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A CLIENT–SERVER ARCHITECTURE FOR AN INSTRUCTIONAL ENVIRONMENT BASED ON COMPUTER NETWORKS AND THE INTERNET

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Abstract – Computer environments used to date in education and training contexts are most often reduced to a closed configuration, where all software and information are grouped as a whole locally and where the contribution of computer science becomes of secondary importance. However, hardware and software technologies today are well-suited to experimentations and innovative utilization within the various approaches in education. The client–server and network approaches in particular, as well as other new software environments, revolutionize the educational process, by opening a whole new dimension in methods of support for courses, a new relationship between instructor and student, new instructional methods, and a first step towards virtual classrooms. In this article, we propose a client–server architecture for an experimental computer environment, as an approach to a virtual classroom. The outcome seems to be that the evolution and the improvement of this architecture remains intimately linked to technological advances anticipated in the areas of hardware platforms, interface software integration, data transfer rates, and the methods used for producing teaching supports. Copyright © 1996 Elsevier Science Ltd

INTRODUCTION

The first experiments concerning the use of networks in the area of education and training go back more than 10 years (Keegan, 1986). The use of a computerized environment and networks was often limited to the simple exchange of messages or the consultation of electronic blackboards (Dumont, 1990). We find such an approach in the distance education activities supplied by Télé-université in Québec, and by the Open University in Great Britain (Bates, 1990), among others. It has been only recently that technology has permitted us to envision the integration of networks as a powerful component in the quest for knowledge and the exchange between various

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players in the educational context (Dixon, 1990). Three major evolutionary changes explain this:

- the improvement in performance occurred in distributed computer networks;
- the substantial progress achieved in the quality and the integration of the human–computer interface and client softwares dedicated to numerous client–server applications;
- the integration of concepts such as distributed multimedia and hypermedia.

If it were necessary to give only one example summarizing these various evolutions, this could be the performance and possibilities found today in the World Wide Web (WWW) and its various client softwares such as Mosaic or Netscape. The complementary services offered by these client interfaces, being graphical and multi-protocol, are available on most hardware platforms, with possibilities of storage, indexation and retrieval of distributed information. Therefore, the immense range of possible applications foreseeable in the future becomes unimaginable.

Several projects intended for educational applications and integrating computers, multimedia and networks, are already under study or in the experimental phase (Perry & Kalinzinski, 1990; Work, 1993). One of the constants in most of these projects is that they integrate many specific developments (Bergeron, 1993), especially at the level of the user interface, and when this is not the case, in an even more restricting manner at the level of the actual hardware being used (Giardina, 1992). To illustrate this last approach, we look at the UBI project which began its experimental phase in 1995. One of the components of this project (which by no means falls short of being ambitious in the planning of the services envisioned, since they are not limited to the educational field alone) is to anticipate a specific and closed terminal, similar to the project undertaken by the French Minitel 10 years ago. In this article, we take the opposing view of this closing down, despite the logical advantages that it can bring in a marketplace reasoning. Indeed, the choice of components that are standard and widely distributed appears to be essential for the development and longevity of such an architecture. Compatibility on various hardware platforms is also an advantage in opening to a large number of users and developers, and to many different contexts of utilization.

In the sections that follow, we are going to present first a description of the essential functionalities, then the architecture in detail, and finally a synthesis of services supported by this architecture.

DESCRIPTION OF THE FUNCTIONALITIES

We can envision a classification of available technologies according to various approaches. We deliberately opt for that of the functionalities offered. It allows to visualize the various elements entering our problematic, and to see how they integrate in an educational approach. First, we will find functions of dialogue and exchange, this exchange can be between two individuals or between the instructor and his public. Second, we find the functions that allow the access or recovery of documents and support necessary for courses. Third, come the environments that allow the search for information, or navigation in knowledge bases, according to a random or direct course. Finally, fourth, come the functionalities allowing the creation and disposition of the educational documents. These various functions being accounted for, the entirety of the communication and access process of the information are covered in this way. However, another type of service will be necessary, one that allows the control and validation of what is learned. It will have to be adapted to the particular teaching contexts in which our workshop will take place.

The dialogue and the exchange

As shown in Fig. 1, the dialogue and the exchange are essential vectors of teaching: exchanges between the teacher and the learners or students, individually or collectively, and dialogues exchanged between learners. In a network environment context, several techniques can be used concurrently: E-mail and information forums (or bulletin board services) are already ancient techniques but still widely used. New possibilities offered by messaging interfaces (MUA or Mail User Agent), in particular the MIME standard (Multipurpose Interface Mail Exchange), which allows the manipulation of 8-bit characters and composing or receiving of multimedia messages, have improved a number of possible uses for these techniques.

The dialogue and the exchange equally can be the effect of distributed visioconferencing, which offers another dimension to the interaction between users.

The possibility of following from a workstation, under a suitable environment, a course while it is being presented in another location, opens new perspectives to distance education. These functions can finally be fulfilled by the MUD (Multi User Dungeon) (Curtis, 1992) or the IRC (Internet Relay Chat). They are both protocols that, with variants, allow dialogues between geographically scattered groups of people. The MUD or its object version, the MOO (MUD Object Oriented), allow one to recreate through programming particular operating contexts that can take the appearance of a virtual classroom (Work, 1993; Masinter & Ostrom, 1993).

The recovery or delivery of documents

To reply to the need of recovery or delivery of working documents, the support for courses or corrections, it will be possible to implement two approaches that can be complementary. The first, which corresponds to the possibilities of remote connection, allows one to consult on-line for available files as if they were local. The second goal is to allow uploading on a distant server documents composed locally, or downloading

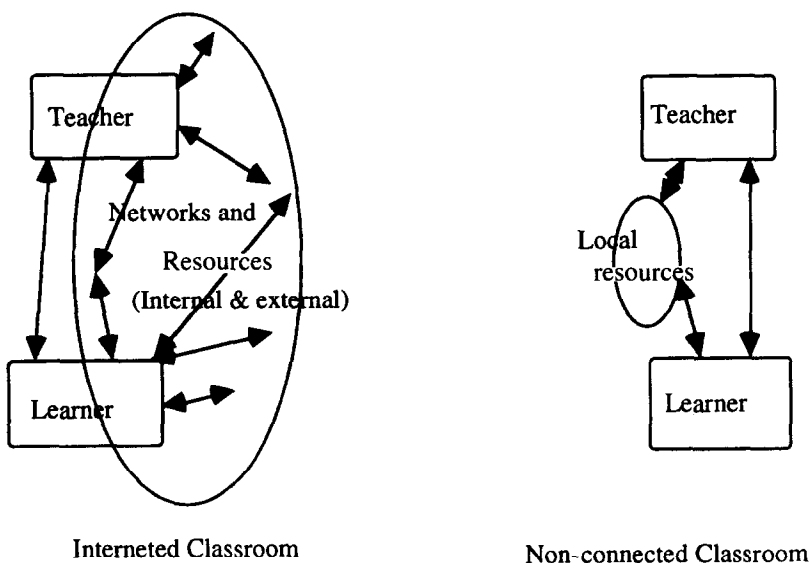


Figure 1. Interneted and non-connected models of a classroom.

on a workstation documents made available from a distant server. This corresponds to the file transfer utilities associated with the various tools of compression and coding of information to insure an efficient transfer.

The search for information

The techniques used in searching for information and navigating on resource servers follow two very similar different reasonings. The first technique is similar to that of the querying found in traditional databases, information bases, or libraries. The search is generally done by key words and access can vary. Results are generally limited to summaries or bibliographies, the entire document rarely being accessible on-line. But this first level of result facilitates acceleration of the work of documentation essential at all levels of education: it is as important to the students as for the teachers.

The second reasoning dominates principally in the navigation within knowledge bases. It is similar to an exploration of an encyclopedia that returns to us subjects that are similar in interest to our specific search. Various data organizations can be envisioned, the richest being that of hypermedias distributed according to the diagram of the WWW (Berners-Lee, 1993).

The production of documents

In our approach to an educational context based on computer networks, the essential objective is the availability and transfer of knowledge. For this to happen, the teacher must be able to offer a content and an instructional procedure using, ideally, this new environment. The major task is to provide the teaching content in a digital format. It is, therefore, necessary to establish on site an environment which facilitates capture, organization and access to this new knowledge, by respecting course and access reasonings. To convivial word processings, it appears useful to add the possibility to organize these documents and their course in a distributed hypermedia scheme that can evolve easily. The various supports can therefore take the form of HTML (HyperText Markup Language) documents, authorizing those notions of distribution and the ability to evolve. Associated functionalities, in particular the facilities of saving and annotating, allow to make these initial documents personalized and/or active supports, enriching themselves as they are used (Eisenhart, 1994).

THE DETAILED ARCHITECTURE

An information infrastructure dedicated to training and education must integrate at least four components (Dempsey, 1993): a network infrastructure providing access to networks and services; a local institutional infrastructure that is a context for valid use of the network and information services; an application architecture defined as a set of high-level protocols and exchange formats which allows the building of flexible open information services; and the network information base, that is, a range of electronic information resources, services, and tools for communication and publishing.

This section describes an advanced teaching environment, based on existing elements, that conforms easily with a realistic budgetary pocket, and constitutes an academic information infrastructure for distance education and training. These first elements can serve as a basis to a proposal for the experimentation in a distance education context, within the framework of a virtual classroom. To limit the scope of this work, we propose only the standard software already included in the operating system

of computers, or application softwares that are frequently available as freeware on the Internet and allow the creation of a user-friendly work environment. The following three features are essential: transportability and both easy recovery and installation. These are the best ulterior distribution wagers in the event of positive experimentation. The existing services can be used, but it is necessary to anticipate complementary specific supports for the courses, if these supports do not already exist.

The framework of experimentation

The framework that we propose is founded on the following set of hypotheses that condition its effectiveness:

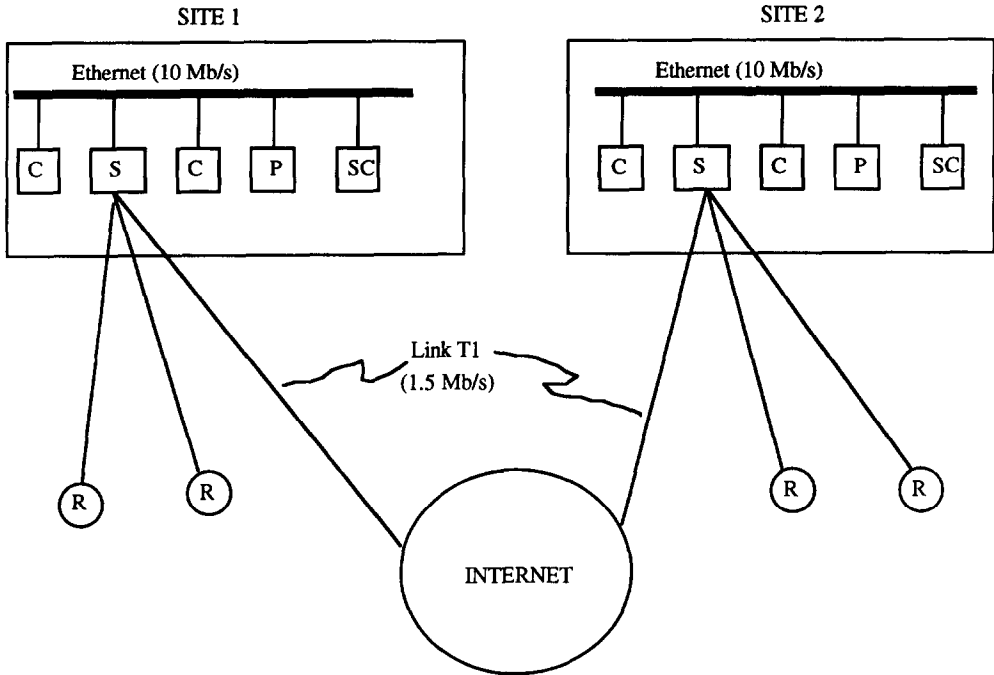
- An homogeneous linguistic context that avoids the duplication of supports, where the domination of a foreign working language is not always well accounted for by “local” hardware and software, nor by educational programs.
- A determined teaching level context, where the educational resources to be made available may vary according to the type of training and academic level chosen.
- The context has to be adequately transposable to allow an ulterior and larger distribution.
- The context must be one of distance education, in two different meanings: the first level of distance is geographical, in that two (or more) classrooms far apart, but following the same teaching, are supervised by the same instructional team; the second level of distance is physical—the context has to allow a participant constrained by any partial hitch to access from another site the same content of training as if he were present in one of the classrooms, with a comparable margin of comfort depending on the bandwidths which are available.
- The technical competence is available to build and manage this configuration, and the instructional team adheres to this approach; these criteria seem obvious, but it is preferable to reassert them.

Hardware architecture

As shown in Fig. 2, the proposed hardware architecture consists essentially of two sites equipped as follows:

- A local network with a high transfer rate, such as Ethernet (10 Mbit/s); this is the minimum specification to which all machines will be connected (Buckle, 1993).
- A connection to the Internet provided by a high-speed line offering a high quality in bandwidth (at least a T1 line, e.g., 1.5 or 2 Mbit/s) towards the distant site.
- Possibility of connection to the “server(s)” from the outside through a number of various media such as telephone and ISDN (Integrated Services Digital Network) lines.

It is generally common knowledge that all aspects related to the network infrastructure are the responsibility of specialized departments (service and support department, for instance) in an educational institution. It is a question of defining a realistic environment, in which these classrooms can be set up. These two distant local networks (possibly of several thousands of kilometers), should be able to be seen as one local network if we so desire, by the utilization of proper addresses and the eventual installation of a file-sharing system such as NFS (Network File System).



Legend:

- C: client server
- S: UNIX multi-user server station
- SC: Scanner
- R: remote stations
- P: printer

Figure 2. Hardware architecture.

As much as the network corresponds to an infrastructure of the institution, the definition of costs and the choice of components depend largely on the competence of the realization team. The hardware for each of the two classrooms would be identical. This common choice will facilitate savings at a number of different levels such as: lower purchase prices, simplification of development and the eventual sharing of software, easier maintenance and a more manageable environment for the indispensable technical competence available. The choice of identical hardware must be oriented largely towards widespread solutions, insuring the existence of many new developments, but at the same time providing enduring use of the investment made and a compatibility with other platforms in the industry for possible future applications. Such considerations must be taken into account when choosing hardware in a client-server environment.

The server machine. The server, being multitasking and multi-user, uses an operating system similar to UNIX at both sites. An economy can be made by installing one common server at only one of the two sites. This server can be seen as local by all the machines if all the network parameters are set correctly and the performance of the line

is acceptable. The reasons for such a choice are related to some specific features of UNIX:

- It is currently the most widely used platform on the Internet, in particular where servers are concerned, and therefore the best choice in the development field.
- It is the type of system on which most network components are easily integrated.
- It is possible to manage concurrently a great number of processes and users.
- It supports numerous types of inexpensive peripherals.
- It supports all the softwares that we consider in our experiment.

This machine serves in some manner as a platform from the classroom to the outside world. It can serve in many common ways, from providing many local services to the management and security of other information servers, including exchange (E-mail, News,...), computations of all sorts, useful and perhaps indispensable in some cases; it also insures information storage. A SUN Sparc, HP or DEC server, running UNIX, with at least 64 Mb of main memory, a few Gb of disk space, a backup system such as DAT reader (Digital Audio Tape), and managing one or two good laser printers, one printer being color, would respond perfectly to all needs. The printers can be connected directly to the network, without overloading the server; at least one printer is required at each site. A color scanner should be included among these shared peripherals.

The client machines. Client machines are individual workstations used by the learners as well as the teachers or trainers. It is desirable, albeit not essential, that these workstations have at least the following components:

- A color monitor, the bigger the better (19" or 21").
- A flexible graphical user interface.
- A multitasking or a multi-user system.
- The integration of a network component (TCP/IP, Ethernet port).
- A complete set of multimedia peripherals—microphone, sound card, camera, and CD-ROM.

We can also add to this workstation configuration some portable solutions (notebooks) having the same basic equipment except for the camera and CD-ROM, to allow several users to temporarily be away from the site, however with an integrated V32 bis or V34 modem, with the possibility of using a cellular telephone.

According to these descriptions, we can envision keeping, by the decision makers, three possible platforms: a UNIX station, a PC running Windows, or a Macintosh. The choice of a PowerPC hardware would be without a doubt one of the more prudent choices today. This hardware will certainly support the three operating systems mentioned, so the possibility of switching from one to the other depends on the evolution of circumstances and needs.

The software components

The softwares must have all the tools needed for accessing and designing courses, such as: other softwares, files, documents, and information. They must also allow the exchange on all modes (textual, images, and sound) between other users, and even with the outside world. We do not envision making any specific developments, this is not the role of an instructional experiment. The focus here is to produce educational material suited to institutional needs.

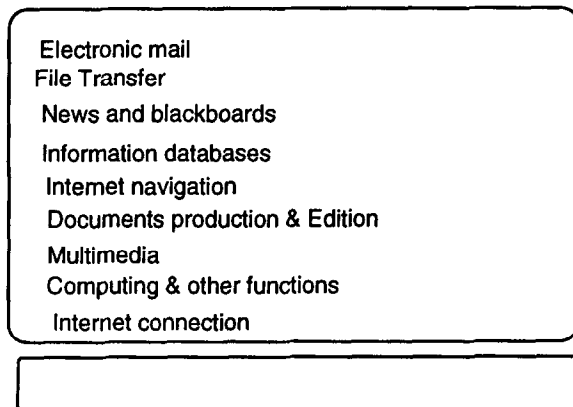
With regard to the workstations or client machines, they must have all the basic tools needed to access the Internet (as described above) and, if possible, a global interface allowing access to a set of desirable functions, such as E-mail, participation in news forums, file transfer, navigation and search abilities, as well as generating or access to multimedia information. Figure 3 summarizes such functions.

In addition to the specific utilities, a client–user interface such as Mosaic may be very useful. Unfortunately, the utilities associated with Mosaic, such as decoders, compression and decompression utilities, sound player and viewer for either fixed or animated images, are not yet integrated in the client software. Finally, it is pertinent to mention the various translators and editors used to produce HTML pages.

By taking, for example, a Macintosh PowerMac, the software configuration could practically include the following elements:

- Eudora for electronic mail.
- Fetch for file transfer.
- NCSA Telnet for remote connection.
- Nuntius or NewsWatcher for the reading and posting of USENET News.
- MacWais for interrogating bases indexed by WAIS (Wide-Area Information Server).
- TurboGopher as Gopher client.
- MacMosaic, MacWeb, or Netscape as a client WWW.
- CU-SeeMe and Maven for multiple visioconferencing and the associated sound.

To this we should add other utilities, such as: QuickTime; MacTCP; PPP (Point to Point Protocol), at least on the notebooks to establish a TCP/IP connection on the telephone network; JPEGView, for viewing and decompressing fixed images; Sparkle, for viewing and decompressing animated MPEG images; Ulaw, for the processing of sound; BBEdit or HTMLEditor, for producing HTML pages; converters for HTML (e.g., RTF2HTML or Mail2HTML, or even Latex2HTML), for retrieving documents created in the respective formats mentioned which are to be converted into hypertext documents; file compressors and uncompressors, like Diskdoubler, StuffIt and CompactPro; and encoders and decoders, like BinHex.



Client Workstation

Figure 3. Desirable Internet functions in the software architecture.

The software corresponding to the client workstations installed must reside on the server, while taking into account whether all the information necessary is available locally (in full or in part). It would be wise to install a gateway between the various “demons” managing these servers, in order to be able to access the WAIS or FTP (File Transfer Protocol) servers by means of the same client. Furthermore, it would be also important to install and configure the MUD server and the reflector CU-SeeMe for these two applications. Finally, it would be necessary to foresee the installation of the News server and the messaging spooler to manage these last two aspects.

On the other hand, an account must be opened in the name of each user on the server. It is there that users will receive their electronic mail and save their files. On the one hand, this would eliminate the problems of backups, which can be carried out in a centralized and automated fashion directly on the server, and on the other hand it also enables other learners or students to use the client workstations in the course of the day or the week, without compromising any confidentiality. This centralization is very useful for facilitating the evaluation process that can be implemented at the site. The gateways used for security measures could also be found at this level, as well as statistics and accounting information on the usage for selected resources.

SYNTHESIS OF SERVICES

From the beginning, it will be very useful to make available an auto-training course about the new educational environment proposed. To learn these kinds of techniques through the use of examples is without a doubt the first step towards cost-effective use.

There already exist on the network resources that can be adapted for all ages and levels of knowledge. For the remainder, it will be necessary to try and use, whenever possible, the resources available on the Internet. It remains evident, nevertheless, that many services are not yet covered, especially in a context other than the anglophone one. As shown in Fig. 4, the classes must make up an integral part of the Internet and benefit from distant and local resources.

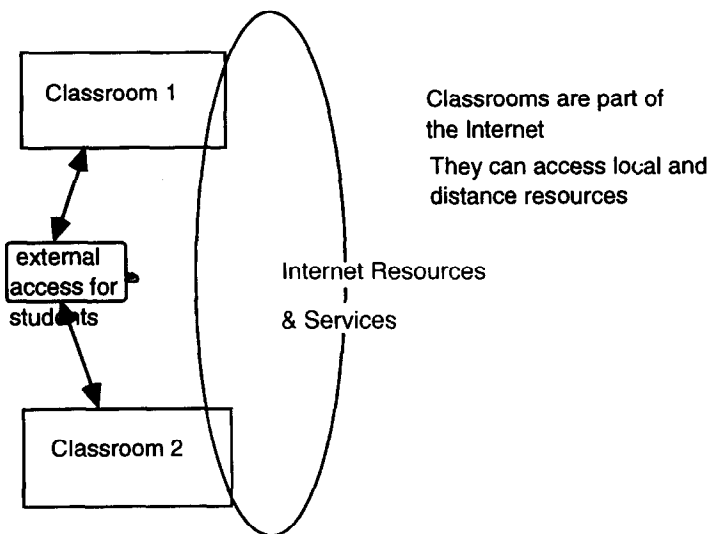


Figure 4. Internet resources shared by various classrooms.

Furthermore, it seems indispensable that the teachers define and design a set of courses covering the educational program, by following the instructional objectives. These courses must be made available as they are produced, on the server being used in the project, with the appropriate security measures necessary to protect against unauthorized use of the services. This is also the case for exercises, control of certain knowledge and associated corrections for which the issues of authorization and authentication of access have to be anticipated. In some cases or certain disciplines, it may be necessary to have access to experimental protocols or laboratory experiments. In other cases, it must be possible to execute procedures—such as compilation of programs, processing of statistical data and text translation—without having to change the software environment.

On the other hand, it is necessary to think about the informational environment: does the educational institution have a library or a documentation center accessible electronically? Would indexation of documents take place under WAIS? Are there various documents that could serve as a base for the foundation of the documentation? Can we make readily available a unilingual or bilingual dictionary, an encyclopedia, a database with pictures and sound, or would it be necessary to anticipate a Gopher or WWW server that would point to other resource available on the Internet? So many questions to which it will be necessary to find answers. These answers may take various forms according to the local context in which they are applied: available local informational bases, or putting on-line a CD-ROM jukebox supporting some of these various informational elements. However, it is important that this does not prevent the navigation and random search: given the new services arriving on-line each day, it is very difficult for an administrator to know at all times if the resources that they have indicated are still the best available on the set of servers at any one time.

It is necessary to define the teaching context in which the shared interactive environment can be used: exchange and accompaniment tools between members in the virtual classrooms thus created, or the primary vector of the teaching discourse. In the current setting and with the means implemented, it still seems difficult to only preserve the second approach. It remains that the set of components of the “classroom”, including its associated environment (library, discussion lounge, work hall, possibility to work in groups or meet the teacher), must be present and accessible in the most natural and user-friendly manner, but within a virtual setting that can be matched with real-life experiments.

CONCLUSION

If we wish to show in a realistic and inexpensive fashion the potential of such an architecture, a good way to begin would be to try to reproduce it on a small scale, this reduces a certain number of difficulties and lifts some constraints, giving better control. Nevertheless, it is necessary to gather together all the components of the system in their true magnitude, if we want to succeed in having a representative and coherent model.

The evolution and improvement of this architecture can come from a certain number of technological advances in the very near future that we can explain as follows.

Improvement of hardware platforms

Shortly appearing on the market will be multimedia workstations, integrating all the necessary peripherals needed to manipulate sound and images (this already exists), but also integrating specialized microchips for MPEG2 compression and decompression,

and processing sound. This must bring a reasonable improvement in quality and performance under identical conditions of data transfer.

Improvement and better integration of interface softwares

One of the directions taken by software developers, which corresponds totally to the utilization needs in our context, is the union and integration of the numerous functions available in one software package. The objective is to have only one client software package to do everything. On the server side, we are headed towards the integration of various functions allowing indexation, presentation, searching, and navigation.

Improvement in the rate of transfer available

It is clear that these rates increase rapidly, and the emergence of ATM (Asynchronous Transfer Mode) or B-ISDN (Broadband ISDN) will be great progress. It is necessary, however, to make certain that this improvement of the bandwidth is not depreciated by an increase of similar proportions in the traffic to be carried.

Improvement in the generation and support of teaching methods

It is in this area that the most obstacles exist. Not only because of the slow arrival of adaptable software in the market (user-friendly hypertext editors allowing efficient producing of HTML documents, multimedia integration tools), but also because what exists in other media is still very important. Most of the currently available documents within the context described are transformations and adaptations of traditional documents. Very few have been written with the organizational reasoning found in hypertext. It is necessary in this field, and even indispensable to the global environment described, to promote the emergence of documents "of another kind". Such an evolution will not come in 1 day, without the help of those who produce documents, or without the active participation and major changes in the fields of publishing and documentation. It is our opinion that distributed hypertext documents, active and enriching themselves by readings, annotations and successive utilization, will allow reasonable evolution in the sectors of education and training.

In the long term, taking into account the progress in miniaturization and communications, one can dream of seeing the workstation reduced to a flat screen connected to the network and incorporating several specialized microchips offering possibilities of virtual reality, automatic translation, freehand writing and sound processing, all of this in a wireless fashion. In about 15 years, that is, on a time scale of one generation, this seems a foreseeable challenge.

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