Web-based information systems

Nicola Aloia, Cesare Concordia, Vittorio Miori

CNUCE – Institute of the National Research Council of Italy
Pisa Research Area - Via Alfieri 1, 56010 Ghezzano – Pisa (Italy)
Phone +39-050-588997- Fax 050-904052
E-mail Nicola.Aloia@cnuce.cnr.it

Abstract

The ever-increasing growth and penetration of the World Wide Web and associated technologies is bringing about significant changes in how information is organized and managed, with far-reaching consequences for the information systems of a great number of organizations. Moreover, the increasing reliability of tools and techniques stemming from the "Web revolution" is rendering it ever more convenient to base the development of new applications on this technology, especially because of the great advantages it affords in terms of scalability and distribution. The present article deals with the fundamental characteristics of information systems based on Web technology and illustrates the problems that need to be tackled in their development and management. By way of concrete example, an information system implemented for the Italian Ministry of the Environment is briefly discussed.

Keywords:

Web Information System, Internet, Open Hypermedia System, Public Access WIS.

1. Introduction

In the mid 80s, technological advances engendered significant costs reductions in electronic components and equipment, thus giving rise to the installation and wide-spread use of computer systems in many organizations and promoting the automation of production processes and information management. Organizational needs for information management systems has increased steadily ever since, fostered by the ever-increasing amounts of data to be handled. At the same time, information itself began to emerge as a commodity, whose production, management and distribution required automation. Soon, the role of information systems extended well beyond their fundamental functions of regulation-system support and administrative/organizational control.

The rapid development of the World Wide Web as a tool for accessing the Internet, determined mainly by the appearance of multi-protocol clients such as Mosaic, Lynx and Netscape, has brought on a new computer revolution. Web technology has offered large numbers of new users a low-cost way to broaden their activities and distribute information to a far vaster audience. At its inception the WWW was used mainly as an environment for the distribution of information by firms and organizations. Over the years "Web sites" have become more sophisticated and services-rich, and have thus been transformed into ever more complex tools to support information systems, where these were present, or making up their initial core, though at times in a rather confusing fashion. The new functionality requirements of Web applications, for instance the ability to access business databases, and the new possibilities consequent to emerging technologies, for instance e-Business, together with the maturation of the tools available on the Web, has made it increasingly imperative to rethink the role of information systems in organizations.

The present work therefore discusses the fundamental characteristics of information systems in which Internet-accessible components are tightly integrated with the organizational system. Moreover, we shall look at the advantages stemming from exploitation of the Web as the infrastructure for creating the constituent subsystems of the overall computer system and analyze the new problems this engenders.

The remainder of the article is organized as follows: firstly, we present a brief, concise review of articles that have provided food for further thought; the following section then introduces the fundamental characteristics of information systems and Web-based applications; then, discussion of the implementation of Web Information Systems (WIS) follows with an analysis of the problems involved in their implementation. Before concluding. we briefly illustrate a concrete example of a WIS implemented for the Italian environmental board.

2. Related works

A wide-ranging treatment of the characteristics and the general problems related to WISs can be found in *Communications of the ACM*, published in July 98 (No. 7, Vol. 41), which contains, in particular, a thorough analysis of the specific problems surrounding Public Access WISs and their

implementation[1]. In the August 98 issue of the same publication there is an interesting article on the state of the art in Web technology that highlights its lacks and the as yet unresolved problems [2], as well as a general analysis of Open Hypermedia System technologies in Web applications [3]. A very important contribution to the development of WISs has been made by the studies conducted by Alberto Mendelzon on formalizing the query languages for information search and retrieval over Web; in fact it is his research group that developed the specifications for WebSQL [4], a high-level declarative language for Web searches, and implementation of WebOQL [5], a system for the extraction of data from semi-structured documents (http://www.cs.toronto.edu/~gus/weboql/index.html). Quite an in-depth analysis of the evolution of business information systems in the era of e-Commerce is contained in [6], where methodological proposals are also advanced for the planning and implementation of business information systems for e-Business.

3. Information systems and the Web

An information system is a set of organized man-machine procedures aimed at providing the information necessary to run an organization. The information system is not to be equated with the computer system itself, which is that component of the information system which handles solely the automatic processing of information.
The following can be taken as the defining features of information systems [17]:

- The components of a system are interrelated and interdependent; independent components do not belong to a single system.
- The system must be viewable as a unified whole. Although constituent subsystems may be recognizable, it is necessary to not lose sight of the overall perspective.
- The systems are furnished with aims or goals, to whose achievement the different interacting components strive.
- The systems exhibit entropy (a term borrowed from thermodynamics). Entropy describes the state of a closed system and characterizes its ability to process information.
- The system must possess the ability to check and control its interacting components, so that the objectives can be achieved.
- Systems are generally composed of subsystems.
- Complex systems generally exhibit differentiations, that is, specialized units that perform special tasks.
- Systems generally possess "equi-finality", that is different ways exist for achieving the purposes of the system.

An information system contains three basic subsystems that go to make up the computer system:

- The communications-management subsystem
- The man-machine interactions-management subsystem
- The data-management subsystem

In traditional information systems, the computer tools used have the task of facilitating the realization, communication and processing of the information, and are constrained by the organizational structure, as well as the hardware and software architectures adopted.

In recent years Web technology has grown at an impressive rate, transforming the various "*sites*" from simple marketing showcases to platforms able to provide support to all aspects of organized activities. The opportunity to use the Web environment for implementing information systems offers considerable benefits, while at the same time posing new problems.

A Web-based information system (WIS) is a system whose implementation and management take place through the use of Web technology [15]. There is a clear difference between a WIS and a simple set of Web pages. In the former, the various components (e.g., database managers, transactions processors, etc.) are tightly integrated and allow performing the requisite activities for an organization's functioning. In comparison to a traditional information system, a WIS is an open system in which the information takes on more and more complex forms, thanks to the inherent characteristics of Web technology. WISs can be thought of as being able to contrast the tendency towards degeneration (i.e., entropy). Therefore, one of their most salient characteristics is their great ability to adapt to change quickly and efficiently.

The implementation of a WIS must comply to the same principles of discipline governing traditional information systems. In the next section we analyze the advantages and disadvantages of using Web technology for setting up information systems.

4. Web-based Information Systems

A fundamental characteristic of WISs is their potential to reach a far broader audience than traditional client/server implementations based on proprietary networks by allowing access to information and functions to the occasional user as well as the 'subscriber'. Such a possibility is underscored by the intrinsic features of Web technology: open standards and freely-available, often cost-free, software. Such characteristic are extremely alluring for organizations distributed over a very wide geographic area or that intend to extend their own activities into so-called e-Business ventures [6]. Another noteworthy area for WIS implementations is

represented by public institutions, which generally produce, collect and distribute a great deal of information, access to which may result of the utmost importance for citizens and enterprises alike. Such systems, called Public Access WIS (PAWIS) [1], have a distinguishing characteristic which cannot be understated: *universal access*, that is to say, access to services or public-domain documents must be furnished to all users, irrespective of their experience and/or hardware platform.

In comparison to traditional information systems, the planning and implementation of a WIS requires new approaches, and although, on the one hand, technology very often provides invaluable support with decided benefits, on the other, its implementation often engenders new problems. Let us consider the three aforementioned main computer subsystems (managing communications, data and man-machine interfacing), and have a look at the advantages consequent to the adoption of Web technologies.

Communications management. The Internet network and TCP/IP protocol, by now the de-facto standard, do not set geographical or hard/software limits to the expandability of the communications management subsystem. Extending the communications management subsystem of a WIS, whose nodes are for instance located inside a single building, by adding a node in another city (or another continent) does not involve elevated costs or particular procedures: the technology involved is the same as that for local installations. The possibility of scaling the system easily from local use to remote use is one of the principal advantages of WISs over traditional systems.

Man-machine interaction management. The most important characteristics of the WIS subsystem managing the interactions of man with machine stem from the universal availability of graphical browsers; hence the ability to utilize multi-platform code (mobile or script-embedded) to implement the client components of the system. This not only significantly simplifies developing user interfaces, which are therefore no longer linked to any particular hardware or software architecture, but it also facilitates their distribution and installation [11]. Another benefit, equally as important, stems from leveraging the so-called *mime-cap Interface* in browsers, which enables browsers to "recognize" the type of incoming data and activate the appropriate program or plug-in for viewing, whenever unable to directly effect its rendering. This leads to nearly limitless scalability of the interfacing subsystem: with the opportune plug-in/ program, any type of data can be visualized, reducing to a minimum the interventions needed of the user or the developer.

Data management. Concerning the data management subsystem of a WIS, the situation is much more complex. In traditional information systems, such functionality is usually imparted through recourse to a DBMS that implements the database schema. In such situations, each schema property has a direct correspondence to a property of the database implemented (that is, the attribute of a relationship or a database procedure). In a WIS, the unequivocal correspondence between database schema and property is no longer fixed *a priori*. This is due to the characteristics of Web URLs [12]. URLs can be viewed as a particular type of data [4], which, apart from having its own peculiar properties and operations, inherit other properties and operations from the data types linked to them, as well as the type of server/protocol referencing them. URLs can be interpreted as pointers to information stored in data managers, which may be a DBMS, file system or program (CGI or servlet), etc. that generate documents *on-the-fly*. In such a context, we must consider the data management subsystem as built, not on prefixed data types, as in traditional systems, but as systems that can be dynamically extended with new types. We can then consider the data management subsystem of a WIS as composed of a multiple-data-type manager, which can certainly deal with DBMSs, but are not however limited to these alone. In this new perspective, the schema implementation is distributed, not only from the point of view of location within the network, but also with regard the data managers involved. The introduction of URLs to the processible data types enormously enriches the possibilities offered to the user by the data management subsystem, while at the same time, however, giving rise to new problems, a subject which shall be take up in the following.

4.1 "The problems with WIS"

In order to develop an efficient and effective WIS, it is necessary to tackle some problems never encountered in traditional information systems. For the sake of brevity, the discussion here will be limited to describing only those problems related to the computer science component, though other issues are at stake. The planning of a WIS must provide for, not only distribution of the information, but also its integration with other tools able to perform complex tasks, such as support for co-operative work or the regulation and control systems of an organization. The very perception of the WIS, on the part of the user, as an integrated services and functionality system is a fundamental element for its acceptance and success. In the following we shall address some of the problems, many of which are present in traditional Web-based applications (so-called *sites*), for which WIS technology should be able to furnish satisfactory solutions.

Search mechanisms. Where do I look? What search terms shall I use? How can I tell if the results are the best possible? Implementing an efficient WIS-based search engine must enable users to easily and effectively define suitable filters through a clear user

interface that "guides" them through the creation of unambiguous queries. The engine must supply alternative suggestions in the event of searches with a negative outcome and allow the user to successively refine the search criteria for better filtering.

Slow data transfer rates. The adoption of suitable techniques of load balancing between client and server through the use of mobile code and opportune communications protocols can improve system performance.

Support for cooperative work. Web-based information systems must support the sharing of data amongst the various partners working on a collaborative project. This may come about in two modes: asynchronous (each collaborator has an individual work session), and synchronous (simultaneous access of a group working together in the same session). The tools adopted range from simple email to sophisticated teleconferencing systems. Integration between Web-based and stand-alone tools for workgroup is still in its initial stages and choosing from amongst the different solutions depends on the particular type of interaction desired, as well as other factors, such as users' experience and hardware available to them. The greatest problems in implementing efficient solutions stem from the peculiarities of the HTTP protocol, and its strict client/server communications model. Such a model is well-suited to resources accessing, but it far from ideal for collaborative work. For instance, the client/ server model dictates that the client must make a specific access in order to verify if any change in resources has occurred. Such polling results inefficient when the resources to be checked are large in number and infrequently modified. Implementing a cooperative work environment based on the updating of Web documents therefore represents a poorly suited solution. Until now the problem has been circumvented through the use of client-side plug-ins or server-side add-ons; however the lack of a native mechanism for notification is sorely felt.

Local caching mechanisms. The mechanisms of local storage, or 'caching', currently adopted by browsers are aimed essentially at limiting as much as possible the downloading of pages to be viewed. Such mechanisms are quite inadequate and significantly limited in their use off-line, that is, without the need to have an active connection. WISs must provide some sophisticated mechanism for local information caching that enables off-line use of applications in those situations where the network connection is through a commuted line.

Links management. The management and control of the links is a very important aspect in the implementation of large hypermedia systems [13]. In Open Hypermedia Systems, it is the links that represent the relationships within the model among the different documents constituting the system, thus making "surfing" possible. On the other hand, as we have seen in the foregoing, in WISs, links are a component of the data management subsystem. Current Web technology imposes a number of limits that prevent efficient links management The most serious limitations stems from the *embedded* nature of links in HTML formalism, that is to say, the fact that are inserted into the document text. This characteristic spawns the following problems:

- it is quite difficult to develop tools for the management, control and /or updating of links
- without the ability to interpret the context, it is not a simple matter to use the links to arrive at the relationships existing among the different parts of the system.

This makes it very difficult, not only to implement searches based on the relationships amongst different documents, but also to determine the properties of the target objects *a posteriori*. This latter obstacle is particularly important. In fact, proper implementation of a data management subsystem presupposes knowing all the properties of the data involved. Some solutions for overcoming this limitation have been suggested, such as for example, the use of meta-level links [14], or first-class link [16], developed for the Open Hypermedia System, but to date none has been successfully implemented. Obviating these drawbacks will likely have to await full implementation of a more structured formalism, such as XML.

Security and authentication. Secure data management and data protection are among the main problems to be resolved in Web-based information applications. In a traditional information system there are various user classes, each with specific "rights". Moreover, because the transactions performed often involve critical data, it is necessary to carefully implement protection and security management mechanisms. Implementing the necessary security mechanisms in a WIS framework can prove to be quite demanding. In fact, although firewalls and other software protection schemes may be effective in preventing attempts at "cracking" computers or networks, they do not furnish any assistance whatever for securing transactions or, more generally, ensuring the security of an information system functionality. In order for a WIS to be considered secure, the followings conditions must be met:

Confidentiality - communications or information flow amongst the various parties must be restricted to the parties alone.
Authentication - all users must be certain of the identities of their interlocutors, as well as the origins of the information being accessed.
Data integrity - data must not be subject to modification during the transfer from one party in a communication to the next.

Selective services access - users should only be able to "see" those services to which they have access.

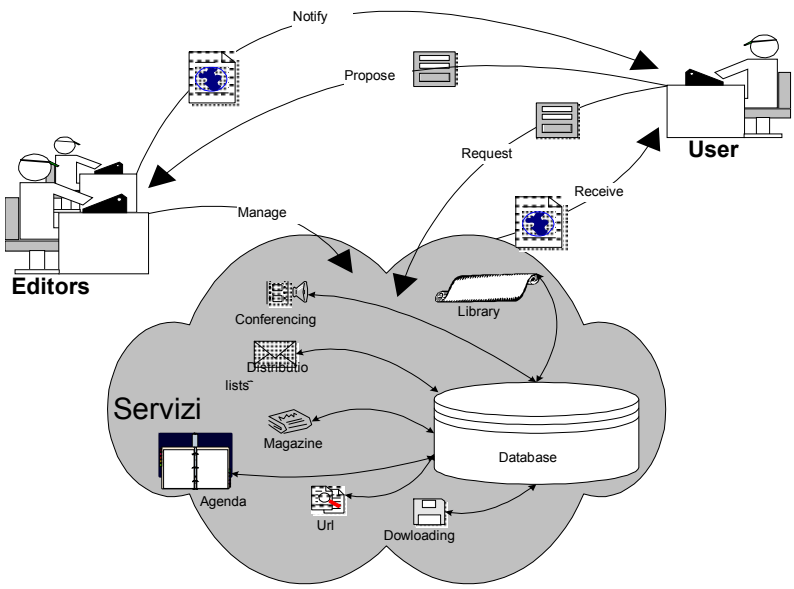
Nowadays, by recourse to secure protocols and data encryption, it is possible to satisfy most of these conditions wholly or partly. Nevertheless, Web technology itself furnishes no native support whatever, leaving most of the onus up to the single applications.

Accessibility. As mentioned, making WIS information and services accessible to the greatest possible number of users is a crucial requisite for public WISs. However, its importance is not limited to such sites alone. The issue must be approached from two perspectives: the technical aspect (for instance, furnishing some alternative to graphical navigation) and the "cognitive" aspect [9] (for instance, keeping users from "gets lost" by following a chain of links and arriving at points far removed from their original objective). To resolve the problems associated with this latter issue, it is necessary to allow users to keep track at all times of the context in which they are operating. This requires careful design and implementation of both the documents' structure and the navigation interfaces. In order to analyze the first aspect, we must first make a further distinction. WISs contain two types of interfaces: one for displaying information and another, separate one for accessing services. Regarding access to information, guidelines do exist, such as those proposed by the Web Accessibility Initiative (WAI) of the Web Consortium [19], which have by now been received with wide-spread acceptance. In many cases their implementation allows a high level of accessibility to the information present in a WIS. Access to services, on the other hand, is quite a different matter. As this is often effected through interfaces developed with mobile code, guaranteeing full accessibility to services may engender considerable problems. Some advances have been made in recent years, both through the integration of Web clients with *access technology* tools (i.e., techniques enabling the disabled to use the computer more easily), and the implementation of *ad hoc* APIs in the main programming languages used for the writing of mobile code [10].

5. Public Access Web Information Systems: the INFEA project

Within the framework of the "1994/1996 three-year Environmental Protection Program", the Environmental Impact Assessment Service (V.I.A. = *Valutazione Impatto Ambientale*) of the Italian Ministry of the Environment, promoted and started up a coordinated program of initiatives on environmental awareness, education and training. The project represents the practical application of the strategy of promoting facilities throughout Italy able, not only to increase public awareness and understanding of specific environmental issues, but to take part in restoration operations aimed at preventing decay and reestablishing conditions of sustainability. These objectives have been pursued through the development of common guidelines and the setting up of Environmental Education Centers (EA Centers = *Centri di Educazione Ambientale*) as strategic nodes in the nascent National System of Environmental Information, and Education (INFEA = *Sistema Nazionale per l'Informazione, la Formazione e l'Educazione Ambientale*).
The telematics experience acquired by EA Centers enables them to serve as reference points for education and professional training using network tools. Distance-learning courses have been developed for the Education Centers on the subjects of education and pedagogical methodologies. The researchers of the CNUCE group have recognized that, with improvements, the system could be transformed into a high-level telematics application for the management and delivery of a large body of environmental information. They have therefore proposed the implementation of a Web-accessible information system, the "INFEA Information System". The project's rather ambitious goal is to reorganize and restructure the various data sources and integrate them with Web-based groupware tools, so as to establish a true Public Access Web Information System. On the technical end, the project involves solving the following problems:

- Managing and distributing different types of information, often made up of unstructured and hypermedia data, and imparting "added value" by emphasizing their mutual relationships.
- Furnishing simple, interactive interfaces for the production and consultation of the information.
- Supporting well-defined user roles within the system
- Creating cooperative-work and distance-learning environments
- Creating an "open" system in which developing new tools and/or modifying



existing ones is performed as simply as possible.

The figure above outlines the structure of the INFEA information system. Regarding the "*human resources*" component of the INFEA information system, it would appear that a "board of editors" needs to be established. This would be made up of experts in environmental issues, who would check the information content of the system and perform the function of filters and coordinators for acceptance and distribution of the information that converges on the system telematically.

From the computer science perspective, we regard the INFEA WIS service as a software application whose specific functions may be called upon in carrying out one or more activities (an example of the services being offered is the forum-manager module, while managing a specific-topic forum illustrates the activities available). All services are founded on a database that integrates the various sources of information. The services deemed relevant for the project are the following:

DbManager Includes all the functionality for accessing the database**.** This is the so-called '*engine*' of the INFEA information system. Besides search functions, it also manages the remote insertion and updating of data. The data manager is the backbone of all activities involving information requests, as well as the data management tools (e.g., agenda).

Agenda Provides tools for managing an electronic schedule of all those events of interest to anyone involved in environmental issues. It employs the DbManager for storing and searching the data. It also offers functions for the management of numerous objects, such as for instance, the publicizing and consulting, through sophisticated search filters, of ongoing programs, seminars, courses, demonstrations, conferences, etc. Moreover, it offers the ability to call project meetings, as well as a *phonebook/contacts manager*, etc. The Agenda service communicates, not only with the DbManager, but with an *ActiveNotifier* service (see below), which notifies interested users of schedule changes (new announcements, venue changes, etc.).

Electronic magazine The functions of this service are correlated to the production and periodic distribution of an electronic bulletin**.** The adopted solution does not include automatic generation of the magazine, but is based on a *shopping cart* metaphor, that is, the user fills his or her "cart" by selecting database items, as well as other materials not necessarily contained in it, such as: articles, photos, film clips, etc. The resulting package is then sent to the editor, which formats, lays out, and publishes the pages in the form of an *e-zine*. The user can view and/or print the magazine, consult the issues history and search the articles present on the basis of content. Moreover, this service manages activities relative to the proposal, acceptance and/or revision of articles, as well as planning the magazine issue in which to publish them.

Computer Conference Provides a series of tools generally furnished by complex CMCW systems (Computer Mediated Communication and Work), which are groupware systems that provide the combined functionality of a number of basic CMC technologies. The application needs that we aim to satisfy include: the creation and management of both synchronous and asynchronous discussion groups, the availability of WBI (Web Based Instruction) tools for distance teaching and learning through the Web, etc. Integrating it with the database management system provides support for various activities in a controlled and generally more effective way, for instance, during a course or seminar, information on firms, agencies, events or materials presents in the database can be displayed.

Distribution lists Manages distribution lists for email, software, documents, etc**.** This modules enables the dynamic creation of temporary as well as permanent lists, and the selection of the target recipients from the database or other permanent lists according to set criteria.

Email This a more or less traditional electronic mail system than allows for the possibility of sending and receiving email from within the system to and from the various administrators or distribution lists. It also enables predefining some formatted information, for instance, the sender's role and an automatic classification by message subject.

URL lists This allows dynamically building lists of references to other sites by selecting them from the database, according to specific criteria, and verifying its consistency.

Library This service allows managing reference material used for consultation, for example, all official documents on environmental education (guidelines, programs, agreements, particularly important briefs, etc.). It also provides tools for populating and consulting such materials.

ActiveNotifier A service that allows communicating with an active object on the user's desktop in order to notify him/her that a certain event has occurred (e.g., start of a certain course, etc). This service can be invoked by other services that determine what events will be signaled (e.g., the agenda to warn of a modification to a certain appointment, the magazine to signal the receipt of material, etc.).

5.1 The interaction subsystem

This important subsystem is made up of a series of man-machine interfaces for interacting with the various components of the information system,

including users' interactions among themselves as well as with the editors. The basic idea is the creation of a *InfeaWorkstation*, whose Desktop configures itself up automatically according to the user's role (regarding the user's access rights) and identity (regarding the desktop state). Desktop objects may be active (they can, for example, signal an activity's start to the user through the agenda). The man-machine interfaces are specific for the various roles and enable managing all the enabled services as effortlessly and flexibly as possible. For example, the man-machine interface at the disposal of editors includes a set of tools for managing the information system (e.g., checking and accepting incoming information proposals, defining access modes, defining and managing forum, etc.).

Users and Roles

A certain number of user roles have been defined within the system. The role determines the set of services and the functions of each set that are available to the user. Accordingly, it must also define the man-machine interface (e.g., a general user can consult the agenda, but not modify the events contained in it). Currently the following roles have been established:

- *Guest:* anonymous Web users to whom none of the following roles is assigned.
- *LabnetUser*: the internal users of the INFEA system divided as necessary into groups.
- *ActivityAdministrator:* responsible for the management of one specific activity (e.g.,. the database, a specific forum, etc.).
- *SiteAdministrator:* responsible for the management of site content (deciding, for example, whether to perform certain updates to the system, and the like); SiteAdministrators may delegate the management of certain activities to an ActivityAdministrator (thereby, conferring or withdrawing this role assignment to that user),
- *SystemAdministrator*: responsible for management of the component software of the system.

Each role may be covered by one or more users. The role determines the tools and activities available to, as well as the access modes for the user assigned to that role. An authorization mechanism, based on the roles concept, has been defined for system's objects.

6. Conclusions.

The present article has analyzed the characteristics of a Web-based information system. We have discussed the advantages of employing new technology over traditional implementations of information systems and considered the new problems that it engenders. By way of illustration, the design of a WIS for the Italian Ministry of the Environment has been presented. The system is currently in advanced stages of implementation through application of the principles outlined in the foregoing.

7. Bibliography

[1] Kambil A., and Ginsburg M. ***Public Access Web Information Systems: Lessons from the Internet EDGAR project*** Communication of the ACM 41 (7) pp.91-98

[2] Fielding E., Whitehead J., Anderson K., Bolcer G., Oreizy P., Taylor R. ***Web Based Development of Complex Information Products*** Communication of the ACM 41 (8) pp.84-91

[3] Lennon J. A. ***Hypermedia systems and applications: World Wide Web and beyond*** (Berlin, Springer, 1997)

[4] Mendelzon A., Tova M. ***Formal Models of Web Queries*** in Prooceedings of the Sixteenth ACM Symposium on Principles of Database Systems, http://www.cs.toronto.edu/~websql/.

[5] Arocena G., Mendelzon A. ***WebOQL: Restructuring documents, databases, and web*** in Proceedings of the 14th International Conference on Data Engineering (Orlando, Florida) 1998

[6] Kalakota R, Robinson M. ***e-Business Roadmap for Success*** (Addison-Wesley 1999)

[9] Nielsen J. **"The art of navigating through Hypertext Communication"** of the ACM 33 (3) 1990, pp 296-310

[10] Aloia N., Concordia C., Furfari F. Miori V. ***"Considerazioni per la realizzazione di sistemi informativi basati su Web accessibili ai disabili"*** 6° convegno "Informatica Didattica e Disabilità"

[11] Aloia N., Concordia C. ***Accesso a Basi di Dati via Web*** Atti del 6° convegno nazionale "Sistemi evoluti per Basi di Dati"

[12] Berners-Lee, T., Fielding, R. and L. Masinter, "***Uniform Resource Identifiers (URI): Generic Syntax and Semantics***", RFC 2396, August 1998.

[13] Frank Halasz ***Reflections on NoteCards: Seven Issues for the Next Generation of Hypermedia Systems*** Communication of the ACM, 31 (7) pp 836-852 1988

[14] Kenji Takahashi ***Metalevel Links: More Power to Your Links*** Communications of the ACM 41 (7) pp103-105 1998

[15] Isakowitz T., Bieber M. and F. Vitali: ***Web Information Systems*** Communication of the ACM, Vol. 41, No. 7, July 1998.

[16] K. Anderson ***Integrating open hypermedia systems with World Wide Web*** in proceedings of the 8th ACM Conference on Hypertext (Southampton, England, Apr.6-11). ACM Press, New York,1997, pp.157-166.

[17] Schoderbek P., Management Systems, Wiley 1977

[18] Aloia N., Canino D., Concordia C. **Un *sistema informativo sulla formazione ambientale fruibile via Web*** CNUCE-B4-1998-06 Report

[19] **Web Content Accessibility Guidelines 1.0** http://www.w3.org/TR/WAI-WEBCONTENT/