per se, as, for example, in systems for *collaborative writing or drawing* (Sharples, 1993; Greenberg, Haynes, and Rada, 1995). Departments of management information systems (MIS) in schools of management or business study problem solving directed at issue organization and decision support, using the term *group decision support system* (GDSS). A key element in GDSSs is the *electronic meeting room*.

Thus, CSCW systems can integrate *shared interpersonal communication spaces* with *shared task workspaces* (Buxton, 1992) and support work that occurs both synchronously and asynchronously. Groupware technology expands the concepts of meeting and of collaborative work, allowing participants to transcend the requirements of being in the same place and working together at the same time.

Much groupware is designed for relatively small groups. Yet technologies such as electronic mail and conferencing systems can facilitate the synergistic functioning of large numbers of individuals. We shall consider systems and applications both for *groups* and for *organizations*, although we will emphasize the former.

A CSCW TAXONOMY

De Sanctis and Gallupe (1987) presented a broad typology of group support systems, subsequently refined by Johansen (1988) into the widely used 2-by-2 matrix shown in Figure 11.1. This typology differentiates groupware technologies in terms of their abilities to bridge time and to bridge space. Group members may work together at the same time, or work whenever they please. They may meet in a single room, or be on different floors, buildings, cities, or continents. Sample applications are included in each quadrant of Figure 11.1. The different activities create different technical challenges for the people who build tools to support them. Use of the tools also gives rise to different social and behavioral challenges.

FIGURE 11.1

Time and space-based views of CSCW technologies.

	One meeting site (same places)	**Multiple meeting sites (different place)**
Synchronous communications (same time)	**Face to Face Interactions** • *Public computer displays* • *Electronic meeting rooms* • *Group decision support systems*	**Remote Interactions** • *Shared view desktop conferencing systems* • *Desktop conferencing with collaborative editors* • *Video conferencing* • *Media spaces*
Asynchronous communications (different times)	**Ongoing Tasks** • *Team rooms* • *Group displays* • *Shift work groupware* • *Project management*	**Communication and Coordination** • *Vanilla e-mail* • *Asynchronous conferencing, bulletin boards* • *Structured messaging systems* • *Workflow management* • *Version control* • *Meeting schedulers* • *Cooperative hypertext, organizational memory*

Extensions of this widely used taxonomy have been proposed. De Sanctis and Gallupe (1987) placed a greater emphasis on differences in group size. Nunamaker et al. (1991) also differentiated between multiple individual sites and multiple group sites. Grudin (1994a) refined both time and place dimensions to include *same, different but predictable,* and *different and unpredictable,* reasoning that supporting an activity that is restricted to a few sites or a limited period of time creates different constraints than more open-ended activity.

These taxonomies can be useful, but most real work involves activities centered in more than one cell. The activity in a meeting is linked to earlier activities that may have been physically dispersed. A system that does not provide capabilities from several quadrants can create problems—participants in a meeting may expect a computer system there to be networked to the computers in their office to retrieve material worked on at a different time, for example. Thus, systems are moving toward "any time, any place" support. Nevertheless, this taxonomy is useful as a way to present and remember the different activities and applications in the world of groupware. We shall use it in this chapter, considering first asynchronous and then synchronous groupware.

ASYNCHRONOUS GROUPWARE

Asynchronous groupware supports communication and problem solving among groups of individuals who contribute at different times, and typically also are geographically dispersed. We consider three categories of approaches:

- Electronic mail and computer conferencing systems
- Structured messaging systems that use rules or knowledge to process mail, perhaps helping to manage and coordinate the flow of work within an organization
- Cooperative hypertext and hypermedia systems for constructing data bases and knowledge repositories that serve as *organizational memories*

Electronic Mail and Computer Conferencing

Electronic mail is arguably the most successful form of groupware developed and deployed to date. It is asynchronous, fast, can be addressed to multiple receivers, and has a built-in external memory that can be processed by computer (Sproull, 1991). Although e-mail has typically consisted only of text, increasingly it is multimedia, incorporating static images, voice, and even video (Borenstein, 1993).

The original intent of electronic mail was to facilitate point-to-point communication, very much like conventional surface mail (also called "snail mail"), but with greater speed and efficiency. Because e-mail can be addressed to multiple receivers, the identical base technology can facilitate discussion by groups or networks of individuals. This technology, variously known as *computer conferencing systems* or *electronic bulletin boards (bboards),* organizes user access and message transmission by topic or time rather than by the names of individual recipients (Kerr and Hiltz, 1982; Hiltz, 1984; Hiltz and Turoff, 1993; Hiltz, 1994). Bulletin board messages are usually organized by *time*; the emphasis is on the broadcasting of information to a community of interest. Conferencing system messages are usually organized by *topic*; the emphasis is on the dialogue that is facilitated among members of a community. Sometimes *distribution lists* are used to route messages to individual electronic mailboxes; at other times, users must access a central repository.

Many organizations have internal e-mail facilities. A rapidly increasing number, though, permit access to the global Internet, which distributes individual e-mail as well as thousands of topically arranged *newsgroups.* Thousands of local community bboards exist, often operated out of a person's home. Major private providers of e-mail and bulletin board facilities, such as Compuserve, Prodigy, and America OnLine, serve millions of people. All of these now have "gateways" to the Internet, allowing messages to flow back and forth to a potential community of tens of millions of individuals (see Chapter 14).

Thus, e-mail enables not only faster and efficient communications, but connections and linkages that were not heretofore possible and that "change the conventional patterns of who talks to whom and who knows what" (Sproull and Kiesler, 1991a, p. 116). The reading by Sproull and Kiesler sketches how computer networks can significantly change the structure of organizations and the conduct of work. They report recent results from laboratory experiments and field studies.

One series of laboratory studies investigated how electronic messaging affects group work (Sproull and Kiesler, 1991b; Kiesler and Sproull, 1992). In these experiments, computer-mediated small group decision making typically involves longer decision times, more equal participation, more difficult consensus-building processes, and more willingness to choose risky options than do face-to-face meetings. In interpreting this result, keep in mind that the richness of face-to-face interactions is lost in the limited interaction possible in text-based computer conferencing.

A significant role of electronic communications (described in detail in Chapter 5 of Sproull and Kiesler, 1991b) is in increasing the informational and emotional connections of employees, particularly those who are "peripheral," geographically or hierarchically distant from the center of activity. A field study summarized by Sproull and Kiesler and described in more detail in Eveland and Bikson (1988) illustrates this phenomena. Matched groups of active workers and retirees spent a year planning a company's retirement policy. One group had the option of using electronic communication; the second task force did not. The electronically supported group developed a structure that achieved greater breadth of access and a greater opportunity to lead or participate. They also maintained a higher degree of contact than the other group, felt more involved in the work of the group, and reported less communication isolation.

A broader treatment of the use and impacts of electronic mail and computer conferencing is the book *Connections* by Sproull and Kiesler (1991b). The book covers issues such as the coordinating effects of computer-mediated communications (CMC), "electronic etiquette" in CMC, changes in group dynamics between face-to-face meetings and electronic meetings, the role of CMC in allowing employees at an organization's periphery to feel connected, and the problems of authority, control, and influence that arise through the use of CMC.

Problems of authority and control are also highlighted in a paper by Perin (1991), who shows how CMC can create *electronic* *social fields* that challenge and stress conventional bureaucratic structures within organizations. A classic case of this documented by Zuboff (1988, Chapter 10) is that of "DrugCorp," where enthusiastic use of CMC for "access to information, thoughtful dialogue, and social banter" seriously threatened management when the content of supposedly closed conferences became public knowledge. The eventual result was the demise of the system's vitality. Clearly, e-mail can be a powerful technology for challenging and possibly transforming the patterns of communication and methods of control in an organization.

Structured Messages, Agents, and Workflow

The dramatic success of e-mail has also led to a number of problems such as an overabundance of e-mail, the receipt of large quantities of unwanted electronic "junk mail," and the inability to find needed information in huge data bases of conference messages. Structured messaging systems represent an attempt to provide users with better methods of organizing, classifying, filtering, and managing messages. One goal is the creation of "intelligent" messaging systems in which useful tasks are delegated to computer processes typically known as agents (see Chapter 12). In some cases the role of messages is to define, embody, and manage workflow in a corporation.

Malone and his coworkers (Malone et al., 1987a, 1987b, 1989; Malone, 1987 video) developed the Information Lens as an environment for intelligent e-mail management using *semistructured messages*, and methods for mail management via the specification of rules for processing messages. They later generalized the Information Lens to allow the description of cooperative work procedures other than electronic mail. Object Lens (Lai, Malone, and Yu, 1988) and Oval (Malone, Lai, and Fry, 1992) enable unsophisticated computer users to create their own cooperative work applications using simple, powerful building blocks. These include the representation of things in the world as semistructured *objects* with template-based interfaces, the summarizing of collections of objects in customizable *views*, and the development of rule-based agents for performing active tasks for people without requiring their attention or direct intervention.

Two other generalizations of the message concept have recently gained popularity. *Multimedia mail* (see also Chapter 13) allows data other than text, such as images, audio (see IBM, 1985 video), and video, to be sent over a network. Freestyle (see Wang Labs, 1989 video), discussed in Case C, was an early pioneer in this area. A popular modern standard is MIME (Multipurpose Internet Mail Extensions) that uses the standard Internet mail carrier (Borenstein, 1993). *Computational mail* is "the embedding of programs within electronic mail messages" (Borenstein, 1992). The resulting *active messages* can carry out particular interactions with recipients in addition to transmitting information (Borenstein and Thyberg, 1991; Goldberg, Safran, and Shapiro, 1992).

One way in which interdependencies among coworkers are managed and mediated and coordination is achieved is through language. A *language/action perspective* on the design of cooperative work has been presented by Winograd (1987–1988). Winograd defines *conversation* "to indicate a coordinated sequence of acts that can be interpreted as having linguistic meaning." A request, for example, can be followed by accepting that request, or by declining, or by making a counteroffer. Each of these conversation steps is followed by other steps in a "conversation for action." Flores et al. (1988) explain the language/action perspective—their theory of "language as social action" and show how it was made the basis for an early commercial groupware product (The Coordinator).

The language/action perspective was very influential, and work on such systems continues (De Michelis and Grasso, 1994). It has, however, touched on a key controversy in CSCW, and in HCI more generally. Information must be formally represented in a system if the system is to act on it intelligently, yet it is unclear how much of our tacit understanding of the world can usefully be represented formally. When is a formal representation a simplification, and when is a simplification more of a hindrance than a help? Perhaps no other groupware application has been as controversial in this regard as The Coordinator (e.g., Bowers and Churcher, 1988; Bannon and Schmidt, 1991; Robinson, 1991). See Suchman (1994) and Winograd (1994) for a debate on this topic, which is to be commented upon by others in the journal *CSCW* in 1995. The larger issue of the limits to the usefulness of formally representing knowledge also influences the discussion of workflow systems and organizational memories noted below, and is central to the discussion of critics, agents, and other intelligent interface support in Chapter 12.

Recently, more comprehensive systems for workflow management within organizations have been proposed and built (Medina-Mora et al., 1992). Because speech act structures must be tailored to different group needs and organizational flavors, toolkits have been developed that allow particular conversational structures to be specified, e.g., Strudel (Shepherd, Mayer, and Kuchinsky, 1990), Oval (Malone, Lai, and Fry, 1992), and the Conversation Builder (Kaplan et al., 1992). Workflow systems are apparently succeeding in application domains marked by fairly routinized activity, but are only beginning to be discussed in the CSCW research literature (e.g., Abbott and Sarin, 1994).

Cooperative Hypertext and Organizational Memory

In e-mail, the focus is on the process of messaging; in workflow processing, the focus is on messages that define process. Yet some applications focus instead on the corpus of messages or other computer documents and their interrelationships. They may then best be described as *cooperative hypertext systems*, in which a web of complex information is recorded and structured into a hypertext (see Chapter 13). Applications of such systems include collaborative knowledge building, asynchronous collaborative writing, and creating an *organizational memory*.

For example, Schatz (1991, 1991–1992) considers how to enhance the process of cooperative knowledge building in carrying out scientific research. The goal of the Community Systems project is to build an electronic scientific community by collecting "all" of a community's scientific knowledge into a digital library and then making it transparently available and manipulable over nationwide networks. The Telesophy system is being used by a community of 500 researchers studying the nematode worm *C. elegans*, a model organism in molecular biology.

Conklin (1992) proposes stronger criteria for organizational memory, arguing that organizations must shift from a document-and artifact-oriented paradigm to one that embraces *process* as well. He suggests that this can be done with software that integrates three technologies—hypertext, groupware, and a *rhetorical method*, such as the *Issue-Based Information System (IBIS)*. The rhetorical method can improve the quality of the dialogue process within an organization by providing a structure for the discussion of complex problems, and it can provide an improved "conversational record" in which conversations are structured according to issues instead of chronology. IBIS development and use is described in Conklin and Begeman (1988), Burgess Yakemovic and Conklin (1990), and Conklin and Burgess Yakemovic (1992). Of course, organizational memory can be applied by HCI professionals to the interface design process; the notion of preserving the design rationale of what was tried, what succeeded, and what did not was discussed in Chapter 2 of this book (see also Carroll et al., 1994 video).

IBIS systems are another example of structuring information to facilitate its processing. A lively debate over the utility of organizational memory was held at the CSCW '94 Conference. The positions are briefly summarized on pp. 445–446 of the proceedings.

Lotus Notes is, in the mid-1990s, the most successful organizational memory product, and arguably one of the most successful groupware products developed to date (Kirkpatrick, 1994). Notes is "an integrated communications and data base network application, designed to gather, organize and distribute information among work groups, regardless of individual members' physical locations" (Connor, 1992). It is also "a platform for developing workgroup applications" (Marshak, 1990). Notes can be used for message routing, report distribution, idea discussion, and for the tracking and management of projects, sales leads, and customer support information. Notes achieves this through the use of a replicated data base algorithm designed for an environment in which servers are "rarely connected" (Kawell et al., 1988). How long information is retained in a Notes application will vary; it can thus be used for ephemeral discussions and is also a reasonable long-term repository in many environments.

The most substantial and longest-term use of Notes other than at Lotus itself has been at Price-Waterhouse (PW). Laube (1992), the PW chief information officer, states that three major business issues confronting their corporation motivated the purchase of tens of thousands of Notes licenses:

- Nobody knew who had the knowledge needed to solve a particular problem.
- Price Waterhouse professionals were constantly reinventing the wheel, solving, on a worldwide scale, the same problems over and over again.
- There was a need for better communications throughout the corporation.

Unlike many technology adoptions, Notes at Price Waterhouse was introduced from the top down rather than from the bottom up, resulting in virtually 100% penetration among the roughly 1,000 partners. The following impacts were predicted by Laube (1992):

- Retention of knowledge, a "filing cabinet in the sky"
- Support for global collaboration and global discussions
- Enhanced communication

The reading by Orlikowski (1992) included in Chapter 3 presents a less enthusiastic view. She analyzes the adoption of Notes by "Alpha Corporation" in terms of the mental models of Notes users and the incentive structure and workplace norms found in the organization. Her study took place in the initial months of the introduction of Notes into Alpha, and therefore may not characterize long-term sustained use in that setting, but it points to the importance of cognitive and motivational factors in groupware use and adoption.

SYNCHRONOUS GROUPWARE

Our second major collaboration technology category is *synchronous* groupware, software that assists a group of individuals in working together *at the same time* to carry out a task such as making a decision, planning a new initiative, structuring a proposal, writing a paper, or sketching a design. The goal of achieving a *shared digital workspace*, allowing collaborators at different workstations to examine and edit a shared view of a document, typically leads to a style of interface and to a set of implementation problems that distinguish synchronous systems from asynchronous ones.

Synchronous groupware can be subdivided into four classes:

- Desktop conferencing systems, which are workstation-based applications for collaborative work at a number of desktops, for example, outlining, writing, sketching, drawing, or building a spreadsheet
- System infrastructure for supporting and implementing desktop conferencing across workstations, for example, via shared screens or shared windows
- Electronic meeting and decision rooms such as group decision support systems
- Media spaces that include computer-controlled audio-visual networks and virtual meeting environments

Desktop Conferencing Systems

One of the earliest demonstrations of a desktop conferencing system was the NLS shared-screen conferencing system (Engelbart and English, 1968, 1994 video). Originally intended for augmenting face-to-face interactions, it was later expanded to support distance conferencing. The idea was simple: all participants saw the same things on their screen (a "shared view"), and each could take turns interacting with the system.

The next milestone in desktop conferencing was Xerox PARC's Colab project, which contained a variety of synchronous multiuser interfaces (Stefik et al., 1987; Xerox PARC, 1988 video; Stefik et al., 1987; Tatar, Foster, and Bobrow, 1991). Tools for collaborative brainstorming, argument development, and freestyle sketching were used by small groups of two to six individuals working in the Collaboration Laboratory meeting room. Each individual had a workstation that was linked to all other workstations, and to a large touch-sensitive screen at the front of the room.

While Colab was designed for face-to-face meetings, many of its ideas are highly relevant to distributed desktop conferencing. For example, a central theme is *WYSIWIS (What You See Is What I See)*, an idealization of multiuser interfaces in which everyone sees exactly the same image of the shared meeting workspace and can see where everyone else is pointing. WYSIWIS is axiomatic to screen-sharing approaches, but more general multiuser interfaces often relax the abstraction consciously to allow for private workspaces and individual activities that need not be in lockstep with the group.

Since then, there has been an explosion of work on desktop conferencing systems. All CSCW collections contain readings and system descriptions relevant to desktop conferencing. Greenberg, Haynes, and Rada (1995) is a specialized collection focusing on groupware systems for real-time drawing. (See also Bier, Freeman, and Pier, 1992 video; Greenberg et al., 1992 video.)

A detailed example of one desktop conferencing tool is offered by Baecker et al. (1993), included as a reading in this chapter. It documents the design of a collaborative writing tool that supports both synchronous and asynchronous work over local and wide area networks, and that allows both WYSIWIS and decoupled views of a document. Design of their system, called SASSE, is an excellent example of following the user-centered, iterative process described in Chapter 2. It was informed by interviews with writers who had worked together collaboratively (Posner and Baecker, 1992) and by a laboratory study of writers working on a specific task using a variety of tools and communications media. It consisted of repeated cycles of design, implementation, and user testing. (See also Baecker et al., 1994 video, and Egido et al., 1987 video.)

System Infrastructure for Desktop Conferencing

There are two general approaches to building groupware. *Collaboration transparency* describes a single-user application wrapped by special system software to make it usable by a group (Lauwers and Lantz, 1990). A *collaboration-aware* system requires an application to be significantly modified or rewritten from scratch. Both approaches raise serious design and implementation issues. Implementing synchronous groupware across a network forces one to deal with difficult problems in distributed processing such as keeping replicated information consistent, creating and maintaining real-time consistent views of a shared digital workspace, and dealing with subtle issues of synchronization and concurrency control (Greenberg and Marwood, 1994).

The most straightforward way of enabling the synchronous collaborative use of interactive software is to provide a collaboration-transparent mechanism that distributes the display of a conventional single-user application program to multiple workstations and that accepts input from any one of the workstations as the program's input. This requires running the program on each of the workstations under control of a *screen sharing* system (Greenberg, 1990; Crowley, 1992).

An alternative to screen sharing is *window sharing*, which has the advantage that users can continue to work in their private workspaces while collaborating within a window that represents the public workspace. Useful papers discussing this approach are Ahuja, Ensor, and Lucco (1990; see also AT&T Bell Labs, 1989 video); Crowley et al. (1990), Lauwers et al. (1990), and Lauwers and Lantz (1990). Many of these authors discuss the advantages and disadvantages of a *replicated architecture* versus a *centralized architecture* for building desktop conferencing systems.

Shared-view systems, whether screen or window sharing, leverage existing software into groupware: off-the-shelf products can thereby be used for desktop conferencing. This major benefit comes with two serious limitations. First, because the shared software application is collaboration-transparent (i.e., thinks only one person is using it), the system offers limited "group" capabilities. This often forces the group to work around the system. For example, participants cannot work simultaneously, and must take turns interacting with the display. The second problem is technical. To make applications shareable, builders must "work around" the limitations of the operating system and application infrastructure. As a result, many collaboration-transparent systems are designed to meet technical rather than user needs, tend to have performance limitations, are buggy, or are missing essential usability features.

Increasingly, researchers are moving beyond the investigation of operating system issues for supporting groupware to the design and construction of environments, toolkits, and languages for building groupware. The GroupKit system (Roseman and Greenberg, 1992; Greenberg and Roseman, 1994 video), which directly supports the implementation of real-time groupware, is discussed and reprinted in Chapter 5 of this book.

A second toolkit for this domain is Rendezvous (Patterson et al., 1990; Patterson, 1991; Hill, 1992; Hill et al., 1993; Rohall, Patterson, and Hill, 1992 video; Brinck, 1992 video). A third approach to the design of a language and system for programming both collaboration-transparent and collaboration-aware multiuser programs is described in Dewan and Choudhary (1991a). The kind and degree of sharing or *coupling* among various views displaying a shared workspace is treated in some depth in Dewan and Choudhary (1991b) and Dewan (1992 video). Dourish (1995) examines requirements for systems to facilitate customization and application evolution.

Electronic Meeting and Decision Rooms

Synchronous groupware differs as to where the collaborators are located. Decision support systems usually involve individuals working in an *electronic meeting room*, where the activity may be carried out independently "in parallel" or may involve a common focus of attention and discussion. (But see Zachary, 1988, for a view of decision support that stresses the role of computation rather than interpersonal communication to aid human decision making.)

Meeting support systems are an unusual category of groupware in that the pioneering early work was done not in computer science departments or product development companies but in schools of management and business schools (Kraemer and King, 1988). This community has long referred to meeting support software (often in conjunction with other groupware) as *group decision support systems* (GDSS). The name derived from the fact that decision making was seen as the main activity of the principal customers of this work, executives and upper corporate or governmental management. More recently, these systems have been generalized and are often called group support systems and electronic meeting rooms.

GDSS systems have tools to facilitate idea generation (brainstorming), idea organization, prioritizing, and voting (Bostrom, Watson, and Kinney, 1992; Jessup and Valacich, 1993). Often participants contribute ideas and vote anonymously, a technique that encourages participation from those who might otherwise be too shy or too intimidated to speak up. Dennis et al. (1988), Valacich, Dennis, and Nunamaker (1991), and Nunamaker et al. (1991) describe these systems and studies of their impacts.

Architectural and ergonomic design was applied to electronic meeting rooms in the Capture Lab (Mantei, 1989; Elwart-Keys et al., 1990; Austin, Liker, and McLeod, 1990) and in the Hohenheim CATeam Room (Ferwagner et al., 1989; Lewe and Krcmar, 1990). Aspects of room layout, the placement of people in the meeting room, and the method of user participation in the meeting can affect the effectiveness and usability of the entire system. The interior design and colors of the room, the shape of the table, the position of the workstations with respect to the table, and the nature of the participants' chairs have a substantial effect on participant interactions.

Electronic blackboards or whiteboards (e.g., Begeman et al., 1986) have gone from being simply public displays to allowing interactive sketching, gesturing, and slide presentation (Elrod et al., 1992). Software that uses such a display is described by Pederson et al. (1993), a reading in Chapter 7.

Although use of these systems long lagged behind expectations for them (Kraemer and King, 1988), several companies began marketing products in 1989. Causing this turnaround, along with improved software and lower hardware costs, was a greater realization of the importance of stressing the process of use, as noted in our reading by Grudin.

Proponents of these systems have used them for a wide range of meeting types, but the ability to work in parallel and generate large lists has favored brainstorming applications. The more tedious task of idea organization has been attacked by using semantic analysis programs to make a first pass at clustering items. Although imperfect, it has been found that people enjoy this stage more when the software has made a first pass (Nunamaker and Briggs, 1994).

Media Spaces

In contrast to computer-supported meeting rooms are efforts to support synchronous problem solving by people in different locations. A *media space* is a computer-controlled teleconferencing system in which audio and video communication and shared digital workspaces are used to overcome the barriers of physical separation (Stults, 1986, 1988; Bly, Harrison, and Irwin, 1993). Media spaces support what Buxton (1992) calls a shared *interpersonal space* as well as a shared *task space*. They not only support an application in use, but give its users an awareness of who is around and how they can be reached (see also Cockburn and Greenberg, 1993).

Media spaces were investigated at Xerox PARC as a tool to support design, beginning in the mid-1980s (Stults, 1986, 1988; Xerox PARC, 1989 video; Harrison and Minneman, 1990; Bly, Harrison, and Irwin, 1993). Researchers concluded that video can reduce physical barriers (through transmission over a network) and temporal barriers (through recording and playback). Designers can learn quickly to make effective use of video as an alternative to face-to-face interaction and as a means of sharing a workspace.

The first geographically distributed media space designed for cooperative work applications was created by Xerox PARC when it established a remote laboratory in Portland, Oregon, in the mid-1980s and linked the two sites with audio and video communication over a 56-kilobit-per-second leased line (Abel, 1990; Olson and Bly, 1991). The central feature of the connection was a *video window* between the commons areas at the two sites. This was later supplemented with a computer-controllable video network that connected most locations in both sites. Although somewhat crude, the media space produced enough cohesion for the two labs to function and feel like one group and to convey a sense of "presence" of remote individuals. On the other hand, certain verbal and nonverbal cues were not transmitted as well as they would be in a face-to-face situation. This resulted in the need to alter social protocols, to supplement video meetings with occasional face-to-face meetings, and to be sensitive to issues of privacy.

The recent media space work of Hiroshi Ishii has been particularly significant because of its innovation, its immediate appeal to audiences, and its attention to the finer issues of collaborative interaction. The evolution of this work is documented in Ishii (1990); Ishii and Miyake (1991); Ishii and Kobayashi (1992); Ishii, Arita, and Kobayashi (1992 video); Ishii, Kobayashi, and Grudin (1993); Ishii, Kobayashi, and Arita (1994); Ishii (1994 video).

Ishii's early work on TeamWorkStation demonstrates the potential for special-purpose hardware to visually combine the displays of shared digital workspaces with the displays of drawing surfaces and desktop materials. Following Stefik's suggestion (Xerox PARC, 1988 video) of the importance of *seamlessness* between individual and group work, Ishii suggests that it is of equal importance to eliminate the seam between a computer application and work without a computer, using paper, pens, and pencils on a desktop. TeamWorkStation achieves this by overlaying translucent workspace images—live video analog images of computer screens and physical desktop surfaces. The computer screen, which is also overlaid, is itself a shared screen, combining windows from individual collaborators.

TeamWorkStation creates a shared interpersonal space using small windows displaying a live video image of one's collaborator, but there is a "seam" between the video window and the task windows. With his ClearBoard system, Ishii removes that seam, achieving "a smooth transition between face-to-face conversations and shared drawing activities." The ClearBoard metaphor is "talking *through* and drawing *on* a *transparent glass window*." By using half-silvered mirrors and polarizing filters, the collaborator's image appears as though behind the display, permitting direct eye contact and an awareness of the direction of the partner's gaze at the objects on the display that appears to be between the two people.

A team at Keio University has adopted another approach to achieving direct eye contact and awareness of gaze direction using a technique that permits more than two collaborators. An arced screen behind each user's desk has a surface that reflects images of remote participants projected from above and behind the user, while allowing cameras behind the screen to record the user and project images to remote participants (Okada et al., 1994). The net effect is remarkably like sitting across one's desk from two or more collaborators.

Other notable media space work has been carried out in the University of Toronto CAVECAT project (Mantei et al., 1991; Mantei and Louie, 1994 video; Sellen, Buxton and Arnott, 1992 video); at Xerox EuroPARC (Gaver et al., 1992); at Bellcore (Bellcore, 1989 video; Cool et al., 1992; Fish et al., 1993; Bellcore

Information Networking Research Laboratory, 1993); and at SunSoft (Isaacs, Morris, and Rodriguez, 1994; Tang, Isaacs, and Rua, 1994; Tang and Rua, 1994 video). (See also Koved, 1992 video; Ropa and Ahlström, 1992 video; University of Maryland, 1993 video; Dybvik and Lie, 1994 video; Pankoke-Babatz, 1994 video; Tani et al, 1994 video.)

Much of this work has involved exploring different interface metaphors to handle these new forms of communication. Unfortunately, often it has involved colleagues whose offices were close, removing the need to make heavy use of the systems. Cruder technologies such as the Internet's MBONE (see Chapter 14) may achieve more use because they address the more severe connectivity needs of those who are geographically remote. When real-time connectivity cannot be established, applications such as video mail can be used instead (Magee, and Cox, 1992 video; Hopper, 1992 video). At Olivetti, media spaces have also been abetted with the use of active badges worn by participants, enabling the system and other users to locate an individual or automatically see who is in a room outside a camera's range (Hopper, 1993 video; Richardson et al., 1994 video; see also Chapter 14). In conclusion, media spaces in the year 2000 may be very different from those of today's research prototypes.

THE ADOPTION, DEPLOYMENT, AND USE OF GROUPWARE

It all sounds like wonderful technology, but will it be used? We have seen that success or failure of conventional single-user computer systems usually depends upon how accurately designers have satisfied the true needs of users and upon the skill and sensitivity with which the technology is deployed. This is proving to be even more true of groupware.

An influential paper by Grudin (1988) focused on three challenges in developing, deploying, and using groupware:

- Most groupware requires that all group members use the application, but not everyone benefits, thereby diminishing its prospects for success.
- Intuition is a less reliable guide in developing and selecting groupware than single-user applications.
- Evaluating groupware is more difficult than evaluating single-user applications because it must be studied in the field over a period of time (an attempt to extend traditional lab methods to groupware evaluation is found in van der Velden, 1992 video).

Our next reading, Grudin (1994b), extends these points to address five additional challenges:

- The need to reach a critical mass of users and avoid "prisoner's dilemma" problems (see also Markus, 1990)
- The difficulty of supporting existing social conventions and not disrupting social processes or threatening political structures
- The high degree of exception handling and improvisation that characterizes much group activity
- The challenge in designing features to be unobtrusive yet accessible when needed
- The requirement that groupware designers and developers think much more carefully about the processes of adoption and use than they have in the past

The eight challenges are illustrated with examples. For each of them, a contrast is made between the experiences of single-user application developers and those of large (mainframe) application developers. Approaches to meeting the challenges are outlined. The last challenge is further explored in Case C, which reviews the design and deployment of an innovative but ultimately unsuccessful groupware application.

Groupware is not the only information technology whose introduction depends critically upon the social and political context in which it is to be used and which in turn modifies the work environment after it is in use, as the discussion in Chapter 3 indicates. However, issues of group setting that made little difference to word processor designers, for example, may become crucial to those developing a coauthorship system.

The goal is to meet these challenges and provide support for ***all*** members of many groups and organizations, to overcome limitations of separation in space and in time. Yet the results will not necessarily be beneficial to all. Workflow management systems and ubiquitous video in the workplace raise serious issues of privacy and allow new kinds of workplace monitoring and control (e.g., Robinson, 1991, and Clement, 1994). There is perhaps inevitably a tension between using technology to augment individual capabilities and using it to reduce the workforce. Our lack of knowledge about existing work practices and the likely effects of new technology on these practices can stand in the way of success.

For these reasons, one important thread in CSCW has been studies of workplace activity—in some cases, workplaces into which new technology has been introduced, but in other cases, workplaces for which technology support is simply a possibility. Examples of such work, carried out by ethnographers, sociologists, and psychologists, include Bowers (1994); Rogers (1994); Blomberg, Suchman, and Trigg (1994); Bentley et al. (1992); and Xerox PARC (1989 video). Translating the findings of such studies into design is never easy (e.g., Blomberg et al., 1993). Yet we optimistically think that by becoming acquainted with a range of such studies, CSCW researchers and developers can better define the constraints acting on groupware design and create better infrastructures for supporting groups. Dourish (1995) is an interesting effort in this direction.

GUIDE TO FURTHER READING

CSCW conferences have been held in North America every two years since the first in Austin, Texas, in 1986 (Greif, 1986). The proceedings of all except the first—Suchman (1988), Halasz (1990), Turner and Kraut (1992), and Furuta and Neuwirth (1994)—are available from ACM Press. European conferences have been held on odd-numbered years since 1989. Selected papers from the first were published in Bowers and Benford (1991). Subsequent European CSCW conference proceedings are Bannon, Robinson, and Schmidt (1991) and De Michelis, Simone, and Schmidt (1993). Papers from three other relevant conferences are found in Olson (1989), Gibbs and Verrijn-Stuart (1990), and Hendriks (1991). The ACM-sponsored Conferences on Office Information Systems and Organizational Computing Systems also include many relevant papers. The annual ACM SIGCHI Conference invariably has sessions devoted to CSCW and groupware. There are also proceedings from trade-oriented groupware conferences (Coleman, 1992, 1993), which provide more detail on some topics than is available in the research literature, notably workflow management systems.

Greif (1988) was the first of several edited collections of major papers. As with so many aspects of modern computing, Doug Engelbart had one of the earliest visions of CSCW, and Greif reprints four of his papers. In the mid-1960s Engelbart demonstrated hypertext and hierarchically structured documents that could be accessed in shared workspaces and discussed over audio and video links. Greif includes influential papers mentioned in Chapter 1 of this book by Bush and Licklider, and then surveys work through the 1970s and mid-1980s, including reprints of eight papers from the out-of-print CSCW '86 Conference proceedings.

Subsequent edited collections include Galegher, Kraut, and Egido (1990); Greenberg (1991); Bostrom, Watson, and Kinney (1992); Marca and Bock (1992); and Baecker (1993). As of this writing, Baecker (1993) is the most recent collection of classic CSCW papers and book chapters. It includes over 70 selections. Included are reviews of all topics discussed in this chapter, as well as three additional topics: the behavioral foundations for CSCW (the psychology of groups, the sociology of organizations, the psychology of media, interaction analysis, and conversational analysis); case studies of cooperative work practice; and enabling technologies for groupware—networks, multimedia technology, windowing environments, hypertext, coordination theory, and distributed systems and concurrency control.

Other resources include an annotated bibliography of papers published through early 1991, included in Greenberg (1991). In addition, the conference proceedings are part of the on-line HCI bibliography described in the introduction to this book (hcibib@cis.ohio-state.edu). The "unOfficial Yellow Pages of CSCW," a description of over 400 experimental and commercial groupware systems, can be obtained by ftp from gorgon.tft.tele.no in pub/groupware or via Word Wide Web at URL http://www.tft.tele.no/cscw/.

The most relevant journals are *Computer Supported Cooperative Work* (Kluwer, first published in 1992); *Collaborative Computing* (Chapman and Hall, since 1994); and *Journal of Organizational Computing* (Ablex, since 1991). Special issues of *Communications of the ACM* devoted to CSCW are December 1991, January 1993, and January 1994, as is the June 1994 issue of *IEEE Computer*.

Reviews focused on specific groupware topics may have begun with Licklider and Vezza (1978), included in Greif (1988), a comprehensive and insightful review of the technical characteristics and political, social, and economic impacts of information networks. Turoff (1991) reviews the early history and significant developments in computer conferencing. Kraemer and King (1988) survey two decades of work on group decision-making support.

Myron Krueger (1991) reviews 25 years of his own pioneering work on media spaces. His Videoplace system, for example, linked the body movements of one individual with the hand movements of another in a collaborative video screen dance, thereby demonstrating compelling possibilities for computer-supported cooperative *play*.

Videos of CSCW systems can be found in several editions of the *ACM SIGGRAPH Video Review*, especially issues 87 and 106, which contain the video proceedings of the ACM CSCW '92 and '94 conferences, respectively.

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