DIF8914 Distributed Information Systems

Distance learning: overview and design issues

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Abstract

The goal of this essay is to give an overview of distance learning. This is a very broad and interesting field, and it could be studied from many different perspectives. Here we focus on the history, different types of distance education, corresponding design challenges and technological solutions and present some examples of commercially available software systems. We devote less attention to the pedagogical and sociological aspects. Finally, some future trends and possibilities are mentioned.

1 Introduction

E-learning or distance learning is education where the instructor and students are (at least partially) geographically dispersed and technology is used to facilitate education (Neal, 2000). Distance learning can supplement or complement traditional classroom education. Research shows that 1/3 of postsecondary education institutions in USA offered distance education courses in 1997-98, and more institutions plan to start such courses in the nearest future. (Lewis et al, 1999).

The main advantages of distance education are availability, reduced cost, flexibility and integration (Beller et al, 1998), (Neal, 2000). Students are capable of taking their courses from their homes, often at their own pace and when they have time, without disruptions to their family life (Neal, 1997). Travel costs and lost workdays are saved if employees have the opportunity to follow necessary education from their workplaces. For example, IBM saved more than $ 157 million in 1999.

These features are especially important in the modern, highly competitive world characterized by international corporations and distributed workplaces. Technological progress, especially in the field of communication, has provided the necessary “push”, while users’ needs act as a “pull”. Distance learning is now used in many important arrears:

- University;
- Business (employees and customers);
- Government and military;
- Continuing professional education (Neal, 2000).

In all these cases there are both economical and pedagogical concerns. The powerful multimedia technology used in many distance courses allows real world simulations, instant feedback and active learning, just to mention some advantages (LaRose et al, 1998). Research shows that distance education is just as effective as traditional education in regards of learner outcomes (Lewis et al, 1999). These advantages, together with the cost reductions mentioned earlier, led to a growing demand for distance education systems, so the market, offering technology, content, portals and add-on services, is growing rapidly. It is estimated that companies spend about $ 2.2 billion a year on distance learning. Around 84-85 % of all education in US colleges in 2002, will be online, compared to 58-62 % in 1998 (Neal, 2000). The next stage will probably be "formation of coalitions and alliances among universities and other teaching bodies"(Beller et al, 1998).

The technologies used in distance education are often standard groupware technologies like videoconferencing, shared whiteboards and workspaces, chat and so on. Therefore it is impossible to write about the former without giving an overview over the latter. The most popular technologies in postsecondary education institutions according to (Lewis et al, 1999) are asynchronous Internet instruction (58%), two-way interactive video (54%) and one-way pre-recorded video (47%). Therefore we will take a closer look at the technologies behind the World Wide Web and distributed multimedia applications.

2 History of distance education

The development of distance education has resulted from so-called push and pull factors: the technological advances created user demand, while extensive usage of technologies led to further development in technology. (Lewis et al, 1999). One can distinguish between four generations of distance education technologies. The timeframe of the first generation is from 1850s to1960 and the technologies employed are print (correspondence classes), radio and instructional television. The second generation (1960-1985) is characterised by use of multiple technologies, but not yet computers (print, fax, television, video and audio cassettes). Further advances in computer technology in the 1980s and in telecommunication technology in the 1990s (Beller et al, 1998) have introduced new forms for distance learning, like computer-based training on CD-ROM, Internet and Web-based classes in the 1990's. We can divide this period into two generations: 1985-1995 and 1995-2005. Both generations are characterised by extensive use of computer technology together with more traditional tools like fax and print. Electronic mail, chat, bulletin boards, computer resources on disks and CD, audio conferencing, asynchronous and synchronous communication between class participants, Internet are the common features for these two periods. The difference is the emergence of high-bandwidth computer technologies in the late 90s. The 4th generation is characterised by two-way interactive real-time capabilities of audio and video, desktop conferencing and video available on demand (Sherron et al, 1997).

More and more universities are now re-evaluating their traditional educational methods. Over 2500 college courses from about 100 universities were available online in 1998 (LaRose et al, 1998). According to other sources (Lewis et al, 1999), 54,470 different distance education sources were offered in 1997-1998 academic year in USA by postsecondary education institutions. We have good reasons to believe that this trend will continue.

At the same time the new technologies provide foundation for creation of new organizational forms. We can mention following organisational arrangements in connection with distance education (Phipps et al, 1998):

- Enhancements to traditional campus-based instruction: an addition to ordinary education;
- Consortia or collaborative: multiple institutions join together to provide distance education;
- Virtual universities: "institutions that offer most or all of their instruction via technological means and are distinguished by their nearly exclusive use of technology as the educational delivery device".

3 Types and modes of distant education

Distance education can be classified by the following table by (IDE, 1998):

	Asynchronous	Synchronous
Independent		
Cohort		
Collaborative		

Table 1. Classification of distance education

Independent learning: student does not rely upon other students.
Cohort learning: groups of individuals who move through a program of study.
Collaborative learning: individuals within a cohort depend upon one another during a part of the learning activity.

3.1 Asynchronous education (with or without instructor)

Asynchronous education means that communication and collaboration between teachers and students takes place across time and space. This kind of instruction is usually provided via Internet, Web-based classes, computer-based training or videotape (Neal, 1997). The instructor, if present, could be on video or online, human or software agent. Interaction with peer students is supported in many distance courses through for example mail, mail groups, bulletin boards, BSCW et cetera (Neal, 2000).

3.2 Synchronous education (instructor-led)

Synchronous education tools support communication and collaboration at the same time. This type of instruction often involves use of videoconferencing or interactive distance learning network (IDLN) (Neal, 1997). IDLN is a tool that allows the instructor to be seen and heard by the audience but the feedback is limited since the students can only communicate with him/her via typed messages. Other important tools for teacher-student and student-student communication include application/screen sharing, whiteboard and collective web-browsing.

In many cases both synchronous and asynchronous teaching modes are used during the different phases of a course. Students could schedule meeting face-to-face or online with the teacher or peers when needed and study the course material individually and asynchronously otherwise. This approach is adopted by for example Electronic Data Systems (Neal, 1997).

4 Technologies for delivering distance learning classes

4.1 Asynchronous distance courses

A central concept in this field is computer-based training (CBT). This is a self-paced training including text, multimedia, audio, video, animation and graphics. Computer-based courses often include practice sessions, book marking and possibilities for progress tracking. The structure of such courses could be linear, dependent on student scores or simply navigation based on student's interests. There can be different degrees of interaction with the learner. CBT courses are often distributed on CD-ROM (Neal, 2000).

Another important concept is Web-based training. It is a very broad concept with no standard model. It could be CBT-course distributed over Web. It has certain advantages over traditional CBT, for example better updating of the online materials, greater accessibility and more advanced mechanisms for teacher-student interaction. For example, CBT courses developed in ToolBook II Instructor can be distributed via LAN or Internet and be viewed through ordinary browsers.

Distance education is closely related to knowledge management and corporative learning in organisations. Intranet is considered to be a standard infrastructure for organisational learning support (Harvey et al, 1997). Companies like Sun Microsystems and Visa International use this technology for publication and reports, collaboration and communication, online reference and training. The advantages of Intranet compared to other IT infrastructures include functionality over different platforms and standards to ensure open communication:

- TCP/IP as network protocol;
- HTTP as a communication protocol;
- HTML as a document format;
- A Web browser as document viewers (Harvey et al, 1997).

The same standards are used by Internet. The World Wide Web is considered to provide a framework and "enabling technology" for CSCW applications in general and distance education in particular. (Bentley et al, 1997). WWW provides a significant degree of integration and information sharing and is "most suited for asynchronous, centralised CSCW applications with no strong requirements for notification, disconnected working and rich user interfaces". The functionality of WWW can be relatively easy extended with the Common Gateway Interface. One of the basic web-based collaboration tools, also used in education, is BSCW. This system allows document sharing, event notification, e-mail and so on. Many commercially available authoring tools, for instance ToolBook II Instructor, provide mechanisms for distribution of the designed courses over the Internet by using plug-ins and code conversion. There are several asynchronous Web-based conferencing tools, for example TeamRooms (Roseman et al, 1996).

There are a number of supporting tools that are used complementary to the “main” technology. Examples are discussion groups, mailing lists and forum and discussion tools (WebBoard). E-mail and messaging can be used as a form of a correspondence class, but it is more appropriate as a supplement to class communication. An example is Instinctive Technology eRoom.

4.2 Synchronous distance courses

One of the simplest technological solutions is audio conferencing by phone. It is easy to use and inexpensive, but the available phone lines do not always satisfy quality demands for conferences with multiple participants. Another possibility is audio conferencing by Internet, if bandwidth is good enough. To achieve sufficient quality it is necessary to use two telephone lines for bi-directional transmission, noise suppression and echo-cancellation mechanisms (Neal, 2000). As with others transmission technologies, it is necessary to establish communication protocols. Audio conferencing has a limited effectiveness and should be supported with visual material when used for a long period of time.

A well-known groupware technology, also used in distance learning, is electronic whiteboards/screen sharing. Examples are Microsoft NetMeeting, DataBoard and SMART 2000 Conferencing Software System.

A special group of distance learning applications is so-called virtual worlds. Examples are MUDs (multi-user dimension), MOOs (multi-user object-oriented environment) and MUVE (multi-user virtual environment). These are virtual places with objects, rooms, identities, roles and chat. Students and teachers are often represented as “avatars”, animated figures that can “speak”, make gestures, show emotions and communicate in more traditional ways via text messages. Some systems like MOOSE Crossing, offers constructionist-learning environment, where students can learn through designing their own objects (Neal, 2000). Since learning is a social activity, it is important to provide effective and convenient technology to support social conversation. One of the most popular applications is chat. It exists in endless variations (for example Internet Relay Chat (IRC)) and is used both for business and pleasure, instead of phone. The Palace is an example of a system that incorporates a virtual world, a slide show and chat possibilities. "The Palace Internet software allows students to listen to a lecture, see a slide show and chat with teachers and other students, all in real time." Another example is WorldsAway (Neal, 2000).

Video communication has an important place among distance learning technologies. It is for instance used in casual and business communication, telemedicine and education. The advantages of video communication are the richness of visual cues and social contact that are missing in chat and whiteboard.

Recent advancements in network bandwidth, compression technologies and computer performance have led to the routine use of video-on-demand. (He et al, 2000). It appears that viewers’ access patterns differ markedly from live attendance or when watching a synchronous transmission. On-demand-video allows users to watch the videos where and when they like, jump from one segment to another, forwarding and reviewing and at the same time be able to access other relevant materials like slides and documents. These patterns of usage demand that digitalized videos are structured in a certain way, with a table of contents available together with possibilities for quick movement between presentation segments. An example of a system that provides these facilities is Microsoft Technical Education (MSTE) for internal technical education to corporate employees. (He et al, 2000).

We have following main types of videoconferencing:

- Room-based. Several people share a video cite. An interesting example is the MAGIC design by (Okada et al, 1994). This system provides a simulation of a multi-way round table meeting with life-size pictures of participants together with multiple eyes contact.
- Desktop videoconferencing. An example that combines different collaboration technologies is the Distributed Collaborative Video Viewing System (DCVV) by (Cadiz et al, 2000). This system allows students to watch a lecture on a video from different locations and communicate with each other by telephone, video or chat and stop/start the video when needed. The system was implemented by combining Windows Media Player and Microsoft NetMeeting.
- Media spaces: physical space is altered and augmented by using electronic media (primarily video). A media space was created in the Xerox Palo Alto Research Centre, connecting Palo Alto, California and Portland. (Bly et al, 1993). Both individual offices and public areas like rest room were connected, allowing workers to locate colleagues and start both individual videophone conversations and group discussion.

There are several technical requirements in connection with use of videoconferencing:

- Equipment (cameras, microphones);
- Technology for camera directing towards the speaker and capturing speaker's gaze (Okada et al, 1994);
- Codex for compressing and decompressing video frames (MPEG);
- ISDN or modem connection;
- Possibilities for multipoint control (DCVV).

Videoconferencing quality can be characterized in terms of following parameters:

- Frames per second;
- Resolution;
- Lag between two sites or audio and video streams.

Other important issues are compatibility between concerning equipment and transmission speed, failures in transmission and room layout (Neal, 2000).

Another interesting set of tools is data conferencing. These tools include web casting, eventware and internet/intranet broadcasting. Both audio, video and PowerPoint slides are combined in real time, with a user interface designed after an office or classroom metaphor, for example PlaceWare Conference Center 3.0 and Microsoft NetMeeting.

To manage distance courses, special administration tools, Learning Management Systems are used. Databases are used for registration, billing, curriculum and access management and scores tracking. Examples of such systems are TrainingServer, UOL and Docent. Packages include among others library of course templates, authoring tools, administration tools, technical support, discussion and collaborative tools.

4.3 Technologies for delivering of hybrid courses

One of the examples of the new trends in distance learning is virtual universities, both corporative and traditional (Beller al, 1998), (Neal, 1997). They combine both synchronous and asynchronous technologies. Different classes and courses are presented through learning and educational portals. Among examples are Thinq that offers customized corporate solutions and eCollege, a virtual campus based on SQL databases. Lotus LearningSpace is an interesting system based on several software modules that can be accessed through Web or Notes. For example, LearningSpace Forum consists of 5 modules:

- Schedule: organising class activities;
- Mediacenter: contains course content;
- Course room: threaded discussion and feedback;
- Profile: personal homepages;
- Assessment manager: exams managing.

This modular approach provides better structure and possibilities for reuse.

5 Design issues

Design cycle for distance education software is mainly the same as for software in general, and consists of following phases:

- Analysis: educational goals, problems, learners;
- Design: description of learning activities and evaluation methods;
- Development: design and test description;
- Implementation: plans for delivering and supporting class;
- Evaluation: make sure the class is effective (Neal, 2000).

It is impossible to cover in detail each of these stages, so I choose to concentrate on the general implementation issues.

Since most universities now offer distance courses, it is necessary to work out a set of design principles in order to integrate new technology successfully into the existing framework. An interesting attempt has been done at The Pennsylvania State University (IDE, 1998). They suggest among others following general guidelines:

- Support for interactions between participants in the learning process;
- Encouraging of social interaction;

- Accessibility of tools;
- Quick recovery from technology-related interruptions;
- Feedback mechanisms;
- Support for creation of a learning community.

In practice these guidelines mean that several tools should be combined in order to ensure effectiveness and user satisfaction since only use of multiple technologies can compensate face-to-face communication (Neal, 1997). It is impossible to describe all these technologies within this report, so we will concentrate on the most important and popular ones. We will give a short overview of technologies behind the World Wide Web and an introduction into distributed multimedia systems.

There is a number of commercially available authoring tools for creating courses tailored to particular needs:

- Flash;
- Authorware;
- DreamWeaver;
- Toolbook II Instructor.

5.1 The Web as enabling technology for distance learning

The Web is based on relatively simple client-server architecture. Clients can request information from servers using a standard HyperText Transfer Protocol (HTTP) (Bentley et al, 1997). In HTTP 1.0 specification it is stated that HTTP is a "protocol with lightness and speed necessary for distributed, collaborative, hypermedia information systems." Further, "a feature of HTTP is the typing of data representation, allowing systems to be built independently from the data being transferred". That means that both clients and servers can be extended to handle new data formats, which is especially important for multimedia applications.

The data format used in Internet is HyperText Markup Language (HTML). This is a simple format for creating documents that are portable from one platform to another. (HTML 2.0 specification). A Web document is structured by standardised mark-up tags. These tags can be understood by both humans and browsers. Standardized General Markup Language (SGML), which HTML is a part of, provides a framework for structured information exchange and distribution, especially as a part of organisational learning process (Arbotrex, 1995).

Another important feature of the Web is the Common Gateway Interface (CGI) that is a standard for interfacing external applications with information servers. This mechanism allows Web browsers to handle different types of data. At the same time many Web servers provide Application Programming Interfaces (APIs) to add new functionality to the servers. Some of the HTTP requests are treated as calls to scripts and the server invokes these programs instead of handling the request. The advantages of CGI are simplicity, language and architecture independence, well-defined standard and process isolation (Bentley et al, 1997).

All these features allow an easier distribution of applications in a heterogeneous environment, usually by extending a Web server through a CGI. Nevertheless, Web has many limitations:

- The only type of communication allowed is client-initiated client-server communication. That implies that feedthrough, user notification and feedback are limited. (For example, students cannot see immediately what their project fellows are doing).
- Poor user interface, only simple widgets available.
- No guaranteed Quality of Service. That means that transmission rates between servers and clients are not guaranteed. Under these conditions it is difficult to provide necessary quality for video and audio conferencing and for multimedia applications.
- Centralised architecture. No support for distribution and replication is provided, which may affect performance for multimedia applications that demand powerful resources.

We can conclude that the Web is best suited for distribution of asynchronous classes, with no strong requirements for synchronous collaboration and advanced user interface (Bentley et al, 1997).

5.2 Distributed multimedia systems

A distributed system is a system designed to support the development of application and services which can exploit a physical architecture consisting of multiple, autonomous processing elements that do not share primary memory but cooperate by sending asynchronous messages over a communication network (Blair et al, 1997).

There are several reasons for using distributed systems in distance education as well as in other applications:

- Resource sharing: databases with course content are shared between students;
- Availability: more computing resources to each user due to redundancy;
- Extensibility: virtual university can be easily extended with more students and courses;
- Performance: a better performance is achieved when numbers of processors are interconnected by a high-speed network;
- Distributed organisations: students and employees from different parts of the world can take courses without having to travel away from their workplaces and families.

There is a number of standards in the field of open distributed processing:

- The Reference Model for Open Distributed Processing (RM-ODP);
- The Common Object Request Broker Interface (CORBA);
- The Distributed Computing Environment (DCE);
- The Telecommunication Information Networking Architecture (TINA).

A distributed multimedia system is a number of multimedia workstations interconnected. Multimedia itself can be defined as the property of handling a variety of representation media in an integrated manner.

We can identify continuous and discrete media types. The former include video, audio and animation, the latter text and graphics.

One of the main challenges for multimedia development is the increasing need for continuous data transfers in real time, for example transmission of a lecture on video. All media types have certain bandwidth requirements (see table 2). Use of appropriate compression techniques like JPEG and MPEG reduces the bandwidth considerably and improve overall quality of a multimedia system.

Table 2. Demands of digital continuous media

Generally, the requirements of distributed multimedia applications are following:

- Support for continuous media: video- and audio conferencing;
- Quality of service management: quality of negotiation, renegotiation, admission control et cetera;
- Real-time synchronization (intra- and intermedia): synchronization between one or more media streams, for example, lip-synchronization;
- Multiparty communications: support for interaction between different groups of users (Cadiz et al, 2000).

To provide the support for continuous media, the existing programming models are not enough. They include:

- Asynchronous or synchronous message passing;
- Remote procedure call;
- Object invocation.

They are mostly suitable for discrete interaction. Continuous media can be modelled by a sequence of interactions, but this is too ineffective. Therefore it is necessary to provide systems support for stream interaction in terms of scheduling, communication protocols and memory management.

We can distinguish between simple and complex streams. The former is a single flow of data where the data is of a single continuous media type, while the latter consists of several flows of data where each flow has potentially distinct media type. Streams can be present in digital or analogue form.

Another important requirement of distributed multimedia applications is Quality of Service, "the necessary supervision and control to ensure that the desired quality of service properties are attained and, in the case of continuous media, sustained." The most important categories in terms of distributed systems are:

- Timeliness: end-to-end delay (latency and jitter);
- Volume: throughput of data, frames per second;
- Reliability: Mean Time Between Failures, % lost of frames.

It is important to ensure real-time synchronization. For intra-media synchronization, or maintenance of real-time constrains across a continuous media stream, this means to ensure that a certain media stream has the right latency, jitter and throughput. Inter-media synchronization is more complex and is concerned with relationships between different streams of data, with respect to a global clock or each other.

Table 2. Inter-media synchronization

In order to allow different groups of users to interact, it is necessary to provide support for multiparty communication. It is achieved by first providing a programming model for interaction and then system support, including construction of multicast graphs using splitting and merging functions. A successful example of implementation of such support is DCVV system (Cadiz et al, 2000).

As mentioned earlier, Internet does not provide appropriate quality of service and does not facilitate synchronous multimedia interactions to a satisfactory degree. The analysis of the available standards reveals that RM-ODP provides the best support for multimedia in open distributed processing (Blair et al, 1998).

6 Future trends

We witness the emergence of new computer technologies all the time, and we have all reasons to believe that the distant education concept will evolve and change. The technological development will lead to higher demand for skilled professionals, which in turn will result in higher demand for courses to educate these professionals. More attention will be paid to "constructing a sense of community" (Neal, 1997) and creation of "virtual campuses" for life-long learning as well as coalitions of universities into an inter-university network (Beller, 1998). As complexity of systems increases, more communication and collaboration will be needed (Neal, 2000).

As we can see, the trends in distance education follow the general trends in organizational development: internalisation, globalisation and decentralization. Another interesting trend is the need to combine different technologies when designing a distance education course, to achieve greater flexibility and user satisfaction. This presents a greater challenge for the designer of the course and underlying system. We can mention following tendencies in software and hardware development:

- More emphasis on handheld and wireless devices, to increase accessibility;
- Next Generation Internet with new applications and capability through greater bandwidth;
- Browsers with greater communication and collaboration capabilities and other new products (Neal, 2000).

7 Conclusions

The goal of this essay was to give an introduction to distance education/ learning. This is a very broad and fast-growing field, so it was impossible to cover all aspects of the subject. Too little attention was given to the pedagogical and sociological issues in connection to distance education. Another very interesting and important part of the field, human-computer interaction and user-interface modelling, was mentioned, but not explored in details due to the limited size of this essay. For the same reasons I had to choose what systems and technologies should be given more attention than the others.

A very interesting problem not explored here is the role of agents in distance education. As earlier mentioned, a distance class is often led or moderated by a human or software agent. Therefore, a course could be modelled as a virtual enterprise with meeting places, where agents representing students and teachers could meet and cooperate (Petersen et al, 2000). This can be a subject for future research.

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Additional resources

http://www.oreilly.com/catalog/wboard4/desc.html

http://www.instinctive.com/product/eroom.asp

http://www.cc.gatech.edu/elc/moose-crossing/teachers.html

http://www.palacetools.com/home.php3

http://www.placeware.com/

http://www.microsoft.com/windows/netmeeting/

http://www.docent.com/home.htm

http://home.click2learn.com/pr/instructorv8.html

http://www.ecollege.com/

http://www.lotus.com/home.nsf/welcome/learnspace