A COMPUTER-MEDIATED STRUCTURED COMMUNICATIONS SYSTEM

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Submitted in partial fulfillment of the
requirements for the degree
of Doctor of Engineering Science
in the School of Engineering Science

Columbia University
1978

CHAPTER 1: INTRODUCTION

> We are optimistic about technological progress, and can envision computer systems that permit communication (voice and other) interspersed with data processing. On a 'conference telephone call', the third party would be a computer. Such a system would enhance, by orders of magnitude, the ability of people to interact and cooperate with one another in a manner both convenient and meaningful to each of the individuals concerned. - - - E. E. David, Jr. and R. M. Fano

1.1 Motivation

Digital computers have been used in telecommunications systems since the early 1960s, generally as process controllers. For example, a digital computer is used to control call switching in electronic telephone offices.[BST64] Only since the early 1970s, however, have researchers begun to explore the use of the computer's information storage, processing and retrieval capabilities as a channel capable of mediating communication among human beings. To understand the motivation for this recent work, it is helpful to review certain basic problems which arise in interpersonal communication in modern society.

As our social, political and industrial organizations continue to grow in size and become geographically dispersed, the problem of spatial separation becomes acute. Allowing people to communicate over distance has been the principal challenge of work in telecommunications during the last century.

The majority of our interpersonal interactions occur in the form of two-person conversations, and the ordinary telephone can often solve the problem of distance at very modest cost. Two-way telephone conversations are quite satisfactory for most purposes, despite the lack of non-verbal cues which we use to facilitate communication in face-to-face situations.[REI70]

As the complexity of our organizations grows, however, multiperson communications have become increasingly important. For example, public meetings of elected officials are considered an essential element of our political process. The open exchange of knowledge through courses, seminars, and other structures is fundamental to academe. In the contemporary technical and highly specialized industrial environment, pooling intellectual resources and collective decision-making are very important. The geographical distribution of large organizations has made the problem of spatial separation acute for such multiperson interactions. Finding a mutually convenient (or inconvenient) place for meetings is often difficult, and the travel involved places a burden on the time of the participants and exacts a cost in both financial and energy resources.

In recent years, many telecommunications media have been developed to overcome the problem of distance in multiperson meetings. Using standard equipment, telephone

conferences involving up to 30 locations can be held.[KUE69] At present, with commercial telephone systems, these must be set up through a special conference operator, who calls each party involved. This is a costly operation in comparison with directly-dialed two-person calls. However, conferences involving up to four parties can be dialed up directly by people served by the most modern telephone offices,[BST64] and military versions of the same equipment are used for direct dialing of even larger conferences.[GOR68]

Experiments with conference calls involving nine or more people have shown that they can be quite satisfactory to the participants; such problems as the identification of speakers and orderly access to the floor are not as serious as had been anticipated.[REM74,UNG73]

Video conferences would be more satisfactory in general, and where pictorial displays are required, such facilities are particularly important. But video conferences are quite expensive and awkward to arrange. This will undoubtedly remain the case for at least a decade. Less expensive techniques for conveying pictorial data in restricted forms are, however, becoming available: for example the remote blackboard[BTL74] and Scribblephone.[BED75]

Thus, the telephone plant now in existence and new facilities rapidly being brought on-line can be effectively used for many interpersonal interactions, both

two-person and multiperson. Where the main problem is the spatial separation of the participants this can be a very satisfactory solution.

A second basic problem which plagues communication in contemporary society is the need for synchronization. As the size of the group which wishes to interact increases, it becomes increasingly difficult to find a time which is mutually convenient for all concerned. A rather crude approach to this problem is typified by telephone-answering and dictation devices which have appeared in large numbers in recent years. Such devices are limited in both capability and storage capacity, and using them to buffer communications among a group of individuals would be especially awkward.

Recently, the digital computer system has been used to deal with the problem of synchronization as well as certain other problems to be discussed in the next section. The computer system buffers information entered by individuals from remote locations. It is used as an intelligent storage device into which individuals can write messages and "play back" those posted by others. Each participant can, at any time that he finds convenient, access the computer to review the status of the proceedings and add his own input as desired. Thus it is not necessary that all participants be available at the same time; their communication transpires asynchronously. Of course, since

the problem of synchronizing schedules becomes more acute as the group size increases, one expects asynchronous computer-mediated communication to have greatest utility for multiperson interactions such as conferences.* Although the ability to hold asynchronous discussions are a principal advantage of computer-mediated communication there are other beneficial characteristics which will be discussed in the next section.

Research into the social and human factors aspects of computer-mediated communiction is in its infancy. Preliminary experiments with such systems appear to have demonstrated their utility;[VAL75a] further social science research now under way[HIL77] will help to clarify their optimum role in our repertoire of telecommunication systems.

1.2 The Nature of Computer-Mediated Communication

Qualitative Aspects

As we have already indicated, one of the principal advantages of computer-mediated communication is the ability to solve both the problems of spatial and temporal

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* It is for this reason that the technique has been referred to in the literature as "computer conferencing" or "computer-based conferencing." However, these terms appear overly restrictive since there is nothing to prevent its use in two-person interactions or nonconference situations such as courses. Therefore we prefer to use the more general term "computer-mediated communication."

separation. Experiments with the FORUM system[VAL75a] have indicated that asynchronous communication is somewhat less efficient than communication in real-time, at least in terms of number of characters sent per unit time spent interacting with the system. In addition the elapsed time of asynchronous communication is relatively long. (Some computer-mediated conferences may never end, as new topics are introduced as old business is completed.) However, there are a number of unique, compensating characteristics.

The ability to compose and edit messages before they are communicated to others allows statements to be carefully prepared, resulting in a higher quality of discussion than occurs in many face-to-face meetings. Misunderstandings or misinterpretations due to "slips-of-the tongue" or poorly-formulated remarks are less likely to occur. Asynchronous communication also allows ongoing information exchange among a larger group of people than can be scheduled for ongoing face-to-face meetings; experiments with computer-mediated conferences among groups as large as 31 people over 4 months have been conducted.[VAL75a]

Computer-mediated communication is not well-suited to transmission of personality factors, a characteristic which is shared by most telecommunications media. This is not always a disadvantage, and in fact may be a significant advantage in situations requiring objectivity.

The use of text allows anonymous or pseudonymous communication, which may be useful to promote objective discussions on highly controversial subjects.

The asynchronous nature of participation can alleviate problems in conventional meetings which arise as a result of mismatches in the styles of the participants. Some individuals like to formulate their remarks slowly and deliberately, thus making others who think and speak quickly impatient. Some enjoy raising tangential issues, or listening to or relating humorous anecdotes, thus exasperating the more business-like, "get to the point" types. Computer-mediated communication makes it possible for each individual to operate according to his own style and at his own pace. Some may quickly scan through the conference record, select the entries they wish to consider in more detail, make their terse remarks and quickly conclude their session. Others might carefully consider all that has been said, ponder over each item, enjoy the digressions, perhaps even address some side remarks to particular colleagues and carefully compare their own additions. Both extremes can find satisfaction through the same medium.

Unlike conventional meetings, where topics are dealt with serially, computer-mediated conferences allow parallel discussion of all agenda items whose consideration is not dependent on the outcomes of as yet unresolved items. The power of the chairman is greatly reduced because there is

no need for rulings on who has the floor. In addition, where frequent meetings are inconvenient, chairmen are often assigned interim authority to make certain decisions. Such delegations are less necessary where computer-mediated conferences are used.

People with physical handicaps who find it difficult to get around easily are obvious beneficiaries of computer-mediated communication techniques. Those who are hard of hearing or who have speech impediments derive special advantages.

Modalities

As we all know, transducers capable of converting both acoustic and optical signals to electromagnetic waveforms and vice versa can be built at relatively modest cost. Through Nyquist sampling and A/D quantization, any waveform can be represented in digital form and the original waveform can be recovered through the reverse process. Furthermore, current computer mass storage devices are capable of operating at speeds necessary to accommodate Nyquist-sampled signals with bandwidths compatible with video signals. Thus it would appear that with current technology, computer-mediated communication can accommodate any of the telecommunications modalities provided through conventional media. Because all modalities - video, audio, graphical or textual - can be treated

uniformly in digital format, a computer-mediated communication system could handle all modes of input from a suitably sophisticated terminal device. An individual could employ whatever combination of video, audio, graphical or textual information seems most appropriate for a particular remark, store the information in the proceedings, and allow it to be retrieved and played back by others at their convenience!

In practice, however, the bandwidth requirements (and hence storage requirements) differ greatly for the different modalities, as well as the complexity of the transducers, encoders, etc.. These factors all influence what can be achieved with current technology at reasonable cost. To indicate what is possible in a relative sense, consider the storage costs which would be associated with the various modalities in a "state of the art" computer mediated communication system.

With good digital encoding techniques, television-quality pictures with little motion (typical of conferencing situations) can be represented using 1.5M bits/sec.[HAS77] Telephone-quality audio signals can be practically encoded using less than 10K bits/sec.[QUR75] In contrast, storage-tube graphics terminals can be driven satisfactorily at 1200 bits/sec while text can be transmitted faster than reading speed at 300 bits/sec. These bit rates can be very crudely translated into storage costs as follows.

Assume that computer-mediated proceedings are retained semi-permanently on a magnetic disk (current cost is about 10^{-3} ¢/bit). The permanent cost of storage per second of signal duration can then be calculated as 15 $/sec for video information, 10 ¢/sec for audio information, 1.2 ¢/sec for graphics, and .3 ¢/sec for text. Of course, numerous other factors such as wideband vs. narrowband transmission facilities, terminal equipment, and the efficiency of the various modalities in communicating information should also be considered, but we shall nevertheless draw some tentative conclusions based on the relative values of these costs. Textual and graphical data can be most efficiently handled by a computer-mediated communications system, and the cost of storage is rather modest. Storage of audio information is at least an order of magnitude more costly, but nevertheless cheap enough with current technology to allow short voice remarks to be used occasionally. Storage of video information is two orders of magnitude more costly than voice, and furthermore requires use of wideband transmmission facilities.

Thus in the near term, we expect computer-mediated communications systems incorporating textual, graphical and voice information to be practical; the addition of a video mode, while technically feasible, will not become practical until dramatic reductions in the cost of both storage and transmission bandwidth are achieved.

Applications

Numerous applications for computer-mediated communication have been proposed. One of the earliest applications was in Delphi exercises, a technique for arriving at quantitative estimates of difficult to assess factors by interweaving the estimates of a number of individuals. Turoff[TUR71] describes several Delphi exercises aimed at forecasting and policy-making in the medical research, health care and industrial areas. In [TUR72b], Turoff describes a possible user interface for a computer-mediated Delphi system.

More general uses for computer-mediated communication are discussed by Bedford[BED75] and Turoff.[TUR72a] These include communication within an interorganizational task force which needs to react to developing situations rapidly but which cannot meet without considerable advance notice; joint authorship of papers; policy implementation and coordination in a decentralized environment, etc.. Pager[PAG72] proposes that a computer-based system be used by scientific communities to referee papers and to organize and communicate both existing knowledge and new results.

Nelson[NEL70,NEL73] has suggested that computer-mediated communication be utilized in computer-assisted instruction. Unlike conventional teaching machine programs, which rigidly dictate the actions of the student and accept

only stereotyped responses from him, computer-mediated communication can be used to set up a genuine dialogue between instructor(s) and student. A system which incorporates this general idea has been implemented.[SCH72]

Carter[CAR75] has suggested that a computer-mediated communication system could be merged with conventional information retrieval systems. The idea is to provide a long-term memory for outputs of query and summarization requests, which could then be reviewed and discussed by a group of individuals (for example managers) who make decisions based on information in the database. Eskin[ESK75] has suggested using a computer-mediated system to handle the on-going dialog among system developers.

In the long run, as home terminals become more commonplace, it may be possible to use computer-mediated communication to involve more people in political processes. Proceedings of political bodies, such as school boards or township committees, could be entered in such a system and citizens who cannot attend a scheduled meeting may be allowed to peruse the proceedings and possibly enter their own comments or questions.[ARN77]

Recent literature contains much discussion regarding the characteristics, advantages and applications of computer-mediated communication [ARN77, BED75, CAR75, DAY75, ENG73, HIL75, HIL76a, HIL76b, HIL77, NEL70, NEL73, PAG72, TUR71, TUR72b, VAL74, VAL75b]. It is not our

intention to duplicate that discussion here; rather our intention is to indicate the potential for the medium and to justify the value of current research in this area.

1.3 Previous Work

The general concept of computed-mediated communication appears to have originated with Vannevar Bush[BUS45] in 1945 and has been espoused by Robert Fano and others[DAV65] in the 1960s. The earliest implementations, however, in use since the 1960s, are probably the "mailbox" or message facilities provided by timesharing systems such as MULTICS[COR72] and inter-user communication facilities available in computer networks such as the ARPANET[THO73]. Office automation systems which incorporate electronic mail facilities[POT77] have been proposed and are slowly coming into commercial use.

Several experimental systems have been designed to facilitate ongoing communication among a group of individuals[CAR76,HAL71,TUR72a,TUR76a,VAL73]. Message facilities are provided as components of such systems to facilitate side discussions, but emphasis is placed on information structures which allow a group of people to confer by accessing and editing a common data base of remarks. The first such system, essentially an interactive Delphi System, was reported by Hall.[HAL71] It provides storage and retrieval capabilities for three categories of

textual data called items, messages and votes. Items are further subdivided into four classes: proposals, comments, facts and estimates. Each item may be linked to one other item, allowing linear lists of related items to be maintained.

Turoff[TUR72a] describes two conferencing systems, "Party-Line" and "Discussion," which have a more general structure than Hall's system. Items entered into these systems are textual and are not subdivided into special categories. A participant is allowed to retrieve and read items previously entered into the system or enter new items. As new items are entered they are displayed in real-time to any participants currently logged on. The Turoff systems were utilized by the U. S. government's Office of Emergency Preparedness in the early 1970s.

In 1972, Vallee et al. implemented, within the ARPA network, a computer-based conferencing system called FORUM.[VAL73,VAL74,VAL75a] FORUM stores textual items with a sequential item number, time stamp and name of the author. In the normal mode of interaction a user reads items entered since his last session. Retrieval of items on such keys as date and time of creation or author name is possible. If several participants are on the system simultaneously, new entries are displayed to them in real time. Twenty-eight experimental conferences were conducted using FORUM during

1973 and 1974,[VAL74] providing the first large-scale use of a computer-mediated teleconferencing system. A version of FORUM, called PLANET, is currently available on a commercial timesharing service.[VAL74]

A computer conferencing system called CONFER[CAR74] has been implemented on the PLATO Computer System[SMI76] by Carter. Its most significant contribution is that it is the first such system to incorporate graphical capabilities. In addition to textual items, two types of graphical items may be entered into the conference proceedings: line drawings and graphs. The system is implemented entirely in PLATO's programming language TUTOR, and requires use of the special graphical display terminals designed for PLATO.

The most ambitious effort to date in the area of computer-mediated communication is Turoff's Electronic Information Exchange System (EIES), which has been operational at the New Jersey Institute of Technology since 1976.[TUR76a,TUR77] EIES allows users to compose textual items and enter them into a conference's proceedings. Normally items entered into the conference since the user's last session are displayed in chronological sequence. Retrieval capabilities similar to those provided in FORUM are also available. Plans also exist in the future to allow users to rearrange items in an arbitrary linear sequence, and to establish an association between an item and one other item.[TUR76a] Ongoing conferences involving

as many as 50 people have been conducted with EIES, and it is providing a vehicle for research into the social implications of computer-mediated conferencing.[HIL77]

1.4 Objectives of This Work

The computer-mediated communication systems referred to previously have demonstrated the feasibility of effective communication despite both spatial and temporal separation; however they have not exploited the full potential of the computer to enhance such communication. Existing systems have tended to simulate conventional communications media by providing an essentially serial channel. In the normal mode of interaction with existing systems, remarks entered into the conference are read back by a participant in the same linear sequence in which they were entered. Some ability to search for entries, for example, by a given author or including a given keyword, is provided.[VAL73]

The present work is motivated by the observation that the human mind and conventional communications media are mismatched in the sense that thought processes display a complex, nonlinear organizational structure while conventional communication provides only a serial channel in which to share them. Evidence for this can be seen in the way conventional meetings are conducted. Usually, the chairman prepares an agenda or outline, which is nothing

more than a hierarchical classification of topics and subtopics to be discussed. To avoid chaos, attention is focused on one topic at a time, and thus face-to-face discussion follows a serial format.

In a conventional meeting, the serial discussion of several topics poses no problem. If one is not interested in a particular subject, previously agreed-on time limits provide bounds on patience. Dealing with one topic at a time allows concentrated discussion on each topic, and losing a train of thought is not a serious problem unless the chairman fails to suppress tangential diversions.

The asynchronous nature of computer-mediated communication introduces some subtleties not present in face-to-face discussions. Time limits on discussions of particular topics must be set on the order of days or weeks rather than minutes or hours. To compensate for the longer elapsed time, and differences in the interests of the participants, there is a tendency to pursue multiple topics in parallel. If the medium provides a serial readout of remarks, however, multiple discussion threads become interweaved in the manuscript and hard to follow (e.g., see sample transcripts in [TUR72a,VAL75a]). Remarks on topics which one is not interested in must be accessed to get to later remarks in which one is interested. (In face-to-face situations, one has the option of not attending certain meetings or of missing certain

discussions scheduled during prearranged intervals.) It is difficult to apply concentrated attention to any single topic when several topics are interleaved in a linear sequence of remarks. The relatively long elapsed time between a user's successive interactions with the system introduces another problem: it may become necessary to refresh one's memory regarding past discussions on a topic before reviewing the latest set of remarks. Unless the set of past remarks on a particular topic of interest can be quickly retrieved and scanned, it is difficult to follow the recent discussion. Other researchers have recognized these difficulties.[CAR75]

Two systems have attempted to address these problems to some degree. FORUM allows the chairman of a conference to establish a partition of entries into topics and subtopics; structurally the conference proceedings can be thought of as a two-level tree.[VAL73] Within each subtopic no further organization can be imposed; items appear in chronological sequence, although the retrieval capabilities referred to earlier allow one to choose subsets of them for review. EIES has taken a somewhat different approach. Two methods are provided* to establish an organization of the conference proceedings.[TUR76a] An aribtrary linear ordering (as opposed to chronological sequence) may be

* These capabilities are planned but have not yet been implemented.

established for a set of entries, if desired. In addition, one may establish an association between one entry and one other entry. This allows establishment of cross-references between items, which is not possible in FORUM, but provides no convenient provision for subdivision of proceedings into topics and subtopics.

In this work we explore a significant generalization of these ideas. Specifically, it is proposed that the communication proceedings can be organized by users into an information structure in the form of a linear directed graph. Appropriate displays and commands can be provided to allow users to rapidly scan the information structure, home in on those portions of most interest to them at a particular time, explore the associated remarks in depth, and easily incorporate new remarks into the graph at appropriate nodes. The structure of the graph can be easily reorganized by the participants, thus providing a very controllable, natural framework for organizing the discussion. Separate topics form disjoint portions of the graph and are read back separately in traversing the structure. Subtopics can be represented as successors of a particular node, and cross-references among items can be established by introducing appropriate edges into the graph. As we shall see, the graph can also be used as a filter to define a subject area which the user wishes to discuss in real time should synchronous discussion occur.

The idea of organizing and perusing a graph-structured representation of the proceedings does not preclude one from accessing items in chronological order, as is normally done with conventional systems, but we expect this to become a secondary mode. Nor does it preclude requesting displays of arbitrary subsets of proceedings using queries on various keys.

The graph structure just referred to is a generalization of a technique used by Engelbart et al. in a sophisticated text processing system known as NLS [ENG73]. In NLS, text files may be explicitly organized by users into an arbitrary tree structure, whose nodes contain text. In addition to tree edges, cross-references may be effectively established between any pair of nodes by inserting references into the text. There are several significant differences between the structure that we propose and that implemented in NLS, however. NLS does not treat cross-references embedded in text in the same manner as tree edges and thus the information structure that is supported by NLS is not a general graph for the purpose of structural manipulation. A second major difference is that a user who wishes to make changes or additions to an NLS tree-structured file operates on a private copy of the tree: he thus locks out other users from making changes to any part of the tree or viewing

any of the changes until he over-writes the original file. In the type of communication system that we propose, however, it must be possible for users to make changes to (non-overlapping) portions of the same information structure concurrently, and for users to view other users' changes immediately. Thus the system that we propose must allow greater concurrency of operation than NLS, a fact that complicates implementation considerably.

The specific contribution of this work to the field of computer-mediated communication can be summarized as follows. An improved design for a computer-mediated communication system, based on the concepts just described, is presented. Such a system, called the Computer Based Information Exchange (CBIE), has been implemented on a PDP 11/50 minicomputer, and techniques used in its implementation are discussed. One aspect which is given special emphasis is ensuring the privacy of communication; the application of recent work in cryptography is discussed. Several novel aspects of the system pose theoretical problems for efficient implementation. These include allowing multiple concurrent users to delete portions of the graph-structured proceedings, and determining an optimal storage assignment for its nodes. Solutions to these problems are presented.

1.5 Overview of Remaining Chapters

Chapter 2 presents the design concept of CBIE from the user's point of view. Existing system features and desirable extensions thereof are described, and an example of their use is presented to illustrate the underlying ideas.

Chapter 3 discusses the system implementation. Although methods used in the design of CBIE are indicated, considerations and techniques are discussed in general terms to provide as much useful information as possible to others planning similar systems.

Chapters 4 and 5 present solutions to the theoretical problems referred to earlier; although these arose in the context of CBIE, they appear to have more general applicability.

Chapter 6 discusses the problem of privacy in a computer-mediated communication system, and shows how recent developments in the field of cryptography can be applied to provide an effective solution.

Finally, Chapter 7 presents a summary and suggests directions for further research.

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