Interoperability models in digital libraries: an overview

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Abstract

Purpose – The purpose of this paper is to provide an overview of the existing interoperability models in digital libraries and to introduce related projects in each model.

Design/methodology/approach – The study starts from searching various databases with a combination of important keywords in the field, such as interoperability, digital library, meta-searching and cross-searching. The study follows up with describing related digital library projects in the field of technical interoperability. The projects are described under three main categories, Federated, Harvesting and Gathering.

Findings – The study shows that most of the studied projects are located in the USA and also most of the digital library projects use OAI protocol and the harvesting model in order to be technically interoperable. Also, the results of the study showed that the projects mostly paid attention to metadata interoperability and only a few mentioned full-text interoperability issues.

Originality/value – The paper makes an original contribution of exploring an area (interoperability models in digital libraries), that is at the forefront of discussion in libraries worldwide.

Keywords Open systems, Digital libraries, Search engines, Iran

Paper type Literature review

1. Introduction

Information is a basic human need, and civilization advances when people are able to apply the right information at the right time (Fox and Marchionini, 1998). Therefore digital libraries (DLs) in the current age, as an effective device in the progress of human civilization, should enable any citizen to access all human knowledge anytime and anywhere, in an efficient and effective way, by overcoming barriers of distance, language, and culture and by using multiple Internet-connected devices (DELOS, 2001; Ding and Solvberg, 2007). In fact, DLs are like islands of order in a sea of chaos and this point is a major for rejecting the claim that the Worldwide Web is simply one big DL. Also, locating them by using web search engines or subject directories is just the first
step in a long process. Users must then go to each one, searching or browsing it, before moving on to the next (Tennant, 1998). Consequently, DLs should interact with each other so as to serve as valuable sources for users. In fact, such interoperability is the ability of different types of computers, networks, operating systems, and applications to exchange information, without prior communication, in a useful and meaningful manner (Moen, 2003).

In the DL field, interoperability as mentioned by Suleman in his theses refers to the ability of a DL to work cooperatively with other DLs in an attempt to provide higher quality services to users (Suleman, 2002). The goal of interoperability factually is to build coherent services for users, from components that are technically different and managed by different organizations. So, as Paepcke et al. (1998) expressed in their article, interoperability is a central concern in building DLs (Paepcke et al., 1998). Accordingly, interoperability is one of the most important issues in DLs and should be of concern at the time of building or improving DLs.

Three levels of interoperability were identified by Arms et al. (2002) for Site for Science, federated, harvested, and gathering. In fact, each level has different operating procedures, standards and protocols. So, we extracted the mentioned levels and discussed about as models of interoperability in this article. Hence, models in this article have the same sense as levels in the Arms’ et al article. Interoperability also requires technical, content and organizational aspects to cooperate. In this study, technical aspects are the central concern and thus content and organizational aspects are not described.

This article, then, aims to overview the existing interoperability models in digital libraries, in the case of technical aspects of interoperability to discuss the advantages and shortcomings of each model and introduce the related projects in the overviewed model. Therefore, section 2 describes interoperability necessities, while section 3, expresses the methodology of the study. Section 4 describes the interoperability models and DLs’ reasons for choosing them. It also describes the related DL projects for the introduced models. Finally, section 5 covers discussions about the described projects mentioned in section 4.

2. Interoperability: necessities
As noted earlier, the emergence of need to interoperable DLs is obviously tangible, so that users could simply search a library or database and obtain their required content. OCLC is an example of such an interoperable system. Its product, WorldCat, was established more than 20 years ago and is still in use. WorldCat’s collection covers a large shared list of bibliographic data in the world (Spies, 2001). So OCLC established a system in which libraries all over the world share their bibliographic data on the WorldCat context.

Almost 15 years ago, Lynch and Garcia-Molina (1995) in a workshop in the USA expressed that the key challenges in DL research are:

- interoperability;
- description of objects and repositories;
- collection management and organization;
- user interfaces; and
- human-computer interaction.
This was subsequently noted by Warren and Alsmeyer (2005) showing that interoperability is one of the most heavily discussed issues in DL research. The requirement for interoperability generally derives from the fact that various DLs with different architectures, metadata formats, and underlying technologies wish to effectively interact, something they can do through applying a range of common protocols and standards (Shiri, 2003).

Consequently, there are many reasons so as to discuss about interoperability in DLs. We mentioned some of them in this section in order to show its necessities for libraries, especially for DLs.

3. Methodology

Searches of the latest research, developments and projects in the field of interoperability in DLs, using the keywords: interoperability; digital library; meta-searching; and cross-searching and their variations (such as meta-searching and cross-searching) in different databases during February 2008 showed the results in Table I.

A preliminary investigation of the retrieved resources showed that there are three sets of agreements concerning interoperability. Formats, Protocols, Security systems, etc. are covered by technical agreements; data and metadata and semantic agreements on the interpretation of the information are covered by content agreements; and the ground rules for access, preservation of collections and services, payment, authentication, etc. are covered by organizational agreements (Arms et al., 2002; Shen, 2006). Whereas the main object of this research is the survey of technical aspects of interoperability, the retrieved documents are studied and surveyed by this point-of-view.

4. Interoperability models

Interoperability between digital archives is applicable by three different models as mentioned above. Each digital archive uses diverse technology and tools that is related to the time of developing, the amount of money that developers want to expend, and also the efficiency that the developers expect. Altogether digital libraries that want to offer integrated services in cooperating with other libraries, often encounter with methods that are appropriate for their users. Also, there are generally accepted standards, in this way, which are less efficient. Sometimes a new method provides more effectiveness for a digital library, but fewer users could use it. For instance, simple tags such as hyper text markup language (HTML) and public protocols like hyper text transfer protocol (HTTP) could be used which are accessible for everyone in the world. Furthermore, digital libraries could use the last version of Java applets related technology in HTML. These applicants could be useful for users that have high-speed networks and use modern search engines. Hence, users that do not have such applicants could not use them.

In fact, the act of removing tension between performance, cost and technology has a direct relation to content and users. Sometimes, it is better to choose simple technology and offer comprehensive but superficial services. At the other time, it is logical to choose high performance technology with high cost. Certainly, just high-motivated digital libraries use these high cost methods which of course, are successive in contrast. Consequently, the above-mentioned items promote diverse methods for interoperability. As expressed above, there are three basic models of interoperability:
<table>
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<th>Elsevier</th>
<th>John Wiley</th>
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<th>LISTA</th>
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<td>0</td>
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<tr>
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<td>8</td>
<td>5</td>
<td>50</td>
<td>675</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>
The first one provides the strongest form of interoperability, but places the greatest burden on participants. The last one requires essentially no effort by the participants, but provides a poorer level of interoperability. And the middle one is the average of the others (Arms et al., 2002).

These three models of performing interoperability are all employed in digital libraries, and also there are factually various performing methods in each model. In addition, there are applications that use a combination of the models or even use all of them in their projects. In this sense, they use, for instance, Z39.50 and OAI in order to make access to some of the collections. As will be discussed in this section, each one is related to different model. In this section, the studied projects and researches are presented in this framework chronologically, three models of performing interoperability.

4.1 Federated model
“Federation can be considered the conventional approach to interoperability. In federation, a group of organizations agree that their services will conform to certain specifications, which are often selected from formal standards” (Arms et al., 2002). Federation, as shown in Figure 1, refers to the case where the digital library sends search criteria to multiple remote repositories and the results are gathered, combined, and presented to user (Shen, 2006). In 1984 the Z39.50 protocol, which is a federated model, developed by the Linked Systems Project (LSP) project for libraries, publishers and information service providers, can be considered as a US National Standard. This protocol has been long used in libraries for searching and retrieving bibliographic information and is supported by the US Library of Congress (Needlman, 2000).

![Figure 1. Data flow for federation](source: Suleman (2002))
Two systems, client and server, are used in this model. The server undertakes to update and respond to queries. The client undertakes to connect with end-users, receive queries from end-users, and send, receive and mix received responses from the server, finally presenting them to end-user. In fact, relations between client and server can be established by certain protocols. There is need to standardize query language and data storage following the same standard in all systems. The other way of running this model can be installed by middleware. The middleware undertakes contact with servers and the user just can make access to resources in other collections along with this middleware and do not need to have any relation with server.

personalized retrieval and summarization of image, video, and language resources (PERSIVAL) is a project in Colombia University that work in the federated model. In fact, Green et al. (2001) described how they combined simple digital library interoperability protocol (SDLIP) and STAnford protocol proposal for Internet ReTrieval and Search (STARTS), two complementary protocols, for searching over distributed document collections. The resulting protocol, which they called SDARTS, is simple yet expressible enough to enable building sophisticated Meta search engines.

Support for Z39.50, a protocol that works in the federated model, in Greenstone is provided through YAZ, open source software, library that can be used by both Z39.50 clients and servers. In fact, Z39.50 serving capabilities are added to Greenstone by developing a new server that uses YAZ as a front end to accept requests from Z39.50 clients and translate them into requests that use the Greenstone protocol. The Greenstone response is then converted, through YAZ, into Z39.50 terms and returned to the client (Witten and Bainbridge, 2003).

Another project that works in the federated model is the Colorado digitization program which was established in 1998 through a library services and technology act grant through the Colorado state library. This project also uses Z39.50, like Greenstone, in order to be interoperable. DC builder is an applicant that uses in the project in order to convert metadata from a variety of systems and formats to Dublin Core (DC) as a metadata standard which is used in the systems. In a PhD thesis by Shi (2005) entitled “Lightweight federation of non-cooperating digital libraries”, the researcher studied federated and harvesting models and finally proposed the federated model because of not having up to date central metadata records.

ZMARKO is used in another project in order to gather bibliographic records from 12 state libraries in Illinois, USA. ZMARKO acts as a data provider allowing MARC records available through a Z39.50 server to be made available via the OAI-PMH (Kazmarek and Naun, 2005). In fact, project team member, Tom Habing, developed an OAI-PMH/Z39.50 gateway for the purpose of creating an appropriate response to OAI-PMH requests layered over the Z39.50 server. The system works partly in a federated model by using Z39.50.

Utah Universities’ interoperability project entitled “Mountain West Digital Library (MWDL)” was established in early 2002. Interaction between the participating universities (Utah State University, University of Utah, Brigham Young University, and Southern Utah University) is fully compatible with the Open Archives Initiative. But in 2003 the University of Utah developed an open source add-on software called ZContent. ZContent is a Perl module developed to convert Z39.50 queries (Arlitsch and Jonsson, 2005). The system thus can work on the federated model next to a harvesting model.
In summary, three of the above five projects work on the federated model as well as the harvesting model. This shows that in some cases projects need to cover some other libraries or information centers that are compatible with the other model since they are compelled to support it.

4.2 Harvesting model

“The difficulty of creating large federations is the motivation behind recent efforts to create looser groupings of digital libraries. The underlying concept is that the participants agree to take small efforts that enable some basic shared services, without being required to adopt a complete set of agreements” (Arms et al., 2002). Furthermore, “The Open Archives Initiative (OAI) is based around the concept of metadata harvesting. In this model, each digital library makes metadata about its collections available in a simple exchange format. This metadata can be harvested by service providers and built into services such as information discovery or reference linking” (Arms et al., 2002).

Metadata harvesting was first developed by the harvest project in the early 1990s, but the approach was not widely adopted (Bowman et al., 1994). The concept was revived in 1998 in a prototype known as the universal preprint server (Van De Sompel et al., 2000). This prototype concluded in favor of metadata harvesting as a strategy to facilitate the creation of federated services across heterogeneous preprint systems. The OAI, which is derived from this experiment, emphasizes the core functionality that can be achieved by digital libraries sharing metadata. It minimizes the cost by using a simple protocol based on HTTP, by providing software that is easily added to web servers, and by documentation, training and support (Lagoze and Van de Sompel, 2001).

In the harvesting model, as shown in Figure 2, DLs – which are members of a consortium, agree to interoperate with each other. Hence, they establish a server in order to present services so each library could update their data on the server by means

![Figure 2. Data flow for harvesting](source: Suleman (2002))
of a simple protocol such as HTTP. Users refer to the server to retrieve information. Having regard to an agreed standard in storage and sharing metadata and also using open achieves for making access facility to information by server are the primary necessities of using this model. In this way, server undertakes to present services related to the DL’s integrated data. Therefore, the possibility of integrated searching in many of DLs is procured for users.

Another way of installing this model is depicted in Figure 3. The difference of this way according to the previous one is in DLs two-way relation with a server. In this case, each one of the members has a copy of the integrated data in server – thus, each of the libraries is a support system for the others and mirror them. Another way of installing this model could be presented by eliminating the server in a complicated way. In this case, two-way relationships would be made possible between DLs as is shown in Figure 4.

Maamar (1998) in his PhD thesis in Université Laval (Canada) expressed how an interoperable environment can be built, using teams of software agents integrated in software agent-oriented framework architecture. He and his colleagues propose the Conception par Frameworks Orientés-Agents Logiciels (C-FOAL) – Concept of software agent-oriented framework method for the development of interoperable environments. The C-FOAL method is applied to the Systeme d’Information Geographique et Agent Logiciel (SIGAL) project, which aims at developing an interoperable environment for geo-referenced digital libraries. To design and develop
the interoperability environment SIGAL, they chose three types of frameworks (Server, Client and Logical source) in order to create a multi-framework architecture. This architecture is based on the Client/Server approach, the mirror sites, and the dynamic generation of client frameworks.

Suleman (2002) in his PhD thesis entitled Open Digital Libraries, proposed the Harvesting model with OAI protocol. Also, networked digital library of theses and dissertations (NDLTD) is a project with 13 members all over the world. As Suleman and Fox (2003) in their research article mentioned, the OAI protocol is used in this project. Also, electronic theses and dissertation metadata set (ETDMS) is used in this project as metadata standard. Harvesting model with OAI protocol is also used in National Science Digital Library (NSDL) so as to metadata harvesting in central repository (Arms et al., 2003; Lagoze et al., 2006).

OAISter in the University of Michigan uses OAI protocol for metadata harvesting, DC metadata standard with XML format. The team members expected to harvest DC encoded metadata in XML format from OAI-enabled metadata repositories, use XSLT to transform that DC metadata into DLXS bibliographic class encoded metadata, the project’s native format, index the metadata and make it available to end-users through an interface that used the XPAT search engine (Hagedorn, 2003).

NASA is also using the harvesting model with the OAI protocol to make accessible their scientific and technical information in ten NASA centers and headquarters and over 50 foreign countries in order to maintain access to the largest collections of aerospace science and technical information in the world. DC is factually metadata standard for bibliographic information and PDF format for full-text information that was used in the project (Nelson et al., 2003). Also, Greenstone, open source software, is capable to be interoperable with others in Federated, Harvesting and Gathering models, through Exchange center application (Bainbridge et al., 2006).

Moreover, China Networked Digital Library of Theses and Dissertations (CNNDLT) is a project that first appeared in 1996, as a means of coordinating electronic theses and dissertations (ETD) efforts among Chinese Universities. The CNNDLT project has been carried out by China Academic Library and Information System (CALIS) and the model applied is the harvesting model with OAI protocol. DC is a metadata standard and PDF is a repository format for full-text data that are used in this project. Each member is responsible for updating their data in a central metadata list (Jin, 2004). In order to harvest bibliographic data from 12 state libraries in Illinois, USA, Kazmarek and Naun (2005) in their research article, mentioned that they used the harvesting model by OAI-PMH besides the federated model by Z39.50.

In January 2002, the National Science Council (NSC) of Taiwan launched a National Digital Archives Program (NDAP) in which many universities and research organizations participated. The project utilizes the OAI-PMH to harvest bibliographic records and DC as metadata standard and XML format as structured language (Yu et al., 2005). Interoperability between Utah universities in the USA is another project that used the harvesting model with OAI protocol and DC for metadata standard. They also, as noted previously, add ZContent applications in order to support the federated model (Arllitsch and Jonsson, 2005).

Interoperability between CDS/ISIS systems is another project, which is proposed by Jayakanth et al. (2006), for using the harvesting model. In the project CDSOAI is used as middleware between data providers and service providers to establish
interoperability between systems. As well as ARC, open source software, is used to integrate data providers. Libraries in the University of Arizona system in order to exchange their digital journals started their interoperability project from April 2005. They used resource description framework (RDF) as repository standard, Qualified DC as metadata standard, and OAI-PMH as interoperability protocol (Han, 2006). Bell and Lewis (2006), in their research article entitled using OAI-PMH and METS for exporting metadata and digital objects between repositories, studied DSpace, Fedora, and UKETD applications in the case of interoperability. DSpace is used in University of Wales Aberystwyth (UWA), Fedora is used in National Library of Wales (NLW), and UKETD is used in Electronic Theses Online Service (ETHOS). The proposed model in the article in order to exchange electronic theses between three repositories is harvesting model with OAI-PMH. In addition, Shen (2006), in her PhD thesis covering applying the 5S framework to integrating digital libraries, studied archaeological digital libraries as a case for building an integrated digital library. The researcher proposed a world schema for metadata repository and harvesting the resources in a central database.

The Hong Kong University of Science and Technology (HKUST) is another example of using the harvesting model with OAI-PMH. In fact, D-Space, open source software, is used in this project for storage and retrieval of information. The HKUST is accessible for all users all over the world using OAI-PMH. In fact, OAISter and Scirus can simply retrieve the HKUST metadata via the OAI protocol. Qualified DC is used for metadata repository, and PDF is used for full-text data in the HKUST (Lam and Chan, 2007). Finally, Alipour-Hafezi (2008) studied interoperability between Iranian web-based library software. He proposed a model based on the harvesting model with OAI according to their current situation. His suggestion for metadata repository standard was DC.

Generally speaking 17 projects briefly described in this section are using the harvesting model via OAI protocol and nearly all of them are using DC as metadata standard. As mentioned in the previous section, three of them are simultaneously working with harvesting and federated models.

4.3 Gathering model
According to Arms et al. (2002) “Even if formal cooperation between various organizations is not achievable, a base model of interoperability is still possible by gathering openly accessible information using a web search engines. Because there is no cost to the collections, gathering can provide services that embrace large numbers of digital libraries, but the services are of poorer quality than can be achieved by partners who cooperate directly” (Arms et al., 2002). They go on to say that “Some the most interesting web research at present can be thought of as adding extra function to the base level, which will lead to better interoperability, even among totally non-cooperating organizations. Even though the concept of a fully semantic web is a pipe dream, it is reasonable to expect that the level of services that can be provided by gathering will improve steadily. ResearchIndex (formerly known as CiteSeer) is a superb example of a digital library built automatically by gathering public accessible information” (Arms et al., 2002). In fact, this model, because of being more public, was only introduced, and except for the ResearchIndex and Exchange center software that was described in the previous section, there is no other DL project to be discussed here.
5. Findings and discussion

Accomplished researchers in the field of interoperability in libraries have backgrounds similar to libraries. By this is meant that the backgrounds of interoperability and libraries are highly related to each other. In fact, anywhere libraries exist, they tried to make access to each other’s collections in order to serve their users. Systems used for interoperability are improved in accordance with the developments in libraries. Digital libraries are still young and demonstrate their services in a virtual environment. In fact, the virtual environment, which is used by these libraries, is the Worldwide Web, which imposes its own necessities. Interaction, which should be performed in this environment, must conform to the virtual environment specifications. The speed of developments in the virtual world is so rapid that the time between birth and death of most devices and protocols is very small. Therefore, those able to retain their permanence become common and their patrons support them. Consequently, others are just used by organizations during their lifetime. On the other hand, it is possible that there are some protocols, tools, or standards, which are not used by libraries or information centers. Thus, one of the reasons, that some of tools or protocols are not described in this research, is their lack of use or their freshness. As a result, the opportunity for their use by libraries has not yet appeared. So those are such a laboratory products. It may also be possible that there are many digital libraries and information centers that use interoperability techniques or devices, but because they have not presented their product or method in scientific gatherings or in learned journals or recorded their findings and utilization, then unfortunately this present research does not cover them. (In fact, the cases that could be discussed in this research are those documented in the mentioned databases in Table I.)

The review of the models presented in this article shows that the documentation of interoperability projects goes back to 1998. Bearing in mind that the appearance of digital libraries goes back to the late 1990s, it is obvious that there is direct relation between the appearance of digital libraries and their use of interoperability techniques. Historic distribution of the discussed projects and the used model, protocol, metadata standard, etc. are presented in the Table II. As is shown, the number of interoperability projects increased after 2003. It is thus highly obvious that the importance of being interoperable is the main issue in building and improving DLs in the current era.

Table II also shows that about 50 percent of the projects are related to the USA, which is the offspring of most of protocols and tools that are used in studied interoperability projects. In is important to bear in mind that OAI, Z39.50 and some other protocols were developed mainly by US research groups and were also published in academic journals and databases, some of which are surveyed in this study. But it must be stated that there are some other projects that are not described in studied articles. XML descriptive language is used in many of the projects as a format of bibliographic data because of its hierarchical structure. Also, Qualified DC is used in many of the projects as a metadata standard. On the other hand, as Z39.50 protocol and also the federated model have long background in search and retrieval of bibliographic records, most of digital library projects use the OAI protocol and harvesting model. It seems that OAI has more capability and as well as simpler usability in proportion to Z39.50. As Z39.50 is related to the previous generation of libraries, it is less used in DLs.
<table>
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<th>Metadata</th>
<th>Interchange mechanism</th>
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Table II. Historic distribution of projects
6. Conclusions
The main object of interoperability in DLs is to build their full-text data accessible for their users. In other words, users in DLs want to get access to information resources which placed in DL which are a member of it or other DLs. Thus, DLs should pay attention to make consortiums with other ones so as to make their information resources accessible for users. DLs should also prepare facilities to exchange full-text data between each other and also other information centers. The findings of this study showed that the studied projects mostly paid attention to metadata interoperability and only a few of them mentioned full-text interoperability issues, while, metadata interoperability is just a tool in exchanging full-text data. As it was shown in the Table II, 30 percent of the projects were using PDF format for their full-text data. Unfortunately, the rest of them did not mention the format of their full-text data in interoperability stages. Therefore, there may be a need for a study about the formats and procedures of full-text interoperability in DLs. Eventually, the full-text data would be used by users. Thus, preparing full-text data is the final destination of interoperability in DLs.

References


**About the authors**

Mehdi Alipour-Hafezi obtained a BA degree in Library and Information Sciences from Tabriz University in 1998, then received an MA in Library and Information Sciences from Azad University in 2002. He started his PhD course in Library and Information Sciences at Azad University, Science and Research branch, Tehran, Iran, in 2005. He has more than seven years of experience in information services and systems gained while working in the Information Center of Iran Telecommunication Research Center (ITRC) and also as the manager of Digital Library Projects and head of the Electronic Library Department in the Atomic Energy Organization of Iran (AEOI). He teaches as a Visiting Lecturer in the Department of Library and Information Science at Allame Tabataba’ee University and also Alzahra University. He is also a member of the Iranian Library and Information Sciences Association. His research interests include digital libraries – particularly XML and its usage in digital libraries, and interoperability between digital library systems and so on. Mehdi Alipour-Hafezi is the corresponding author and can be contacted at: meh.hafezi@gmail.com

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Ali Shiri has a PhD and is an Associate Professor in the School of Library and Information Studies at the University of Alberta, Edmonton, Canada. Before joining the University of Alberta, Ali has worked as Senior Researcher at the Centre for Digital Library Research in the University of Strathclyde in Glasgow, UK. Ali’s research areas include: information retrieval interaction and user behavior, digital library user interfaces, user-centered search term selection and query expansion, social tagging trends and interfaces, and knowledge organization systems in digital libraries, institutional repositories, and subject gateways.

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