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Digital Libraries: Analysis of Delos Reference Model and 5S Theory

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ABSTRACT
The proliferation of digital libraries (DL) in the twenty-first century has revolutionized the way information is generated and disseminated. This has led to various practical and research models of DLs. This paper discusses the concept and development of digital libraries, and examines various components and characteristics of DLs. It further identifies various models and theories of digital libraries with a special focus on the DELOS Reference Model and 5S Theory. The relationship between the two focused frameworks is analyzed for better understanding of their application in the DL universe.

Keywords: Digital libraries, DL Initiatives, ICT, DELOS reference model, 5S framework

1. INTRODUCTION

The advent of information and communication technology (ICT) has revolutionized the way information is generated and disseminated in modern times. As a result, many organizations have moved from

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paper-based systems to become more digital-oriented organizations. This wave of change has also been observed within libraries. According to the British Library Digitization Strategy Plan 2008- 2011 (2008), "the advent of the Internet and the ability to digitize large quantities of text and images and make them available over the Web has transformed ways of working" (p. 1). The need to harness the numerous benefits of this modern technology has given rise to various digital library (DL) initiatives across the globe. Libraries, especially academic libraries, are now investing heavily on electronic library services with a view to providing seamless access to library collections. The traditional methods of collecting, storing, processing, and accessing information have undergone a massive transformation due to the growth of virtual libraries, digital libraries, online databases, and library and information networks (Varatharajan & Chandrashekara, 2007). Information users in the present digital era can access the vast digital collection of libraries by using computers connected to the Internet to search and retrieve needed information from electronic catalogues, e-journals, and large databases of digitized scholarly information (Marcum & George, 2003).

This new trend in library practice has generated a great deal of challenges in the areas of design, application, acceptance, and the use of technology by potential library users. Another major challenge to libraries in the digital era is the difficulty surrounding DL *interoperability*- that is, the ability of two or more systems to exchange information and use the information that has been exchanged (Gradmann, 2009). Athanasopoulos et al. (2011) attributed this problem to the lack of a common model and single interoperability solution or approach that is generic and powerful enough to serve all the needs of digital library organizations and digital library systems. Candela (2003) stressed the need for a common model that will address these new emerging issues. Several models and theories of digital libraries have been developed with a view to guiding digital library designers towards building digital libraries that will meet the information needs of various users. There is a need to examine some of these models and theories for better understanding of their validity and reliability in the digital library universe. This paper, therefore, sets out to analyze models and theories of digital libraries with special focus on the DELOS Reference Model and 5S Theory.

2. THE CONCEPT OF THE DIGITAL LIBRARY

The digital library is not a new concept in librarianship. However, its evolution in the modern era has opened up a new chapter in the history of information generation, processing, preservation, and dissemination. The goal of the DL is to facilitate easy and remote access to library collections. Roknuzzam et al. (2009), quoting Gapen (1993), defined the DL as "the concept of remote access to the contents and services of libraries and other information resources, combining an on-site collection of current and heavily used materials in both print and electronic form, with an electronic network which provides access to, and delivery from, external worldwide library and commercial information and knowledge sources" (p. 374). According to Mutula and Ojedokun (2008) an ideal DL should be able to provide users with access to electronic information resources via electronic means. This is reflected in a recent definition of DL by IFLA (2010) as a "collection of digital objects, of assured quality, that are created or collected and managed according to internationally accepted principles for collection development and made accessible in a coherent and sustainable manner, supported by services necessary to allow users to retrieve and exploit the resources" (p. 2).

This development in library practice had been predicted by Vannever Bush, who envisioned a device which he called the 'memex,' a mechanized system based on microfilm technology which would be able to store large amount of books, records, and communication, with the ability to be consulted and retrieved with exceeding speed and flexibility (Bush, 1945). This prediction was further made clearer by Licklider (1965) in his book titled *Libraries of the Future,* where he demonstrated future roles of computer and digital technologies in the development of library practice. He envisioned a future library system that would extend further into the process of generating, organizing, and using knowledge with the application of digital technology. These various definitions presented a common

element of the digital library as a collection of digital information that has to be collected or created, processed, and managed to provide universal access to digital content. Therefore, for a library to be referred to as digital library its collection needs to cut across various forms of digital resources and provide universal access to digital content.

3. COMPONENTS OF DIGITAL LIBRARIES

DLs are comprised of various components that interact together to serve information needs of end users. The literature shows that digital libraries, like traditional libraries, share common functional components such as content, digital object, metadata, repository, identifier, Internet and Intranet, digitization, and user interface (Arms, 1995; Magnussen, 2003; Pandey, 2003; Altman, 2006; Bhuyan, 2007). These components can be grouped into five core element which include content, organization, service, technology, and people (Carter, 2002). Each of these five elements is discussed in the paragraphs that follow:

Content: The core function of any library is dissemination of the right content to its community. The dissemination of content, in traditional libraries, comes in the form of physical objects such as books, journals, and audio and video tapes. These physical objects are integrated into digital libraries either through conversion or creation of newborn digital objects of the old contents. Digital objects also come in different formats such as data sets (e.g., a table of results, the genomic information for an individual), or multimedia information (an image, graphic, animation, sound, musical performance, or video) (Fox, 2002). DL contents, just like the practice in the traditional library where contents are catalogued and shelved for easy access, are also catalogued in the form of metadata and managed in the digital repository for easy accessibility. According to Henry (2012), one means of providing reliable access is to mirror (i.e., replicate) the DL in multiple locations so that if there is a problem at one location, the mirrored site can provide continued access to the digital contents and services.

Organization: Organizing information resources to facilitate easy access to a collection has been the major task of libraries for several decades (Chowdhury & Chowdhury, 2003). Libraries and other information institutions have used different types of knowledge organizational schemes to provide easy access to their collections. Following the emergence of digital technology, organization of content in the DL, as in traditional systems, required a bibliographic record mechanism called metadata. Metadata is structured information that surrogates the real described object (NISO, 2007). Metadata is expected to provide vivid description of digital content for easy discovery and integration across various digital repositories. The Internet is a tool that has greatly increased access to digital materials. However, it has done little for the integration of materials across these repositories. It lacks organizational control of the available search tools and search engines. In the case of DLs, contents are organized for easy and seamless access through the application of metadata.

Service: Services to users in traditional libraries such as reference services and selective dissemination of information (SDI) are designed to assist users in their efforts to navigate library collections. In the DL system, remote users can also enjoy personalized services such as online reference services, which are rendered to digital library users in order to solve or address their information search problem (e.g. "ask a Librarian"). Several reference and information services are now available on the web and many of these services are provided by non-library organizations. Some web sites provide listings of libraries that offer real-time reference services. The services use such specific software as live interactive communication tools, call centre management software, bulletin board services, and other Internet technologies (Parida, 2004). These services also guide and assist users in navigating the various information repositories.

Technology: The role of technology in digital environments is to support other elements. These elements include content, organization, and service. The use of appropriate technology when designing a DL determines the level of functionality of the system with respect to digital object processing, organization, preservation, and dissemination. Different technologies have been applied to achieve DL growth; these technologies include locally developed databases, net-

work connections that aid access to other databases, computer hardware with audio-visual capability and video conferencing kits (Parida, 2004).

People: The human elements of DLs make decisions about content, design, and modification of organizational structures. The categories of people in the domain include librarians, repository managers, and system administrators. These people ensure that the system works in accordance with the mission and goals of the library and information institution. The librarians select the content they are interested in making available based on the mission of the parent institution. In addition, they assist end-users with searching techniques that facilitate easy usage of digital libraries (Tibenderana, 2010). In the same vein, the repository managers may adopt policies that implicitly select the digital objects that can be deposited into the repository. The system administrators maintain the index server and select the digital objects that are indexed in the server (Logoze & Fielding, 1998)

DLs are still developing and most of the components identified by various researchers in the field of digital libraries focus on the above five core elements of digital libraries. The goal of any information institution is to meet the information needs of its parent body or community. Therefore, digital objects must be properly selected based on the needs of potential users and organized for easy accessibility. DL architecture provides good user interfaces that enable users to navigate the vast numbers of digital objects in the library repositories with ease.

4. CHARACTERISTIC OF DIGITAL LIBRARIES

DLs have unique characteristics. Their unique characteristics have been discussed in various conferences and fora in many parts of the world, such as: European Conference on Research and Advanced Technology for Digital Libraries (ECDL); International Conference on Asia-Pacific Digital Libraries (ICADL); and International Conference on Theory and Practice of Digital Libraries (TPDL), just to mention few. Several researchers have equally examined the various characteristics of digital libraries against the features of traditional libraries (Cleveland, 1998; Chowdhury, 2003). These characteristics show the flexibility, portability, and accessibility of DLs over traditional libraries.

DLs generally share the following common characteristics:

- They provide round the clock services to users within and without the library environment. Users can access digital objects at any time 24/7.
- They provide a coherent view of all information contained within a library, no matter its form or format (e.g. text, audio, and video).
- Contents in digital libraries can only be accessed through the help of computers.
- Several users can access a digital object at the same time in different locations.
- Digital libraries do not require large spaces, unlike traditional libraries where physical space is needed for building and maintaining collections.

These characteristics show a shift from traditional library practice, where users need to physically visit library buildings to have access to collection. The dynamics of services in digital libraries has over the years attracted several models and theories of DLs proposed to serve as a framework for building digital libraries that will meet the information needs of users in the new global environment. As pointed out by Gonçalves et al. (2004), formal models and theories are crucial in order to specify and understand clearly and unambiguously the characteristics, structure, and behavior of complex information systems. In line with this assertion, different practical and research efforts towards models and theories of digital libraries have been developed. The Digital Library Initiative (DLI) projects in the USA and the eLib projects in UK have been the major drivers of these efforts through research and practical projects. There are now a number of models of digital libraries that can serve as a framework for best practices.

5. MODELS AND THEORIES OF DIGITAL LIBRARIES

5.1 Models and Theories

The terms *models* and *theories* are used interchangeably in the context of this paper. This is in line with the position of Minshull (1975), as quoted by Coleman

(2002), that "a model can be a theory, law, hypothesis, structured idea, a role, relation, equation, reasoning, or synthesis of data" (p. 1). A model, according to the Business Online Dictionary (2012), is a "Graphical, mathematical (symbolic), physical, or verbal representation or simplified version of a concept, phenomenon, relationship, structure, system, or an aspect of the real world" (p. 1). In the same vein, Dulle (2010) defined a model as any abstract representation of some portion of the real world, constructed for the purpose of understanding, explaining, predicting, or controlling a phenomenon being investigated. A model can be used for better understanding of a phenomenon, therefore models and theories of digital libraries will be analyzed for better understanding of their application in the design and development of digital libraries.

The DL is one of the byproducts of the evolution of digital technologies in the late twentieth century. In effect, it has witnessed a great deal of development in the areas of design, application, and use. Most of the institutions and agencies that have embraced DLs have adopted various approaches. Some have employed a system-oriented approach while some embraced user-centered approaches. These developments have driven the need for common foundations that foster best practices to shape development in the field of DLs (Candela et al. 2011). Over the years, various models and theories have been developed with the aim of addressing issues generated from the development of DLs. Examples of such efforts include the DELOS Digital Library Reference Model, the International Committee for Documentation of the International Council of Museums (CIDOC), the Conceptual Reference Model, the Cornell Reference Architecture for Distributed Digital Libraries (CARDDL), and the 5S Theory.

These models of DLs are some of the on-going efforts in the DL universe towards providing a framework for standards and best practices. The DELOS Reference Model and 5S Theory are general attempts toward a conceptual framework, while the CARDDL and CIDOC Conceptual Reference Models focus on specific domains of digital libraries. The DELOS Reference Model and 5S Theory, apart from being general models, are also the two prominent models of digital libraries (Gonçalves et al. 2004; Candela et al. 2007; Shen et al. 2008; Murthy et al. 2010). They are therefore analyzed for better understanding of their application in the digital library universe.

6. THE DELOS DIGITAL LIBRARIES REFERENCE MODEL

The DELOS Digital Library Reference Model is a conceptual framework aimed at addressing major entities and their relationships in the digital library universe. The DELOS DL reference model is one of the results of the DELOS Network of Excellence, a DL project partially funded by the European Commission. The DELOS project aims at integrating and coordinating the ongoing research activities of the major European teams working in DL-related areas with the goal of developing the next generation DL technologies. Among the objectives of the project are to:(i) define unifying and comprehensive theories and frameworks over the life-cycle of DL information; and (ii) build interoperable multimodal/multilingual services and integrated content management ranging from the personal to the global for the specialist and general population (Casarosa, 2007). In achieving these objectives, the DELOS Reference Model was designed as a framework for the development of appropriate systems. The model is built on six main domains: content, user, functionality, quality, policy, and architecture. These are briefly discussed:

(1) *Content* – represents the information managed in the DL. The most general concept in the Content Domain is "Information Object", which includes text documents, images, sound documents, multimedia documents, and 3D objects, including games and virtual reality documents, as well as data sets and databases. (2) *User* – represents the actors interacting with the system; the DL connect users with information content that supports them in meeting their information needs. (3) *Functionality* – represents the facilities supported which aid in services rendered by DLs to end users. This is to ensure that the system functions reflect the particular needs of the DL community. (4) *Policy* – represents the rules and conditions, including digital rights, governing the operation of the elements of the

DL. For example, policy specifies acceptable user behavior, digital rights management, privacy, and so on. (5) *Quality* – represents the aspects of digital library systems to be considered from a quality point of view and general functionality of the system. (6) *Architecture* – represents the software (and hardware) constituents concretely realizing the whole.

The DELOS Reference Model is a product of brainstorming workshops of stakeholders in the digital libraries field. This led to the drafting of the Digital Library Manifesto with the aim of identifying the cornerstone concepts within the DLs community. The manifesto introduced a three tier framework:

- Digital Library Management System (DLMS)
- Digital Library System (DLS)
- Digital Library (DL)

The interconnectivity of these three systems and the six main domains of the reference model is graphically shown in Figure 1.

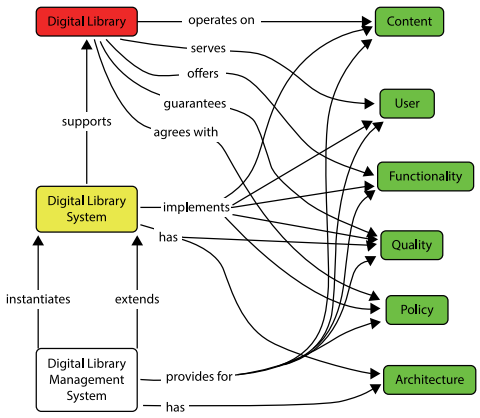

Fig. 1 The DELOS Reference Model Concept Map (Candela et al 2011)

The first tier, Digital Library Management System (DLMS), is a generic piece of software providing basic functionality required by the particular DL. The second tier, Digital Library System (DLS), is built on top of DLMS and enriches it with specific functionality and/or configurations required by the digital library. Finally, the third tier, Digital Library (DL), is understood as an organization collecting and preserving digital content and giving access to it (Murthy et al. 2010). This three-tier framework interacts with the six domains of the DELOS Reference Model (content, user, functionality, quality, policy, and architecture) to provide allembracing DL services. The players in the DL universe include End users, Designers, System Administrators, and Application Developers. These individuals play a significant role in DL design and application.

For almost a decade after its emergence, the DELOS Reference Model has made significant strides in defining the essential DL concepts and relationships (Candela et al. 2007). It has provided a common vocabulary to facilitate communication between researchers, users, and designers of digital libraries. It has also laid out the digital library concepts in a clear and structured way. However, the model was heavily revised with guidance and contributions from the international members of a range of DL working groups during the DL.org project (Candela et al. 2011). Apart from its comprehensive and explicit illustration of DLs domain, the model provides a conformance checklist that can serve as a benchmark or assessors to determine whether or not their library is compliant with the DELOS digital library reference model. The model has identified players in the DL universe which can equally serve as a guide to any library, organization, and individual intending to embark on a DL project. Evidently the application of the DELOS Reference Model will guide designers of DLs in how to address various components of digital libraries.

7. The 5S Theory

The 5S Theory is a product of efforts aimed at providing theoretical and practical unification of digital libraries. It provides a foundation for the definition of the digital library through the use of five (5) fundamental abstractions, namely Streams, Structures, Spaces, Scenarios, and Societies. The 5S Theory defines a "core" or a "minimal" DL, i.e., the minimal set of components that make a DL, without which a system/application cannot be considered a DL (Murthy et al 2007, 2010). Its flexibility as an instrument for analyzing DL development and organization has been demonstrated in several respects (Shen et al. 2008; Murthy, et al. 2010). Table 1 shows how 5S constructs can be employed to describe key concepts of DLs such as digital objects, metadata, collections, and services.

Table 1. The 5S Framework

5S	*Examples*	*Objectives*
Streams	Text; video; audio; image	Describes all types of content, as well as communications and flows over networks. Streams describe properties of DL content such as encoding and language for textual material or particular forms of multimedia data.
Structures	Collection; catalog; hypertext; document; metadata	Specifies organizational aspects of the DL content, that is, the way in which parts of a whole are arranged or organized. Structures can represent hypertexts, taxonomies, system connections, user relationships, and so on.
Spaces	Measurable distance; spatial, topological, vector etc.	A space is a set of objects together with operations on those objects that obey certain constraints. Spaces define logical and presentational views of several DL components, and can be of type measurable, measure, probability, topological, metric, or vector space.
Scenarios	Searching, browsing, recommending	A scenario is a sequence of events that also can have a number of parameters. Events represent changes in computational states; parameters represent specific variables defining a state and their respective values. Scenarios detail the behavior of DL services.
Societies	Service managers, learners, teachers, archaeologists, etc.	A society is "a set of entities and the relationships between them" and can include both human users of a system as well as automatic software entities which have a certain role in system operation. Describes managers, responsible for running DL services; actors, that use the services; and relationships among them.

These abstractions provide a formal foundation to define, relate, and unify concepts in the DLs. They are used to define other DL constructs such as digital objects, metadata specification, collection, repository, and services (Doerr et al. 2007). For example, a digital object may be defined in terms of its structured storage stream and structured metadata specification. The interplay of the 5S constructs and how each of the constructs leads to a minimal digital library system is illustrated in Figure 2.

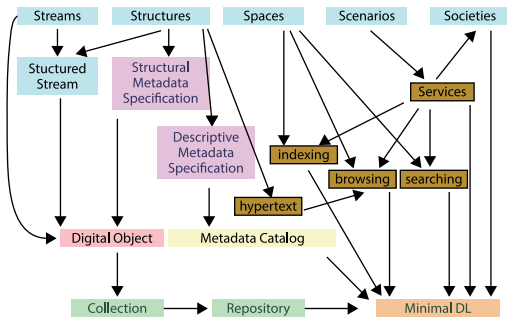

Fig. 2 5S Framework (Gonçalves et al. 2004)

The 5S framework describes minimal requirements for a DL and how the 5S constructs relate with the various components of DLs. For example, digital objects are composed of streams. These include: data; structured streams (tables of contents, chapters, etc.); and structural metadata specification (which describe each digital object for easy retrieval). Scenarios, according to Gonçalves (2004), consist of "sequences of events or actions that modify the states of a computation in order to accomplish a functional requirement" (p. 2). The scenarios as shown in Figure 2 link the DL services and the societies it serves. The 5S framework focuses on defining the minimal set of features belonging to a digital library. The minimal DL is defined as a quadruple (Repository, Metadata Catalogue, Services, Society) containing the core digital library components. The applicability, versatility, and unifying power of the 5S model are demonstrated through its use in three distinct applications: building and interpretation of DL taxonomy, informal and formal analysis of case studies of digital libraries, and utilization as a formal basis for a DL description language (Gonçalves et al. 2004).

8. COMPARISON OF DELOS REFERENCE MODEL AND 5S THEORY

The DELOS Reference Model is intended as a roadmap to enable the wider digital library community to follow the same route and share a common

understanding when dealing with the entities of the DL universe (Innocenti et al. 2011). In addition, the 5S Theory is built on this premise to provide a foundation for the definition of the digital library toward achieving theoretical and practical unification. The two models/theories have common objectives. These objectives are to provide a standard framework for DL projects. However, the methods employed in the presentation of DL frameworks are quite different, though their concepts still address the core components of DLs. While 5S Theory applies a rigorous definition of various concepts to DLs, the DELOS model focuses on identifying the main concepts and relationships encompassing the entire digital library. This is opposed to the 5S definition of individual DL aspects in terms of abstract entities, and these five levels of abstraction and their associated formalisms also render it difficult to adopt due to the complexities involved (Phiri, n.d.). The DELOS Reference Model's six (6) main domains: content, user, functionality, quality, policy, and architecture, are explicit and serve as a foundation for assessment of DLs. However, the organization of three distinct systems (Digital Library, Digital Library System, and Digital Library Management System) into one framework makes the DELOS model complex in nature. It also lacks strong emphasis on social aspects of digital libraries compared to 5S Theory (Fox et al 2003). There are some areas covered in the DELOS Reference Model's six main domains which are not distinctly represented in the 5S main constructs. They include policy and quality domains. 5S Theory provides a separate quality model which makes up for quality constructs not explicitly covered in the main 5S constructs.

Apart from the above differences there are some common relationships shared by these models. These common relationships are in such areas as Streams, Contents, Societies, and Users constructs. These two related concepts address the same component of a DL. The commonality of the two concepts can be vividly identified when applied to different DLs such as institutional based DLs (e.g. a University Digital Library) and a collaborative DL (e.g. the Networked Digital Library of Theses and Dissertations (NDLTD). For example, a university DL will serve the information needs of members of the university community, referred to as ***societies*** and ***users*** in 5S and DELOS Reference models respectively. However, in the case of a collaborative DL like NDLTD the *societies* and *users* will be determined by a number of institutions that are members of the collaborative project. NDLTD is a collaborative project of various universities, libraries, and other supporting institutions towards electronic thesis and dissertations (ETDs). In effect, its collections will be made open to all members. In the same vein, in regard to the digital objects or collections referred to as *streams* and *contents* respectively, in the case of a university DL the streams or content will be tailored toward meeting information needs of the university community, while in the case of a collaborative DL the streams or contents will cut across the information needs of members of the collaborative project.

9. CONCLUSIONS AND FUTURE WORK

The proliferation of digital library initiatives with different patterns of application systems calls for a unified model that will shape the development of the DL universe. The DELOS Reference Model and 5S Theory are the two prominent attempts in that direction. They are developed to guide in the design of various digital library initiatives. The aim of this development is to guide DL designers towards building DLs that will meet the information needs of users in the new global environment. However, there is still a dearth of research on their application. Therefore there is a need to examine various digital library initiatives using either of these two models as a framework for better understanding of patterns of DL initiatives. The outcome of such research will help to validate the applicability and usefulness of such models.

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