Pergamon

0360-1315(95)00013-5

Computers Educ. Vol. 24, No. 3, pp. 141 155, 1995

0360-1315/95 $9.50 + 0.00

AN INTERNET BASED COLLABORATIVE DISTANCE LEARNING SYSTEM: CODILESS

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Abstract—In order to meet the growing demand for flexible and continuing education, distance learning is increasingly being used to supplement the conventional classroom based education. The learning approaches that have trained students to work alone and independently are also being augmented with collaborative approaches that better fit the needs of today's organizations. To devise a model and develop an implementation for an effective and efficient collaborative distance learning system, the authors have started an international cooperative project. In this paper, we describe our research objectives and illustrate the key design criteria and system features by using the experiences from recent work on collaborative distance learning. We describe the conceptual model and architecture of the system (Collaborative Distance Learning Support System: CODILESS). The system aims for effective learning and efficiency, both from the learner's and course provider's point of view. CODILESS supports both collaborative and resource based learning within the same environment by integrating asynchronous and synchronous multimedia communication with electronic learning resources on the local workstation and on the Internet.

INTRODUCTION

New roles of distance learning

New technologies are transforming the ways in which businesses operate and people work, boosting demand for new knowledge and new types of skills. They are providing new alternatives of learning, offering a potential solution to meet challenges such as demand for more flexibility in delivery of education in terms of time, location, content, and form. Students need to be able to learn when they want, where they want, what they need (just-in-time), and in a format appropriate to them.

Distance learning has traditionally been used to give educational opportunities to such groups of students for whom the conventional educational models are not suitable, such as people at work, those studying at home, living in isolated areas, or people with physical limitations. However, the methods that have primarily been used in distance education can also be used to supplement conventional education. For example, alternatives are available to students in large cities who spend much of their time commuting to institutions—or who, for other reasons, prefer completing part of their studies off-campus.

> "Time, in addition to distance, is a factor. Educators no longer employ distance education simply to extend traditional course to geographically isolated students and adults. Today adults from urban as well as rural communities enroll in distance education courses, participating from college classrooms, corporate offices, and homes. More than distance, it is increasingly the time demands and constraints of today's adults that shape many programs ... learners will increasingly want and need education and training on demand" [1].

Collaborative learning

With conventional distance education delivery mediums (mailed texts, video, radio, T.V.), the instructional techniques that emphasize a student's own activity and interaction among students, such as collaborative learning, have not been feasible. Early experiences and research results of collaborative learning stem primarily from face-to-face classroom situations. With the rapid development and integration of computing and communication technology, support for student–teacher and student–student interaction becomes viable, allowing even geographically dispersed groups of students to collaborate effectively. By introducing a computer based collaborative learning system, the following benefits may be realized in distance education [2]:

(1) The students benefit from different perspectives of the material they are learning. The group inherently brings with it a wider range of experience than does an individual member. This enables students to obtain help from their group to tackle larger projects than they could individually.
(2) The learning experience can be structured so that students will find themselves presenting and explaining parts of the material to other students. Discussion with peers can be more relaxed and free than with a teacher. By communicating what they have learned to others, the material will become more integrated into their general understanding ("best way to learn something is to teach it").
(3) Working with groups is highly motivating. A group provides the pace for its members. People want to be seen doing their best. The support and sense of identity provided by the group allays fears and builds confidence.

The ability to communicate with the instructor and other students provides certain social motivation. In several distance education courses, the dropout rates can be over 70%. The students that form *ad hoc* study groups to ensure the pace of their studies usually make progress further than those studying individually [3].

RELATED WORK

Computer support for collaborative distance learning

The earlier work in the development of technology support for collaborative learning (at a distance) has focused on asynchronous interaction using electronic mail and conferencing systems, most of which have been based on textual interaction and placing emphasis on "the written word" [4]. Although limited to intensive interaction, the asynchronous text based medium has made it possible to overcome barriers of distance in space and time. It has also brought certain new and unique aspects to human communication.

Written communication, compared to face-to-face communication, equally positions the participants, minus prejudices about each other based on race, gender, age, national origin, and physical appearance [5]. However, the limitations that stem from the purely text based nature of written communication are obvious: misunderstandings are common due to limited "communication bandwidth", and the sheer effort required to input adequate information in textual form is sometimes extensive.

Distance learning systems, using video-conferencing, have also been developed to support synchronous interaction. However, due to the very high cost in setting up and using video-conferencing, it has primarily been used to duplicate the classroom over wide geographic areas, rather than for student–student or student–teacher interaction. To apply these technologies has required expensive data communication links, as well as special hardware and software that has been difficult to integrate into other systems. Lower cost alternatives, such as audio-graphics, have been successfully used to provide shared workspace (whiteboard) with audio link in real-time among a small number of students, although the video connection has been missing. More recent systems have used a hybrid approach by combining different technologies (e-mail, conferencing, CAI material, video link, audio-graphics, phone, fax) to provide comprehensive support, with each task matched to an appropriate medium for delivery and fulfillment [6].

While many systems support student–teacher and student–student interaction—e.g. allowing students to ask questions to tutors—the role of these interactions has often been secondary to the activities on the course. Particularly notable is the pioneering work of Hiltz, Turoff and their colleagues at the New Jersey Institute of Technology in developing explicit support for collaborative learning. They have developed Virtual Classroom [7,8], a set of group communication workspace and facilities constructed in software, as a teaching and learning environment located within a computer-mediated communication (CMC) system. The Virtual Classroom and the work at the British Open University in developing the "Electronic Open University" which aims at supporting collaborative learning at a distance [2,9] have provided useful insights and experiences for our work. When comparing Virtual Classroom learning with traditional classroom learning, Hiltz observed that there was no significant difference in scores measuring mastery of material taught. The students felt that online courses were more convenient, combining them to choose their work times and their own pace. On the other hand, they felt that Virtual Classroom was more demanding, since they were required to actively take part in the work. Hiltz also found that the extent of collaborative learning was highest in the mixed mode courses, where part of the learning happened in traditional classrooms.

Mizell and Nova University staff developed a system in which more than 30 participants can "speak" with each other by typing texts [10]. With their method, a teacher shows text slides prepared in advance one by one. Students can ask questions to the teacher by typing text. Their experiments with the system point out the importance of student activity. Students get easily bored during an online "lecture", even if supplemented with texts, if there is not frequent interaction. This experience made them send learning materials to students beforehand, with follow-up discussions or simulations being conducted online.

At the University of Phoenix Online, undergraduate and graduate degree programs are provided online for working adults, using a text-based asynchronous communication system [11]. Lewis and Hedegaard found that interaction in online groups tends to be more evenly distributed than in face-to-face groups. They mention that online graphics and video applications make the learning environment even more useful. Shaeffer and Farr emphasize the importance of faculty development and interactivity among students [12].

Riedl *et al.* report a system for exchanging video, voice, and data by connecting schools using three ISDN (Integrated Services Digital Network) lines [13]. The system is designed to be used in a classroom equipped with a large screen. It is linked to the Internet allowing teachers and students to communicate with each other when their schedules would not otherwise allow it. The system requires high-cost equipment, including video CODEC, and can currently connect only two points simultaneously, although extensions are in development.

The results observed in experiments and actual courses using systems suggest that collaborative learning at a distance can be effective when supported with appropriate technology. For collaborative learning to be effective, learning tasks must be designed to require interaction. Additionally, the limitations of earlier systems have been pointed out. There is an obvious need to go beyond text based communication to allow richer forms of information to be passed among the participants. The option for a face-to-face synchronous work mode has been shown to be useful in situations requiring clarification or in which issues need to be resolved.

Experiences from an experimental course

Objectives of XT001. In this section, we describe results of an experimental computer supported distance education course, "XT001-Renewable Energy Technology (RET)", in which one of the authors participated [14,15]. The course was produced by The British Open University and its purpose was to apply, in distance learning, such learning approaches that were inherently conversational and collaborative, and learning approaches in which students actively engaged with the learning materials through exploration and interaction. The course ran from October 1993 until January 1994 with 24 students, including 17 from the U.K., 2 from University of New South Wales, Australia, and 5 from Espoo-Vantaa Institute of Technology, Finland.

Learning activities. Students worked in groups on three different activities, each of which used a different approach to collaborative learning. These activities aimed at explaining what the different renewable energy technologies are, how they fit together, and what non-technological aspects might occur. The three activities were:

- joint document production: "Renewable Energy Technology in Europe". Students worked in groups to construct a joint document:
- exploration of a "virtual world": "Integrated Energy in Ecotopia". Students acted as "research assistants" in a firm of energy consultants jointly developing an energy policy

for the imaginary country of Ecotopia. Their principal tool was a spreadsheet model of the Ecotopia energy system, that also contained linked frames of spreadsheet models and graphics to provide a simple and understandable view of the model;

— role playing: "A Wind Farm for Ambridge". Students took on various roles in a simulated public planning inquiry into the siting of a wind farm in the fictional village of Ambridge. The students were given a set of role briefs and a small library of background documents relevant to wind farms and planning inquiries.

Evaluation. The collaborative approach really worked in terms of creating motivation, enjoyment, and feelings of togetherness. It provided students with support they did not get from tutors, both academically and in using the tools and materials. The combined experience of a group of students is a significant addition to the resources provided for a course. Students also pointed out the advantages of working on their own, while having the ability to follow how others were proceeding.

Interactive learning techniques, such as exploring a virtual world or participating in a role playing activity, provide insights students would be unlikely to gain with traditional texts, lectures and exercises. The technology-based learning support environment: the combination of "library", "study", and "meeting room", as an integrated computer based environment, worked well. FirstClass™ proved to be an excellent choice. It would have been practically impossible to use another conferencing system that would operate as smoothly as part of the computer based environment.

Students made extensive use of the learning resources on a CD-ROM, developed specifically for the project, containing a library of learning resources. They also used the meeting room actively, exchanging 60 to 80 messages for each activity. To reduce telephone charges, they connected to a host computer only when uploading and downloading messages, and read and wrote messages offline. The total connect time for the most active students ranged from 3.5 to 32.5 h, with an average of 18.5 h.

Figure 1 shows an example of messages exchanged between students. One student states in her messages that she feels confused about the other student's message. In asynchronous message exchange, clarification can not be done immediately, and this may often cause confusion and misunderstandings. The designers of XT001 tried to pay special attention to ensure constructive and efficient communication by devising a set of empathy templates and explaining their use [16]. Also, the electronic face icons included in the messages, although static, helped to overcome some of the barriers resulting from the lack of face-to-face communication. However, a synchronous audio and video communication mode could have helped avoid such problems by allowing participants to clarify their points and resolve certain issues instantly.

The students felt that collaboration is an effective use of their time (average response is 7.0 out of 10.0) and that it improves their motivation (average response: 7.8). One student reported that he could ask questions and express ideas to tutors that he would not in front of a whole class. Students were very impressed by the high quality of the learning materials, especially the CD-ROM libraries and Course Book, which provided them a very large, up-to-date set of materials with which to work (average response: 8.6). The students produced detailed, well-illustrated reports, with colors and, in some cases, sound and animation. Some students remarked that they preferred a mixture of face-to-face and electronic meeting, and when available, face-to-face contact made for even better collaboration.

Recommendations. The experiment produced a set of recommendations for the designers of such learning environments and courses. Interactive and collaborative learning techniques should be included in the distance learning repertoire. The conferencing system itself should have the following features:

— clear, simple, and easy to learn user interface
— the ability to upload and download files, either attached to messages or directly to a conference or folder
— possibility to easily use "complex" information types (text, graphics, images, sound, etc.)
— flexible structure of conferences and permissions
— distributed conferences and gateways (e.g. for local access)

For effective collaboration to occur between students, students also need structured exercises in

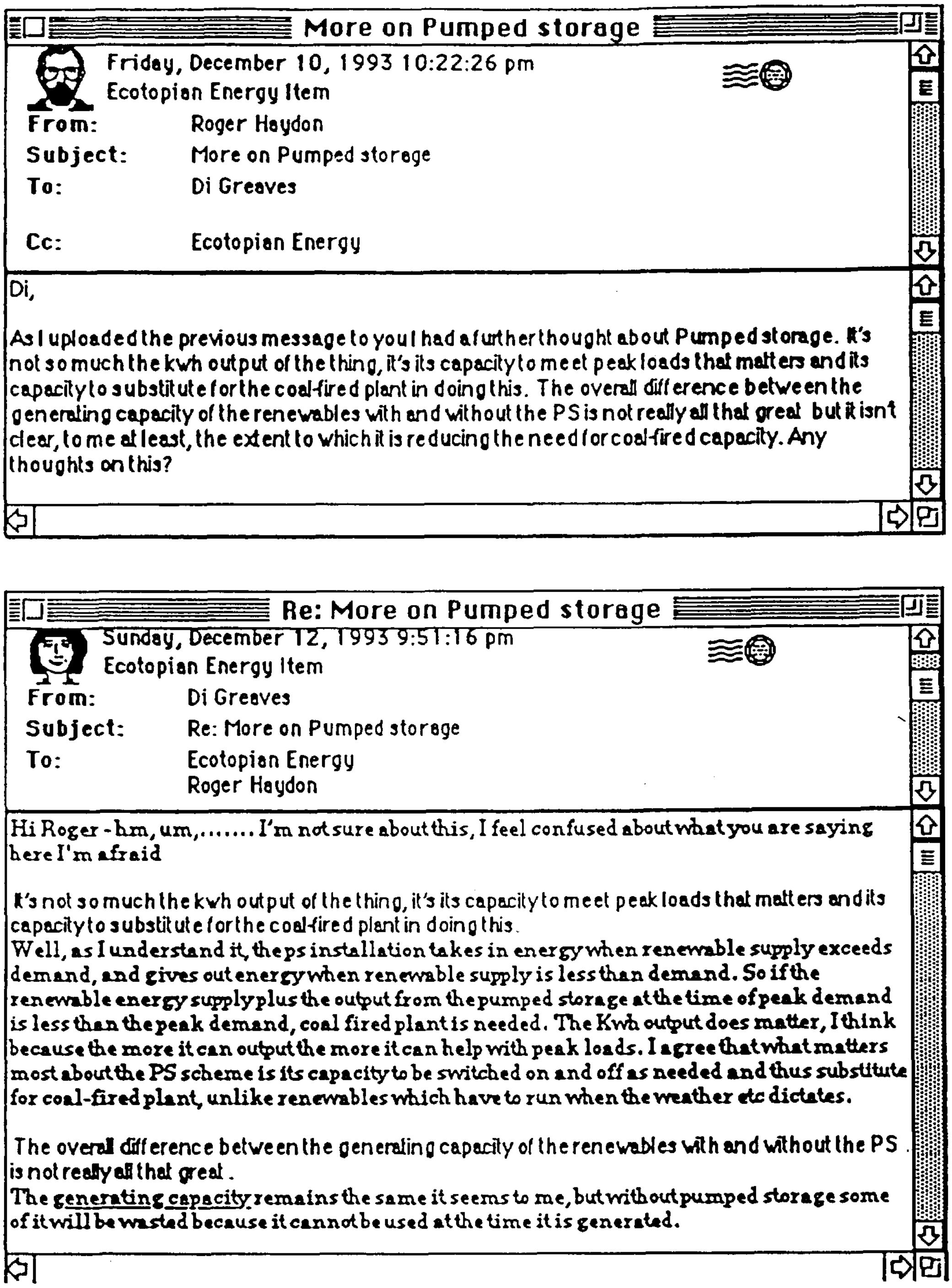

Fig. 1. Example of students' interaction.

which they get to know each other as part of group formation. In addition, they also need guidance in how to communicate supportively and how to achieve confirmation of mutual understanding and agreement.

While the meeting room was the basis for collaborative work, many students were limited in its use, due to costs of telephone connections. Thus, universal local call access to a conference system

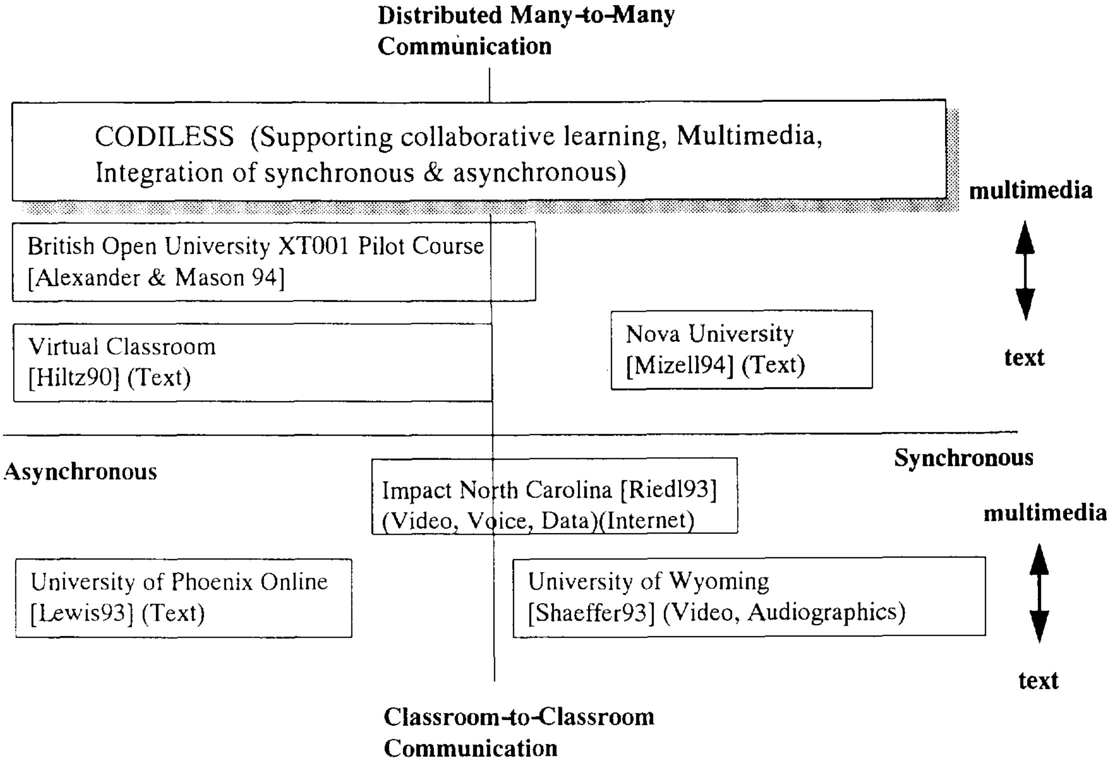

Fig. 2. Positioning of the CODILESS system.

is very important. Also, the course was deliberately based on technology available at the planning stage (2400 bps modems). The use of high-speed modems (14.4 kbps or higher) would have greatly increased convenience, while significantly lowering costs.

Research goals

In conventional distance education, students feel isolated without someone from whom they can seek for advice, and are apt to lose their eagerness to learn. To a large extent, this problem can be overcome with computer conferencing based systems, although the interaction is asynchronous. While this is beneficial in allowing the participants to work at their convenience, there are occasions where synchronous contact would be preferable. For text based communication, the "chat" and "talk" services support this kind of interaction. However, one conclusion from earlier experiments is that occasional face-to-face meetings would make the learning process more efficient. Providing only asynchronous text based interaction is not enough in situations where complex information needs to be interactively processed.

We propose a new kind of system, providing effective and efficient support for collaborative distance learning by integrating synchronous and asynchronous communication and access to learning resources within a single environment. The asynchronous communication can contain text, graphics, images, etc., while the synchronous communication can include video, voice, and sharing of workspace (such as a whiteboard) for joint work. Our research goals are as follows:

(1) To provide students with a computer based collaborative learning environment that integrates asynchronous and synchronous communication in different media.
(2) To provide students multimedia and multi-window, easy-to-use interface and to reduce communication costs without degrading data quality.

Figure 2 positions our research with other principal systems developed or under development for distance education. The main dimensions are the communication mode (synchronous or

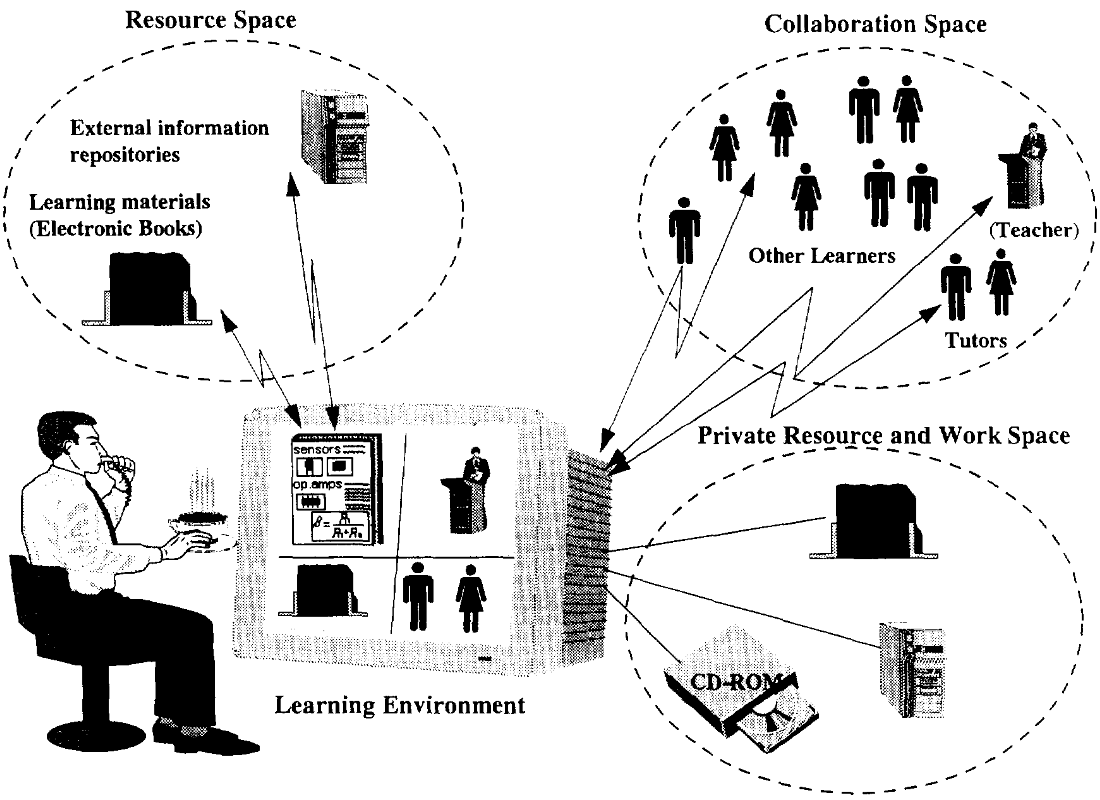

Fig. 3. Conceptual model of collaborative distance learning.

asynchronous) and space (distributed many-to-many desktop communication or classroom-to-classroom communication).

CONCEPTUAL MODEL OF CODILESS

Learning with CODILESS

An essential element of collaborative learning is intensive interaction among peers. In learning, as in other collaborative work, students alternate between private activities and collaborative activities. While much of the production is done via private activities, participants need to interact with each other to distribute tasks, agree upon common goals, explain and clarify their views, integrate their work, resolve problematic issues, and so on.

The interactions happen at discourse level. The actions, in turn, take place at the action level where task objects (e.g. chapters of a paper) are created and manipulated. The actions can be either collaborative actions where participants examine or modify the task objects in a shared (public) workspace or they can be individual actions, where the object is an individual (private) workspace. For the most part, the actual production process is usually carried out by individual members, and in certain instances, the intermediate results are brought together for discussion, problem resolution, analysis or integration. The information that is subject to discussion, and the results that are created in the course of the work are often derived from sources that are external to the discourse (e.g. data bases, spreadsheets, simulators, models, online sources).

The distinctions that have been made among computer support of different work modes (i.e. asynchronous vs synchronous, same place vs remote places, collaborative activity vs individual activity) need to be blurred. In the conceptual model and actual system implementation, we aim at achieving seamless integration of these different modes for efficient collaborative learning support. Our conceptual model of collaborative distance learning is outlined in Fig. 3.

Models for collaborative resource-based learning at a distance have already been suggested and applied, such as the one developed at the British Open University for collaborative distance education [9]. Our model extends them by adding real-time multimedia communication and access to external information sources (i.e. such resources that have not specifically been developed for the course).

The student has learning materials, such as course texts, as well as support material, such as dictionaries and encyclopedias, available in the learning environment. The student have access to teachers (maybe the developer of learning materials), tutors (advisors), other students, and other information resources (such as online databases). For communicating with the outside world, the student has tools equivalent to a telephone, a fax machine, a T.V. set, and mail, as tools integrated within the learning environment.

Organizing a course in CODILESS environment

The organizational model for arranging a course in such a setting can be as follows. The student pays tuition and a learning material fee for a course. He receives a CD-ROM disk including the course materials, and a user ID for using a Collaborative Learning Server (to be described later). The student can learn offline, using the tools in his workstation and the resources on the CD-ROM, and online using the network connections. The student can easily switch and exchange information between these different modes as part of the same environment. The different learning activities can be mapped to offline and online learning in a variety of combinations, depending on the organization of the course, cost of communication, and other factors. Some of the possible mappings are shown in Tables 1 and 2.

Based on experiences from courses utilizing computer mediated communication (computer conferencing), one of the main factors affecting the use of the online mode is easy access to the online connection, as well as its cost to the student. We propose an Internet based system where the usage would depend on local phone call charge (provided that there is an Internet connection provider within the local call area).

Students can utilize the advantages of both online learning and offline learning. A student can send electronic mail to a teacher, tutors and his peers when he has questions. He can also post the question to a bulletin board for the course, in which case the answers can come from any of the participants. When a teacher or tutors have already logged in, a student can talk or chat with them through Internet, and can also communicate by using voice. When a student would like to more extensively examine the course materials, not only can he consult the CD-ROM disks at hand, but also retrieve information from various file servers and databases around the world through the Internet.

This arrangement also supports the different collaborative learning settings. A learning group is organized in three ways: a group (usually) assigned by a teacher to solve specific (assigned) problem, to produce reports and to collaboratively learn tasks, a group organized by students to teach each other for a deeper understanding of course materials, and an *ad hoc* group formed online to ask and answer questions while learning online. While having a meeting with one party, a student can ask questions to another student outside the party by exchanging messages online. Therefore, students can learn from each other by forming various groups according to their objectives.

COLLABORATIVE DISTANCE LEARNING SYSTEM: CODILESS

System architecture

The Collaborative Distance Learning Support System: CODILESS is conceptually based on the group collaboration support model, which one of the authors has proposed earlier [17]. As shown in Fig. 4, this model is for supporting geographically distributed individuals to work together using a multi-point communication network and group collaboration agents.

The structure of the group collaboration agent is shown in Fig. 5. Group Collaboration Function Unit (GCFU) is for processing the knowledge/information stored in the Knowledge/Information Base. It has four layers: communication support, basic task support, multiparty conference support,

Table 1. Mapping student activities to offline and online learning

Activity	Offline learning	Online learning
Lectures	Electronic lecture (multimedia presentation, CAI tutorial)	Video- or audioconference, audiographics
Questions		Computer conferences (bulletin boards)
Discussion —Class discussion groups and *ad hoc* discussion groups Private student student and student teacher discussions		Computer conferences Sub group computer conferences E-mail messages
Learning from resources —Search for, access and read course materials —Access to other related materials —Executable models, simulations, etc. —Transfer speed of learning materials	Electronic library Indexed library of electronic books (CD-ROM) Indexed library of reference material Local software required Fast (immediate)	Indexed library of electronic books (online) Internet search facilities and resources (WAIS, WWW, etc.) Remote execution possible Slow (depending on connection)
Individual and working-group composition and storage of documents		
—Create, modify, and manage documents individually	Local tools and local file system	
—Create, modify, and manage documents collaboratively Asynchronously —Sychronously (in a meeting)		Computer conferences Shared directories Shared whiteboard
Evaluation and feedback —Self-assessment	Computer based tests giving feedback	Computer based tests giving feedback
—Assignment distribution and return (timed student-teacher feedback)		Computer conferences, e-mail, shared directories
—Exams (timed student teacher feedback with no other communication permitted)		Online exams
—Access to own grades and averages		Online gradebook
Self-supplied description of interests: contact information; recording of online activity		Student directory

and collaborative application support. Lower layers provide services to the layer directly above them, upon request from those upper layers.

The Knowledge/Information Base consists of four sections: communication information base, basic task knowledge base, conference knowledge base, and application knowledge base. Each base corresponds to a layer in the GCFU. The integrated user interface serves as a bridge between individual group members and GCFU. The authors suggest that the group collaboration support model is useful as a model for a collaborative distance learning system and can be used in effectively implementing the conceptual model described in Fig. 3.

Implementation principles

The network configuration of the system is shown in Fig. 6. It is based on the conceptual model and the group collaboration support model described earlier. We have chosen to use Internet not only for data communication, but also for synchronous voice, pseudo-video, and shared whiteboard communication.

There are several reasons for making use of the same medium (the Internet) for all different modes of interaction. For the provider of the courses, it means less expensive equipment as there is no need to purchase video CODEC and conferencing software for audio and video data. For the students, it usually means reduced telephone charges without degrading communication quality (provided that there is an Internet access point within the local area). However, the Internet

Table 2. Comparison of asynchronous and synchronous online learning

Activity	Online asynchronous	Online synchronous
Lectures		Video- or audioconference, whiteboard
Questions	Computer conferences	Video- or audioconference, whiteboard (subgroup or all)
Discussion	Computer conferences	
—Class discussion groups and *ad hoc* discussion groups	Sub group computer conferences	Video- or audioconference, Whiteboard (subgroup)
—Private student–student and student–teacher discussions	E-mail messages	
Learning from resources		
—Search for, access and read course material	Indexed library of electronic books (online)	
—Access to other related materials	Internet search facilities and resources (WWW, etc.)	
—Executable models, simulations, etc.	Remote execution possible	
—Transfer speed of learning materials	Slow (depending on connection)	
Individual and work-group composition and storage of documents		
—Create, modify, and manage documents individually		
—Create, modify, and manage documents collaboratively		
—Asynchronously		Computer conferences, shared directories
—Synchronously (in a meeting)		Shared whiteboard

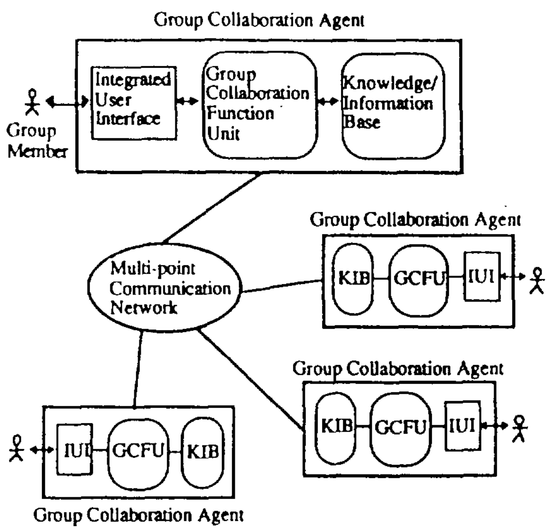

Fig. 4. Group collaboration support model.

protocols have originally been designed for one-to-one communication, such as between a host computer (server) and another computer (client). For making multiparty real-time sessions feasible, multiple-broadcast (multi-cast) functions need to be added to a collaborative distance leaning server.

Asynchronous communication. For non-real-time media (text and image) exchange, we add Collaborative Learning Server: COLS and Local Communication Server: LOCS to Internet. We

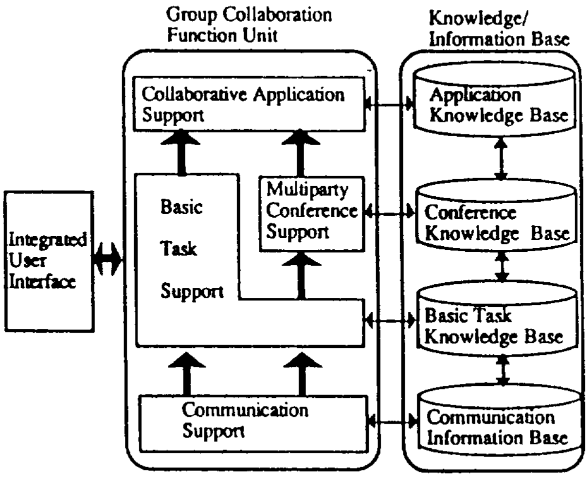

Fig. 5. Group collaboration agent.

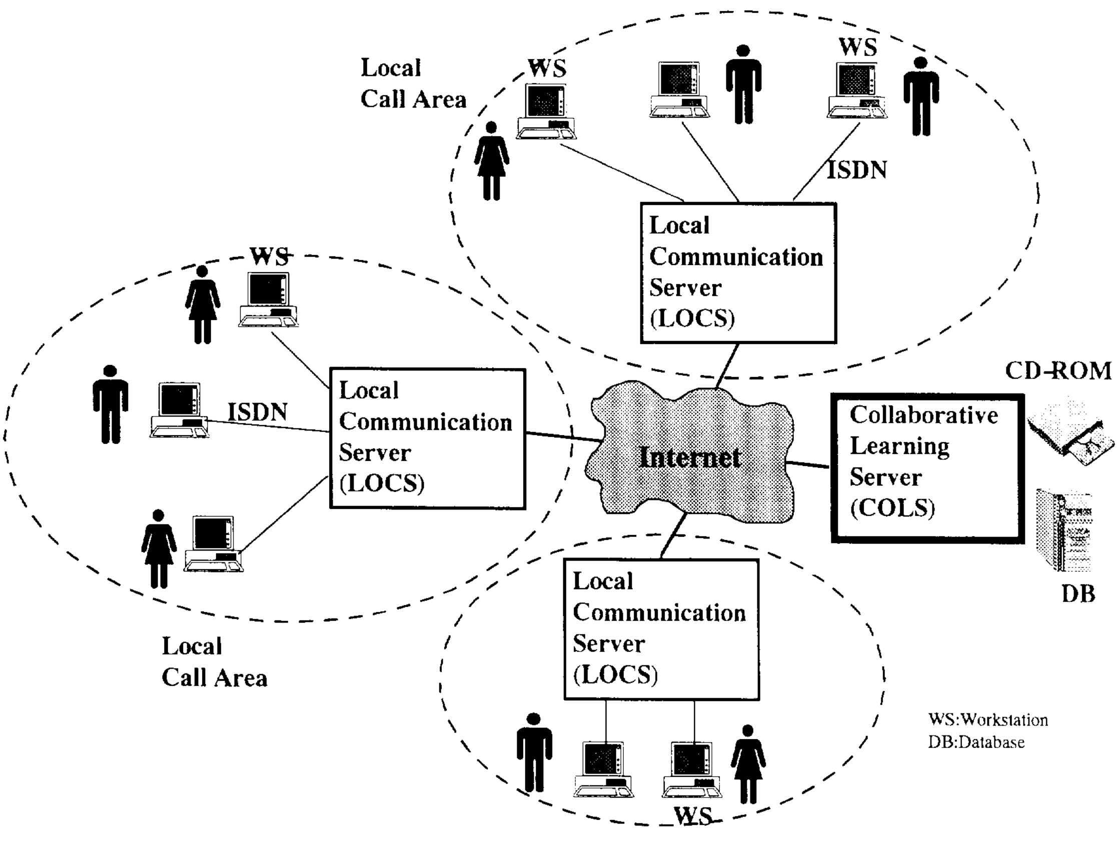

Fig. 6. Network configuration for collaborative distance learning.

assume that there is a COLS for one or more courses, adjusted to the processing burden. COLS contains learning resources, such as course texts, reference materials, and dictionaries on magnetic disks or CD-ROMs. COLS provides learning materials and supports non-real-time exchange among students by providing functions for e-mail and electronic bulletin boards. Real-time interaction is supported with one-to-one talk and multiparty relay chat.

LOCS is a "local" computer which each student connects with ISDN (64 kbps) or phone line (14.4 or 28.8 kbps). ISDN is preferable for quick response time, especially in exchanging voice and pseudo-video charges. The main tasks of LOCS are to broadcast information transferred from COLS to local students' workstations which are directly connected to the LOCS, and to transfer information from the local workstations to COLS and broadcast the information to the local workstations at the same time. The reasons to provide COLS and LOCS are as follows:

(1) By assigning global broadcast (data transfer from a COLS to LOCSs) to COLS and local broadcast (data transfer from a LOCS to user workstations) to LOCS, the burden for data broadcast from a COLS to user workstation is taken by LOCSs, too. As the LOCSs work simultaneously, information exchange among students become faster.
(2) A student's ISDN or phone charge is reduced by connecting his workstation to LOCS nearby, instead of calling (connecting to) COLS far away.
(3) COLS maintains consistency in students' interactions. Instead of controlling a floor (a right to update the collaboration window), COLS broadcast messages on a first-come-first-served basis. This makes all the students' collaboration windows consistent, even when students update the same part (i.e. text, graphics, image) of a collaboration window, because the update messages (packets) sent from students are processed on a first-come-first-served basis at COLS sequentially.
(4) As COLS implements both storage of learning materials on its magnetic disks and broadcast of materials, students can more quickly access and share learning materials. Especially when students would like to share large multimedia data, they can share the data much faster than when the data is transferred from another host computer and then broadcast to students' workstations.
(5) Students can easily find other students who are learning collaboratively or studying online alone using COLS. By issuing a command, a student can find information about who is learning online, what groups are already formed and the names of group members. He can start or join a collaborative learning group by selecting a student or a group on screen and asking the party's permission.

Real-time multimedia communication on the Internet. MBone (Multicast Backbone) is a virtual network that multicasts audio, video, whiteboard, and other streams that need to be distributed to large groups simultaneously. While multicasting has been available on LANs for several years, it has only recently become feasible on a worldwide scale. This is due to installation of high bandwidth Internet backbone connections and widespread availability of workstations with adequate processing power and built in audio capability [18].

A network with the speed of 15 kbps is required for real-time voice communication. By using the Internet, one line (ISDN or phone) can be shared by data and voice communication, which reduces a student's communication charges. For example, for audio communication, the student's voice input from a microphone is digitized, compressed and broadcast as packets. Students' workstations receive the packets, de-compress them, changes them to analog to be heard through speakers.

For video communication, MBone requires as fast as a 130 kbps communication channel. To reduce the congestion when using MBone for video communication, we have decided to send pseudo-video images in the CODILESS system. Our earlier experiments suggest that even occasional update of video images (every 5–10 s) is efficient when combined with audio communication, and other media, such as shared whiteboard The system broadcasts students' face images one frame for every 5–10 s. The update frequency varies with network traffic. The face images are taken by a video camera attached to a student's workstation, digitized, compressed, and broadcast as packets. The mechanism for broadcasting video is the same as for other data: LOCS broadcasts locally, and COLS globally. Students' workstations receive the video images, de-compress them and display them in a video window. Using such a method for video broadcasting, the expensive video CODEC becomes unnecessary, though a video digitizer board, which is much cheaper, is necessary.

Student equipment. Figure 7 shows equipment for a student workstation. A workstation supporting IP (Internet Protocol) multicast addressing, a CD-ROM drive, a microphone, a sound

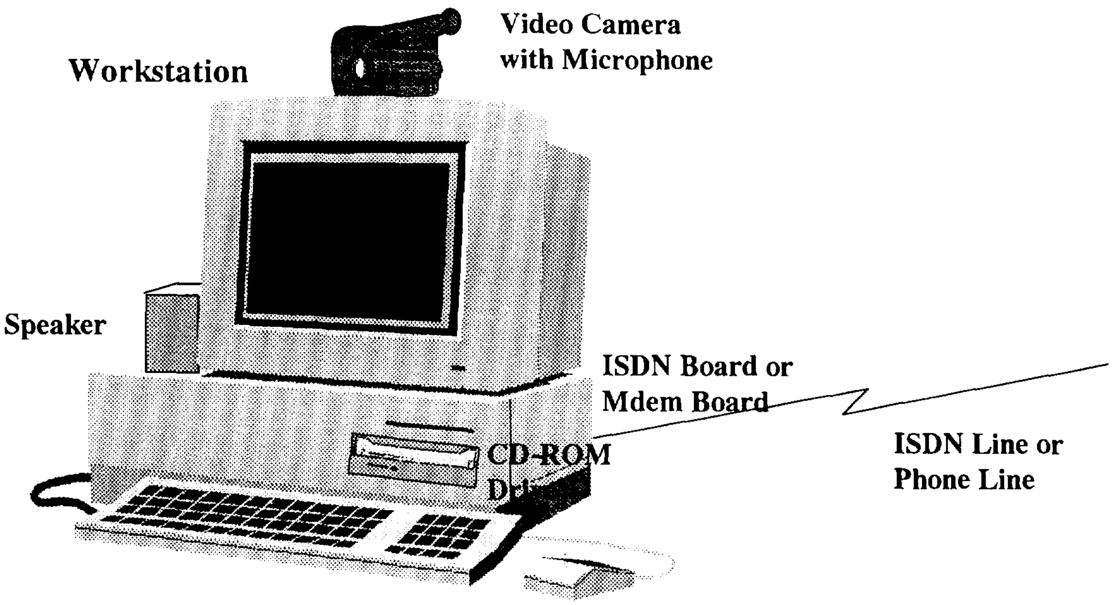

Fig. 7. Student equipment.

card, an ISDN board or a modem, and an ISDN line or a phone line are required. The student connects to a LOCS nearby with an ISDN line or a phone line. A video camera and a video digitizer board are optional but desirable, because video images enhance the visual effectiveness of collaborative learning.

User interface

The workstation (client) software of the CODILESS system is built on top of a graphical user interface (X Window). A screen example is shown in Fig. 8. Five kinds of information are displayed on a screen: collaborative learning information which students exchange online (shown in the upper right corner of Fig. 8), learning materials in COLS (shown in the upper left corner and lower right corner of Fig. 8), real-time video information (shown in the lower right corner of Fig. 8), information from Internet resources (WWW, Gopher, etc., e-mail is shown in the lower left corner of Fig. 8), and private information (private files and databases, etc.).

Four types of windows are provided which correspond to each of these information types: collaboration window (for displaying structured text of discussions, editing collaborative documents, etc.), online material window, video window, and personal window (for retrieving from CD-ROMs and personal databases). A student can open multiple online material windows, Internet windows, and personal windows. Private information can be shared by copy and paste (or cut and paste) operation to a Collaboration Window.

CONCLUSIONS

We have briefly described our research objectives for developing an Internet based system for collaborative and resource based learning. We have introduced a conceptual model and an implementation model for a collaboration support system (CODILESS). The design criteria and the features and capabilities of the system are based on recent experiments on collaborative learning at a distance ([14] in particular) and the work in developing desktop multimedia conferencing systems [17]. The CODILESS system provides the following key features:

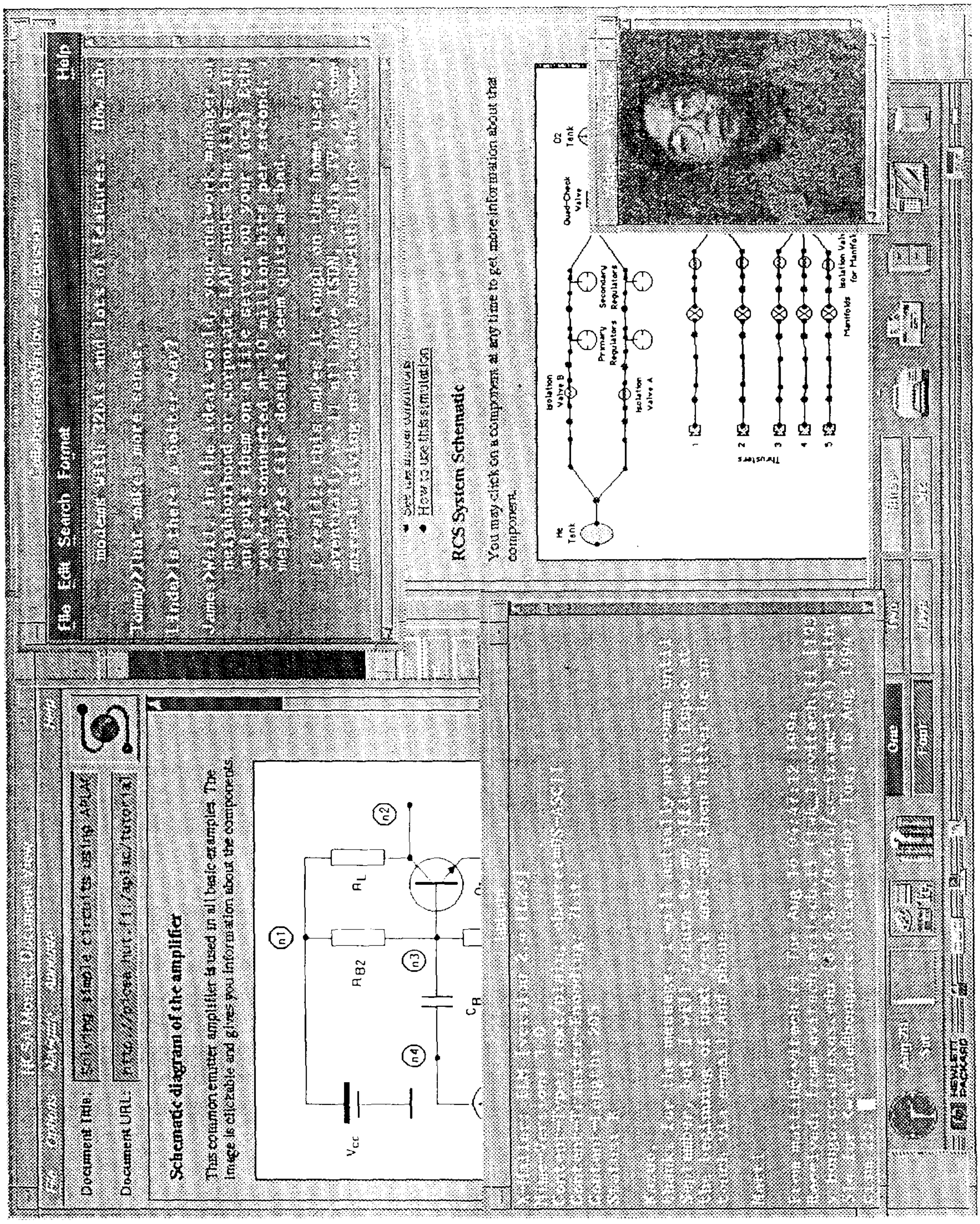

Fig. 8. Screen example.

(1) Support for effective collaborative learning among students by integrating synchronous and asynchronous communication. Students can exchange various forms of information, such as voice, pseudo-video, image, and text, through the same network (the Internet).
(2) Support for lively synchronous information exchange:
The system provides students voice, pseudo-video and collaborative windows, for exchanging information real-time. Students can find other students online easily and begin collaborative learning smoothly.
(3) Providing information access facility for students:
Students can retrieve and relate information both from the learning materials prepared for the course and from the various information sources available on the Internet
(4) Cost efficiency:
Student communication costs are potentially reduced by designing the system to use just local ISDN or phone call for connecting to the Internet.

The CODILESS system is in its first experimental stage. The authors are striving for experimentation with students to enrich the functions and to assess the effects of voice and video on collaborative distance learning, relating learning materials to information on the Internet, structuring student interactions, and searching for the most appropriate study fields for collaborative distance learning.

Acknowledgements—The authors would like to thank Mr Zhangxi Lin of Fujian Computer Society, Mr Xin Yue Lyu of Ministry of Posts and Telecommunications, People's Republic of China, Mr Erik Patynen and Mr Tuomas Kytomaa of Espoo-Vantaa Institute of Technology, for their advice and great contributions for developing the CODILESS system. We also would like to thank Mr Ramnath Chellappa and other doctoral students at the Center of Information Systems Management, Graduate School of Business, University of Texas at Austin for their help and advice.

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