Design and Architectural Issues for Digital Libraries over the Internet

ARMENI S., CHRISTODOULAKIS D., GAROFALAKIS J., KAPPOS P.

Department of Computer Engineering and Informatics

University of Patras

26500, Rio, Patras

GREECE

Abstract:- In the recent years, there has been significant growth in the use of Digital Libraries to support electronic delivery of information. This paper defines the architecture, the functionality and the design elements to be considered during the implementation of a sophisticated, contemporary and highly interactive Digital Library. After surveying the current architectural and operational trends, a four-cell architecture is presented that reflects the strategy trends for the creation of the Digital Libraries. Social aspects and user interface techniques define the outline that influences the whole structure of the Digital Library.   CSCC'99 Proceedings, Pages:5451-5458

1.1 Introduction

Digital Libraries (DLs) are more than an electronic version and extension of the public conventional paper-only libraries and the difference is expected to grow in future. As Wiederhold claims [1], replacing paper with electronic storage leads to three major differences: storage in digital form, direct communication to obtain material, and copying from a master version. In that sense, DLs stop imitating the public libraries any more. A library is the medley of various objects, such as the operation of the creation, storage, classification, access, selection, disposition, and the distribution of the information to the customers. A digital library is an integral of the above-mentioned characteristics and by no means can it be considered separately. Improving the digital library as a whole, it means modifying all the above in a sophisticated and organized way. The research field of DLs must be viewed as a union of subfields from a variety of domains combined with new research issues [2].

It should be noted that no matter how well defined is the design of the DLs, the user's volition is the primary factor that determines the user's acceptance to that system [3]. The scope of this paper is to present and survey the current developments at the DLs' area as well as to raise some criticism at the design state of DL systems. The classification of the DLs is firstly made by the application point of view and secondly as an internal four-cell hierarchy. The previous organizational structure is beneficial for the abstraction during the design phase of any DL system. It raises important issues that can be constructive in any attempt to provide distributed information in a uniform way.

The paper is organized as follows: Section 2 provides the properties and the kinds of the existing digital library systems. In section 3 the integrated services of DLs are addressed, giving more emphasis at their architecture, their user interface and the security issues for their smooth operation. The last section provides essential conclusions elicited from the present work.

2.2 Current Developments

DLs gave scientists the opportunity to communicate with each other easier, to have direct access to publications and to consult more sources of information instantly than ever before [5]. The current developments in the field of DLs are though several perspectives surveyed at the following sections.

2.1.2.1 Definition of a Digital Library

The technical community considers DLs as a collection of digital materials combined together using electronic means, while for the traditional library community a DL is a supervision of the whole organizational process.

In their first steps, DLs were principally based on the architecture of the physical libraries (e.g. the process of selecting, ordering and acquiring new books, their categorization, etc.). However, the contribution of the technological achievements led to dramatic changes, while new opportunities and new problems came up. In the beginning the use of computers in traditional libraries was limited to

helping the librarians organize books supplying them with a service to make their work easier. The evolution of that primary use of computers has gradually led to including all text and multimedia data into computers. The combination of the above information and the provision of services have resulted in the introduction of DLs to the community [Fig. 1]. For better understanding of these changes, it is necessary to have a quick view of the characteristics of the DLs and the services they provide.

Plain paper data were useful in DLs only at the first time when data are extracted from the paper version and are inserted into the database. Since the pieces of information are kept in a digitized form, the users are able to acquire them using electronic methods.
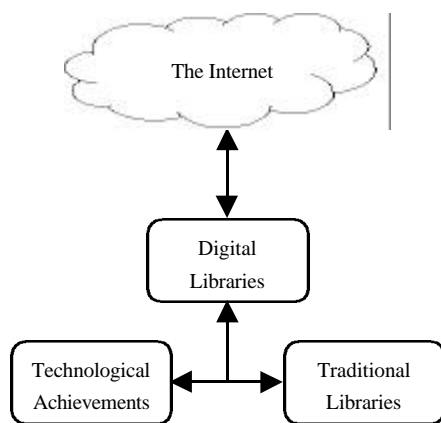
Fig. 1: A Digital Library on the Network

The times of long visits to the library to browse through books and journals tend to come to an end, since users are now accustomed to accessing the databases while being inside the easiness of their work using their favor workstations. The pleasant atmosphere of the library has been pushed aside, since the main relation is now between the user and a network connected computer. Searching has become even easier and quicker, and the number of databases in which one can gain access simultaneously is increasing continuously. The users can get the information as a result of the query from different resources in a piecemeal manner.

This abundance of information has limited users' attention, causing a change in the way the users are reading. The new way of reading is as essential as the traditional one. With the new one, the readers can quickly select the information they need, while the old one still provides a deeper, more sustained, and uninterrupted reading [4].

The users are able to find references about a book, or be informed where they can find it, or buy it, but it is doubtful if they are going to find it online as a concrete material.

The direct access of all users to the source works (documents, songs, videos and the like) violates the intellectual property rights of the creators if they are used without the author's allowance. Most authors lose huge amounts of money, without having a way of getting them back. Also, the copy from a master version has repercussions to the publishers and the editors. The need for more information has, in a way, forced the publishers to increase the number of publications, while the budgets stabilize and the number of subscribers decreases [1].

2.2 Authentication and Authorization

DLs are known for their availability and accessibility. More specifically it would be right to say that DLs can be easily accessed, if someone is allowed to. Of course, everyone connected to the Internet can gain access to the majority of electronic libraries possessing a valid username/password combination.

The authentication is the process of identifying which user wants to gain access to a server mostly by a combination of username and password pairs. After successful authentication, the user can only use resources that are explicitly assigned to him. Roles or groups (e.g. operators, administrators, staff) have been assigned to all users so specific services can be accessed by specific groups. Usually, after the payment and the subscription, a user can be identified and is then able to have access to the member area of that service by entering the correct username and password.

2.3 Categories of DLs

Categorization of DLs was imminent due to the existence of many types of them. DLs can be categorized according to the combination of the services they provide and the data they contain. Considering the existing electronic library systems' categorization, four different groups can be made:

The first group of DL is the one that contains classified articles, papers, and publications in general. The users are able to inquire the databases via a search machine, making use of keywords. The result of the query shows the related publications. This is like a public library, where the experienced library staff, who helped the patrons in their search, has been replaced by search engines. A difference is that users cannot borrow books, nor have a copy of the paper if it is not online. In that case, they still have to visit the library.

The next kind is the one that looks like an online bookstore, (e.g. http://www.amazon.com). In this case, all users have access and the ability to inquire the databases. Moreover, they have the ability to order the preferred books by simply entering their credit card's

number while the shipping of the products occurs quite soon.

The third category is the one that carries multimedia data, such as images, sound and video, in addition to the textual data. An example is the Carnegie Mellon University's Informedia Digital Video Library [6], where one is able to determine a video's distinguishing content without investing long viewing times or requiring high bandwidth network-transfer speeds. Geographical Information Systems (GIS) form a similar type of DL, whose data are coordinates and electronic maps.

The fourth developed kind is the one that integrates the first of the aforementioned kinds with the additional features of reviewing and publishing. Online journals [7] are well defined, providing specific roles for each operation, apart from the good organization of the structure they should have. The operations of obtaining, reviewing, accepting and publishing the works must be combined with the operations of storing and classifying the data.

2.4 Comparison of Categories

Some common characteristics can be observed through the services that DLs provide. All kinds are comprised of an organizational system, which can be divided as administrative management and technical. For example, in traditional libraries the director was responsible for the managing of tasks such as: selection of books, their ordering, etc. Things such as the repairing of the shelves were taken care by the technical staff. This structure still exists in DLs, where the selves are renamed to directories. The difference is that researchers do both management and technical support, under the supervision of the librarians, the merchants and the people that organize conferences.

Every electronic library constitutes an online information provider, which allows any Internet user to gain access to it. Moreover, search facilities are provided so that, users are able to acquire the information. Another common element is the use of the Hypertext Markup Language (HTML) as the main language that builds the User Interface. Finally, the idea of pricing is getting used more and more, and electronic commerce becomes quickly a worldwide reality.

2.3.2.5 Open Issues of DLs

The difficulties faced in DLs can be distinguished as administrative and technical. Due to the existence of different kinds of DLs and uses of them, many divergent problems are met.

The administrative problems of electronic libraries, which are like the public ones or play a similar role to bookstores, are complexed, but not insuperable, because they are solved for the traditional libraries at first. For example, the apportionment of the works, or the classification of the books and generally the subject assignment has already been solved. Furthermore, all the concepts of the public libraries have been transferred to the DLs of that kind such as the role of the secretary. Dramatic changes in this area are not expected to occur, except for improvements and refined implementations of the existing systems.

DLs that play the role of journals have also main administrative and organizational problems. The real organization of the journals gives an excellent example and guidance for the implementation of an electronic one. However, the human interference is still necessary, so that wrong submissions can be validated before sending the manuscripts to the reviewers. Such automation is still an open research issue incorporating artificial intelligence and heuristics.

The network services, in addition to the administrative issues, contribute to the quality of the service. As far as the DLs are concerned, they do face compatibility problems, when different systems and databases have to be interconnected. In this case, searching through databases has to be taken into consideration. Search engines can be used to collect data from different information sources, index them in its local database and then provide a uniform way of presenting the results. An important matter is to define the optimal way of merging the results. To keep the quality of search high, it should be quick and efficient. Talking about DLs it should be noticed that not all articles are available as full text. In that case the users are obligated to visit the library if they want to have a paper, that is not online. Moreover, the different DLs of various universities are mostly not connected to each other. If users have to order a paper from another library, they still have to visit their local library repository. There is not such a rendering of service to help the users online in these cases.

The use of many DL systems is not always easy and their user-interfaces are complicated. Most of the times users prefer to abandon a new-looking interface or use it sparingly if they have to devote a lot of time to learn a new user-interface.

The appearance of electronic libraries is based exclusively on Hypertext. The lack of expressive and rich visualization of hypertext facilities is apparent. Current web browsers are inadequate for detailed, serious work in many disciplines, since the current HTML implementation does not fully support the character sets needed for phonetic or scientific notation except for digitized data (e.g. images, sound, etc.). Also graphs can be represented only as images and not in an enumerative form. The whole system should be interactive, but simultaneously it should also provide

protection of the original images from deliberative or accidental modification by the users.

Another problem that is neither administrative nor technical, is the high cost of the procedure of designing the databases and inserting data into them. Ôhe development of the digitized instructional material by the library staff, the design and implementation of sophisticated web pages, the class materials, the conversion of hand written notes into a form suitable for digital representation form serious costs that cannot be overlooked.

Due to high costs in DL maintenance, many of the services are provided after payment. The use of agents is instructive wherever negotiations take place or shopping model based systems exist. The agents are computer programs that act independently and communicate with each other providing sophisticated, user oriented assistance in many perspectives. A society of agents consists of many agents, which are capable of working together. The simplest predominant charging model is the annual subscription model. Consequently, if users are interested in only one paper, they are seldom given a pay-per-view chance.

Great attention should be paid to keep the system intact from external intruders. Later on common rules that should be followed to minimize unauthorized access to the web system that serves the whole system.

3.3 Design Trends

It is difficult to be absolutely certain about the evolution and development of the DLs in future. Whatever DLs are supposed to be, they will inevitably share many properties with current libraries and will differ from them in innumerable ways as well [10].

3.1 The Four-Cell Architecture of DLs

DLs of any kind can be viewed as a structure of four cells [Fig. 2]. The basis of the structure is the Technical Cell. It deals with the storage issues, the interconnection of the databases with the web and the communication protocols [2]. The next two cells are the heart of DLs and expound the administrative and the metadata issues. The process and the modification of the data are a matter of the Metadata Cell. In contrast to the Metadata Cell, the Administrative Cell determines the way the tasks are going to be synchronized, the use or not of a lexicon, the different facilities and the definition of the roles in an electronic library. The security of the systems is between the Technical and the Administrative Cell. The upper cell is the User Interface Cell, which takes care of the appearance of a DL, provides on-line help and

generally formulates the look-and-feel of the front-end interface.
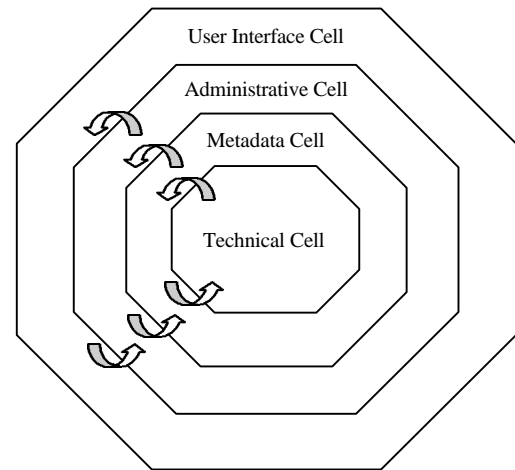
Fig. 2: The Four Cells of a DL

A good strategy is to design the system from the outside cell to the inside, while the implementation should start from the inside cell to the outside. It is obvious that any change at the internal cells has an important effect at the external cells. Developments can occur in any of the four cells. The technological aspects as well as the social aspects are the ones that define the features of DLs.

3.2 Integrated New Services

It is expected that future services will integrate and modify the existing facilities and will adopt new ones.

Since DLs are based on the architecture of the hypertext, the system can be an open platform, if open distributed hypertext can be adopted [11]. Goals such as openness, distribution and hypertext views can be incorporated in DLs. Openness can be achieved by allowing easy integration of new applications and new media types. One step further in the direction of implementing an open system is to cater for the distribution of application services as well as the hypermedia documents themselves.

Some application services may cause a lot of problems in their future use, if the specification of the role of the semantics is not done in an adroit manner [12]. Semantics could be handled in several ways: one significant method is to understand the meaning of the contents by applying natural language processing techniques whereas another one is to utilize the relationships between concepts built up in a thesaurus. Although now the use of lexicon is bounded only in several systems, in future it is expected to be a common case. Information retrieval systems should make use of a lexicon [13], [14] or of a system that classifies the concepts (e.g. frames or ontologies). The representation of knowledge can contribute to more

efficient search results. Furthermore, searching for keywords may be replaced by searching the metadata, which performs quicker and is more powerful [15].

Another facility that just appeared in the Internet is the Alta Vista's automatic translation service. It translates any HTML document from English to French, German, Italian, Portuguese, Spanish and vice versa. Of course, no machine translation application can to generate perfect translations. The quality of the machine translations ranges from pretty good to barely comprehensible. In fact, they are advertised less than 90% accuracy. They are designed to give the user the gist of a Web page's content, but nothing more. As it can be expected, there are rough spots, some of them humorous. The applications work well with everyday words, but they don't do so well with sites, which contain specialized terminology.

New ways of marketing and advertising techniques are going to be incorporated into DLs. Contemporary trends in advertising include rotating banner advertisements, on-demand multimedia material delivery and automatic software upgrades. Moreover, useful services can be the automatic notifications of new additions to a digital repository.

It should also be noticed that the creation of multinational companies in the WWW could bring a revolution in the commercial world. Additionally, various kinds of issues (e.g. legal) have to be examined in order to join to the e-commerce world [16], [17]. The need for co-operation among the scientists of various domains is now more obvious than ever before.

3.3 User Interface & Metaphors

No matter how efficient one application is, it must have a friendly User Interface. In this direction research in Human Computer Interaction (HCI) has been spectacularly successful and has fundamentally changed computing [21]. User Interface and metaphors play an important part of investigation for HCI. These can help users better understand the concepts behind the actual information that are provided and the path traversed [22].

The term 'metaphors' is traditionally associated with language use. When we want to convey an abstract concept in a more familiar and accessible form, we frequently resort to using metaphorical expressions [23]. Desktops, icons, menus, windows, copying, pasting, cutting are either system objects or actions are part of a virtual interface metaphor. In fact, it is difficult to think of a system that is not based on some form of metaphors.

Exploiting the potential of metaphors is a crucial point since their advantages are universally known. Appropriate metaphors, agents or characters, who act on behalf of a user, in a virtual computer-based environment and good navigation tools are needed to help the user define her destination, the path she has followed, the indexes of the sites and the way she can gain access to pieces of information. However, their performance is going to change. As mentioned in [24] the innovation of new kind of real-world metaphors is inevitable.

The traditional desktop-office will remain in future only in isolated home computers. Nowadays, there is imminent need of a new, efficient desktop for DLs. DLs and every multi-user system that supports distributed, asynchronous interaction will not be benefited from flat rooms-like interfaces. Real-world metaphors are needed such us: a virtual city, shop's windows, secretary desk, bookstores, merchants and so on.

When the user enters the main page, it is a good strategy for the system to firstly inquire the user for his age and use that simple information to change the user interface according to his age. Since two different user interfaces of one system, one for children and one for adults, is not a prohibiting overhead, greater possibilities exist to satisfy the potential user.

Carroll et al. [25] suggest four steps in the design of interfaces in which metaphors are used. At the beginning the candidate metaphors must be identified, while the second is the detailing of the metaphor/software matches with respect to representative user scenarios. Next step is to identify mismatches as well as their implications and finally to design strategies to help humans manage the mismatches.

These instructions can provide a basic strategy on facing the most common issues on user interface design. The users are familiar to working in room-like, flat interfaces, and seldom accept new experiments for other work environments. The controversy between the scientists and common users exists; users do not easily accept modifications of their favored desktop while scientists try to invent new schemes of communication.

3.4 Data Security

Any Internet connected site is instantly accessible by all network users. However, that situation is a double-edged weapon. It surely provides wide diffusion of its information but is also closer to any intruder. The administrator of that system should deploy all available techniques to shield his system to any unauthorized Internet user.

The transfer of confidential information through the Internet poses the need for advanced security measures from any unauthorized Internet user. The necessity of secure channels of communication and different levels of security is a major problem during the design of every Internet-based transaction system and consequently, of DLs. This section gives

guidelines on how to secure Internet connected systems from both inside and outside intruders. There are several categories that security is applied [19]:

System Security

The security of a computer system starts from the resistance of the operating system. All patches must be applied to enhance the system's security and all security "holes" must be closed. Only authorized users must log in to the system, guest accounts must be disabled and the administrator should apply correct file/directory restrictions.

Communications Security

The data among computers are transferred from servers to clients and vice versa. If those data are transferred without encryption it is possible for anyone to sniff them, log them to a file and then use them in any hazardous or offensive way.

Data Security on End-Systems

After the two above actions we should pay attention to secure the data which arrive to the end system and are stored to its hard disc. Those data should be encrypted by the receiver-program before being stored as a file to the hard disc. One common way of further enhancing the security on end systems is to, firstly, cipher the data and, then, store a piece of that information on the hard disc ciphered and the rest data transferred to another system by secure E-mail. With that technique we distribute the confidential data to two machines, increasing the strength to a potential intruder who now must crack two systems instead of one.

An important component of an overall security strategy is the deployment of firewalls. Although firewalls cannot prevent data-driven attacks, they provide control of traffic that is incoming or outgoing to the corporate web site. Traffic can be accepted or rejected based on application type and source address.

The strictest method for setting-up a firewall is to deny all access that is not explicitly permitted. A more liberal policy is to permit all access that is not explicitly denied. When tight security is desired the first rule should be followed, while organizations with less to lose in a security breach might choose to adapt to the latter strategy. The strictest rule is also the most difficult to live with, in the case of an application gateway. Each application that is permitted must have a proxy. A proxy is a software program that runs on the firewall and appears to internal users to be a host, whereas it appears to the Internet to be a client. The proxy translates packets between the two applications. In the case of E-mail a good proxy will strip out internal host names from mail headers and replace them with the firewall's host name, in keeping with the policy of hiding internal host names and IP addresses.

The Secure Sockets Layer (SSL) protocol [20] is designed to provide privacy between two communicating applications (a client and a server). Secondly, the protocol is designed to authenticate the server, and optionally the client. SSL requires a reliable transport protocol (e.g. TCP) for data transmission and reception. The SSL is a protocol layer, which may be placed between a reliable connection-oriented network layer protocol (e.g. TCP/IP) and the application protocol layer (e.g. HTTP). SSL provides secure communication between client and server by allowing mutual authentication, the use of digital signatures for integrity, and encryption for privacy.

In addition to the above mentioned network security concerns, we can not neglect another serious security concern that has to do with intellectual property rights for the data contained in DLs [18]. The fast expansion of information networks and the introduction of DL technology has risen the problem of media copyrights, author rights, access control and payment for digital material. Once it is published, it is difficult to control the use, manipulation and distribution of digital information and even more to guarantee related rights. The advent of distributing data over high-bandwidth Wide-Area Networks looks like a worst-case scenario for intellectual property. Owners of content - text, images, sound, and motion pictures - are understandably fearful of releasing proprietary information into an environment which lacks of security and has no accepted means of accounting for use and copying. One of this is the watermark, which is a hidden message within a digitized image, video recording or audio recording. The watermark is integrated with the content of the data file itself and requires no additional storage space.

~~3.12~~ 3.5 Social Aspects

The social aspects of DLs should be given great concern while building client software to gain access to a DL. '…*Although electronic journals are becoming more common, they have not achieved as much penetration as many expected…*" claims Marchionini [9]. The previous case is also applied to DLs.

It takes time to realize that the personal relationships with experienced library staff that knew visitor's interests has disappeared in DLs. Furthermore these relationships, are replaced with search profiles that supply regular updates on new publications in a particular field of research. Thus new metaphors are absolutely necessary. If the new system isolates human beings, then it is natural not to be welcomed. The pages should therefore convey a cozy view and personalized feeling without distracting the user. The user should be free to choose from a variety of colors

for text, the shape of the buttons she likes or the selection of inclusion of graphics in the pages while browsing the electronic library.

Changes in the structure of DL are already visible. They start playing different roles. For the moment, the most dominant role in DLs is that of the librarian and the merchant's. The roles of publishers, editors, librarians, and research assistants must be bound to online services in order to build a viable library resource. DLs from their side should reimburse authors and publishers for their efforts. Therefore, new vocations (e.g. manager of Internet preface) are created and specialized trained staff is needed.

Small pilot distance learning systems are based on DLs [8], while large Open Universities systems could be based on them, providing all the facilities of real public libraries. It is apparent that the Internet provides the users with a cheap mean for communication. With its increasing growth rates more and more people can connect to distant DLs and are benefited from that new status of DL remote access. All administrative problems are not yet solved and are considered a synchronous point of technical and organizational discussion.

4.4 Conclusions

No one can ever be sure about the new developments of DLs. There is always a dilemma when new improvements are tested. The current needs or statuses determine possible strategic choices for DL designing. Social status, such as the decision for mass or elite education, focus on both research and education, has deep reflections to the architecture of DLs. Furthermore, contact- and market-needs lead to new kinds of DLs.

A four-cell architecture of DLs was presented. The outer cells usually interest the users and the librarians, while the inner ones are carried out by the scientists and the technical staff. Every cell has limited signs of improvement and it is important to notice that every change at inner cells effect the outer cells.

The appropriate capacity to prepare the new strategies and activities is already in progress. The appropriate technologies and support services to execute the strategies are also partially available. The only real drawback seems to be the lack of a social research in combination with the market research, and a good, well-defined design that could be able to integrate all the existing technologies under a common umbrella of the several available categories of DLs.

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