Towards A Central Digital Library Knowledge Space Aligning And Connecting Digital Libraries Globally

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Abstract

Digital Libraries are organized collections of digital knowledge content developed, maintained and made available to the public in order to meet the totality of information needs for a given end user. The investigation of Digital Library world, provided in this paper, has been based on a series of information resources (research articles, project reports, items from conferences, workshops, professional group discussions) regarding core Digital Library issues (reference models, metadata, interoperability, quality, technical and organizational aspects). Through summarizing the state-of-the-art, the article considers the most relevant research problems and open challenges for Digital Library. A number of professional communities are uniting their collaborative efforts to create community Knowledge Bases providing timely support to information workers about personalization of recommendations as well as common vision of different tools and resources that can be applied to the specific Digital Library information management context (considering its heterogeneity) to align Digital Library resources (contents and data) worldwide. Great potential of Digital Library services offers a range of benefits to researchers, teaching academics, learners, institutions, the global research community and the wider world. Some of these benefits are key drivers for the development of a Global Digital Library, which will provide more benefits and more value for each stakeholder group than ever before. On the road to a Global Digital Library it is quite necessary not only to have a common vision, but also a common virtual collaborative Digital Library Knowledge Space welcoming centrally all interested parties to exchange and to promote openly their proposals, questions and solutions to contribute to and to assess together the accuracy of conceptual scalability and computational complexity of Digital Library universe. The collaborative Digital Library Knowledge Space structure should have sufficient flexibility to accommodate the needs of various groups of information specialists and users.

Introduction

> 'At a cross-cultural level, libraries, museums and archives work together to a growing extend, to make their digital collections and objects available on the web for a large audience, very often through one central access point, a so called portal or Digital Library'. (IFLA, 2014)

From a technology point of view,

> 'Digital Libraries are distributed software architectures that aim at collecting, managing, preserving and using digital objects (or resources) for the long term, and providing specialized services on such resources to its users' (Fortino et al., 2014),

through a plethora of different realizations of Digital Library (DL) coexisting systems (Brahai et al, 2013).

Since different DLs, on the one hand, are gradually improving their services (employing the fullest potential of digital technology) to better meet information needs of diversified types of users (included researches, publishers and others) offering them the broadest and most complete service as possible (IFLA, 2009) and, on the other hand, are continuously experimenting a series of difficulties in regularly updated systematic (and cross-referenced) description, management over lifecycle, comparison and reuse of their digital resources, the lack of a shared and balanced approach on how to harmonize different DL profiles and structures is yet quite evident. In the meantime, to define DL world rigorously, a number of foundational theories - capturing the intrinsic nature of various entities of the DL universe - have been developed (e.g., DELOS (Candela et al., 2007), 5S Framework for Digital Libraries (2009)), though independently from specific standards, technologies, implementations or other concrete details regarding harmonizing and interoperability issues. It can be deduced that the actual DL scenario needs a common/widely shared approach (conceptual, theoretical, and practical) to address all areas that can impact alignment of DL (functionalities, resources) management worldwide, by exploring and adopting widely-shared expertise in digital information management[1] and in Semantic Web to break down data silos (as still different "Library data can be difficult to find on the Web" (Data.bnf.fr 2011:1)). In this view, different parties contributing to the development of DL systems, structures and contents worldwide, need to strengthen their collaboration as much as possible, in order to share, empower and reuse new efficient knowledge about tools and strategies necessary to align DLs (i.e. to harmonize DL processes and link DL contents and data) globally.

> 'The tools required to create, share and provide access to digital content are rapidly becoming the fuel behind the creation of new knowledge and community empowerment […] There is a library movement underway. The movement involves the development of a vision that will soon become a reality: a Global Digital Library'. (OCLC, 2011: iii, 5)

[1] UKOLN Informatics. http://blogs.bath.ac.uk/ukoln-informatics/

The idea behind the development of a Global Digital Library, that will be proposed in this article, is to design an open common DL Knowledge collaborative Space (e.g., Digital Library Community Tool Box) welcoming all interested parties (techy and non-techy, legal and informal, profit and non-profit, individual or group entities) to exchange and to promote openly their proposals, questions, solutions, standards, models, frameworks, policies and other information resources around the core areas of DL methodologies and technology. Practically, such DL Knowledge Space should represent a well structured, trustworthy and trusted (i.e. trusted "that will not fail" and trustworthy "whose failure can break the security policy" (Anderson, 2001:10)) central node, where different interconnected Groups of Interest can openly aggregate, update and exchange their knowledge regarding variegated DL aspects and activities.

Some of the recent best practices in aggregation and alignment of workforce diversity contributing to extend the community strategic knowledge management framework are represented by APA APARSEN[2] (and its knowledge-sharing spaces such as Virtual Centres of Excellence[3] bringing together expertise in Digital Preservation), EUROPEANA Professional[4], COAR (Confederation of Open Access Repositories)[5] and RDA (Research Data Alliance)[6]. Considering, that data sharing and curation via centralized infrastructures and networks have a large measurable impact on research efficiency and on return on investment in the data and services (Beagrie & Houghton, 2014), a central DL Knowledge Space can be connected with a pletfora of virtual communities contributing to excellence of cultural and research (Open Science[7]; The Hague Declaration, 2015) digital ecosystems, included Digital Arts and Humanities (Schimmer et al, 2015).

This paper will focus on a practical investigation and presentation of the state-of-the-art issues permeating and influencing creation, publication, organization, storage, preservation, dissemination, interoperability and re-use of DL resources worldwide.

The final goal of this exposure is not only to present breadth of resources and initiatives undertaken to support the DL universe, but also to increase general awareness of the necessity to create a Common central DL Knowledge collaborative Space, that can accommodate, make globally visible and easily retrievable different architecture resources (tools, models, frameworks, guidelines, standards) in support of aligned management and quality ("Service provision should be of measurable quality and performed according to codified policies" (Fortino et al., 2014)) of DL services based on interoperable policies (Innocenti et al., 2011), from a single access point.

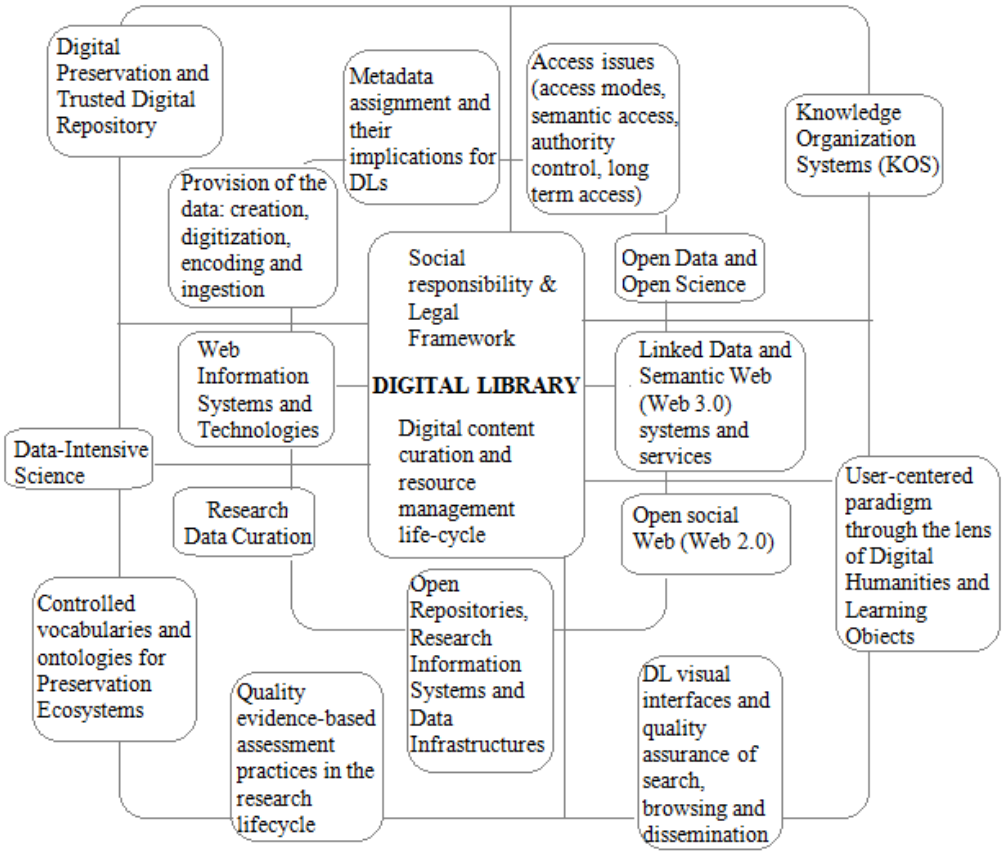
The study is based on a review of existing concepts and models, different professional group discussions, projects, technical and research literature developed under the Digital Library and Digital Repository umbrella .

[2] Alliance for Permanent Access and APARSEN project: http://www.alliancepermanentaccess.org/
[3] http://www.conservazionedigitale.org/
[4] Centro Italiano sulla Conservazione digitale: http://pro.europeana.eu/
[5] Confederation of Open Access Repositories: https://www.coar-repositories.org/
[6] The Research Data Alliance: http://trust-itservices.com/portfolio/rda-research-data-alliance
[7] FOSTER-UNESCO Open Science: https://www.fosteropenscience.eu/event/foster-unesco-open-science-doctoral-schools

Digital Libraries With Focus On A Number Of Collaborative Missions

> 'By making the wealth of material contained in Libraries, Museum, Archives and any Knowledge Repository worldwide available, [Digital Libraries] are giving citizens in every place of the world the opportunity to appreciate their global cultural heritage and use it for study, work and leisure. They are revolutionizing the whole knowledge management lifecycle' (Ioannis et al., 2011).

Hence DLs respond to the growing urge to share the wealth of cultural and research knowledge residing in digital resources and collections, they stimulate both new research perspectives for the humanities and reinterpretation of digital cultural heritage for global science and cultural innovation processes. The quality of this first order (user-oriented) DL mission depends directly on how DL resources are created, described, managed through their lifecycle, disseminated and reused. To this end, different DL actors (designers, system administrators, application developers, end-users) (Candela et al., 2007) should continuously and collaboratively work on a number of interrelated issues (by interconnecting roles and responsibilities of DL infrastructures (Tammaro & Casarosa, 2014; Pervan, 2015; Ganguly, 2015), the most common of which are represented in Figure 1.



Fugure 1. Digital Library: cross-referenced issues.

Different communities with high reputation at the national and international levels (e.g., AIB, AIMS/FAO, ALA, ARL, COAR, DCC, DLF, German National Library [of Economics, ZBW], GETTY, Global Digital Libraries Collaborative, ICCU, IFLA, JISC, LIBER, Library of Congress, OpenAIRE, NDLTD, RDA, SPARC, UKOLN, UNESCO) are committed as a collaborative advisory and advocacy force creating and promoting excellence in and awareness of research and applications in existing DL Ecosystems.

While welcoming growing awareness of digital maturity across different DL ecosystems as well as of the importance of extending and strengthening collaborative infrastructures (8th International Open Access Week 2015: "Open for Collaboration"[8]), different DL actors have been pushing their endeavors to create central virtual Knowledge base spaces (e.g., APARSEN roadmap to a Common vision[9]; BARTOC.org[10]; COAR Knowledge Base[11], CIARDRING indexing criteria[12]; VEST Directory[13]; Research Data Alliance/RDA[14]) and harmonizing frameworks (e.g., BIBFRAME[15], EDM[16], RDA Toolkit[17]) with objective to provide timely support to information workers about common vision of different tools and resources that can be applied to the specific DL information management context.

Collaborative efforts undertaken by various DL actors are paving the way also for other investments, such as development of federation search infrastructures (e.g., e-Infrastructures Austria[18], Europeana[19], HathiTrust's Digital Library[20], Science and Technology Digital Library[21], The European Library[22], Zenodo[23], World Digital Library[24]) favoring different joint strategies to connect previously disconnected communities. However, community involvement and collaboration around different DL areas poses still different critical issues and many research challenges to deal with, some of the most recurrent are the following (Table 1):

Table 1. Some critical issues and research challenges around Digital Library.

1.	How to create a seamless global DL research network, in which content providers and different types of users of all countries can participate to share collaboratively their knowledge?
2.	How to provide a central authoritative support and real-time updates to shared (within community space) tools and methodologies with the ability

[8] 8th International Open Access Week: "Open for Collaboration" announcement: http://www.sparc.arl.org/news/2015-open-access-week-theme-announcement
[9] The APARSEN roadmap to a common vision: http://www.alliancepermanentaccess.org/index.php/aparsen/
[10] BAsel Register of Thesauri, Ontologies & Classifications: http://bartoc.org/node/614
[11] COAR Knowledge Base: https://www.coar-repositories.org/activities/repository-interoperability/ig-controlled-vocabularies-for-repository-assets/wiki/
[12] CIARDRING: A directory of information services and datasets in agriculture: http://ring.ciard.net/indexing-criteria
[13] http://aims.fao.org/vest-registry
[14] AIMS: Agricultural Information Management Standards: http://www.trust-itservices.com/portfolio/rda-research-data-alliance
[15] Bibliographic Framework Initiative. Library of Congress: http://www.loc.gov/bibframe/
[16] Europeana Data Model Documentation: http://pro.europeana.eu/share-your-data/data-guidelines/edm-documentation
[17] RDA toolkit: http://access.rdatoolkit.org/
[18] E-infrastructures Austria: http://www.e-infrastructures.at/en/startpage/
[19] Europeana: think culture: http://www.europeana.eu/portal/
[20] HATHI Trust Digital Library: http://www.hathitrust.org/
[21] Science&Technology Digital Library: http://stdl.cnr.it/it/
[22] The European Library: http://www.theeuropeanlibrary.org/tel4/
[23] ZENODO: http://zenodo.org/communities/
[24] World Digital Library: http://www.wdl.org/en/

	to sustain innovative management of cultural heritage resources, publications, datasets, experiments, software, web sites, blogs (Assante et al., 2015)?
3.	How to develop and to maintain active (i.e. able to evolve and be monitored) checklists/Data Management Plans (DMPs)[25] and other Data Asset Frameworks (Barsky, 2014), shared in real-time by a nucleus DL Knowledge Space providing all necessary indicators to assess quality and and sustainability of DL information resources and processes?
4.	How can increasingly large and complex digital information and data (Big Data)[26] - on support of new modes of science and innovation - be managed in respect of Digital Rights Management and long-term preservation (Schrimpf, 2015; Kulovits et al., 2013)?
5.	How to appropriately represent and ensure licensed (Ball, 2014), Open Access and freely shared content[27] (NISO, 2015), in respect with different national copyright[28] and organizational issues, moral rights and regained author rights[29] (Mounce, 2015), copyright policy in the context of right to science and culture (UNspecial report, 2015) and of other connected issues?
6.	How to produce the context within which information can be continuously accessed, properly rendered, validated and transformed into knowledge[30], and re-used over a long time span?
7.	How to integrate/link DL (bibliographical, authority) data on the Semantic Web in a sustainable and trustworthy (Blumauer, 2013) manner?

Clearly, that in this complex scenario all entities developing and promoting their know-how and resources (proposals, solutions, models, frameworks, standards, use cases, best practices, services, applications and tools) on support of DLs must forge new partnerships, foster new combined skills and competencies, and develop new cooperative organizational structures, "thus to make it possible for others to identify [collaboratively] errors, to support, reject or refine theories and to reuse data for further understanding" (Assante et al., 2014) as well as to maximize the (re)use of existing guidelines and best practices (Summann & Shearer, 2015) as much as possible to support of interoperability and of resilience of DL systems around the globe.
The next sections will walk the reader at each aforementioned DL issues in a more in-depth manner through introducing models and frameworks needed to fully develop different "portions" of a systematic series of actions directed to some end: to support effective DL processes.

[25] Active Data Management Plans RDA IG: https://rd-alliance.org/groups/active-data-management-plans.html; ICPSR Data Management & Curation. Guidelines for Effective Data Management Plans: http://www.icpsr.umich.edu/icpsrweb/content/datamanagement/dmp/
[26] New H2020 project Big Data Europe: http://big-data-europe.eu
[27] Rounded Globe – a new Creative Commons electronic publishing Project: http://roundedglobe.com/about
[28] US Copyright law: http://www.library.illinois.edu/sc/services/copyright/index.html
[29] Issues in Scholarly Communication. University of Illinois: http://www.library.illinois.edu/sc/services/scholarly_communications/index.html; http://guides.library.utoronto.ca/author_rights
[30] TIMBUS Project:http://timbusproject.net/

The Overview Of Some Core Digital Library Reference Models

> 'A Digital Library is an online 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' (IFLA/UNESCO Manifesto for Digital Libraries)

Investigation of the state-of-the-art of conceptual models, metadata schemas and Application Profiles (APs), involved in the regulation of different aspects of the DL world, has detected a really vast panorama of resources and methodologies - inter alia - in incremental update and exponential growth. The proliferation, adoption and assignment of different metadata, their application profiles and standards (Ya-Ning, 2011; Sicilia, 2014; Baptista et al., 2015; Zeng & Jian Qin, 2016), i.e.:

- use of different (and not cross-referenced/crosswalked) descriptive schemas for libraries, museums and historical archives;
- description of manuscripts just like archival records and not according to different metadata models and often not shared local terminology/controlled vocabularies (Xu, L., & Wang, 2015),

has largely affected the problem of aggregating cultural heritage and research resources from heterogeneous digital repositories, making it difficult to develop meaningful aggregations, that do not lose information during the integration of various metadata records.

> 'As a practical matter, the infinite regress of meta-interpretive representation information stops when it reaches the level of the presumed knowledge base of a designated community, that is, the common baseline understanding that can be assumed on the part of targeted consumers' (UC Curation Center, 2015: 5).

A new LOD-LAM Project of the Kent State University (USA) is developing a number of efficient practices to counteract inadequate (or entirely absent) communication among Digital Objects (DOs) hosted in Libraries, Museums and Archives (LAM) designated communities by leveraging the power of linking/connectivity (Byrne & Goddard, 2011; Southwick, 2015) offered by the Linked Open Data (LOD) Universe.[31]

Different aspects mined from existing best practices, guidelines and policies developed in the DL context can be methodically distributed in a number of research clusters or application processes on support of lifecycle curation stages[32] of DOs (e.g., articles, datasets, images stream of data conceived as an aggregate of data and the

[31] LOD-LAM Project:http://lod-lam.slis.kent.edu/about.html
[32] DCC Lifecycle Curation: http://www.dcc.ac.uk/resources/curation-lifecycle-model

representation information/metadata) (iPres2013, 2013). These clusters include, but are not limited to (Table 2):

Table 2. Main clusters/processes determining quality of DO across its lifespan.

	Processes		Digital Object is:
1.	Conceptualization		• 'unit of information that includes properties (attributes or characteristics of the object) and may also include methods (means of performing operations on the object)'[33]. • 'An entity in which one or more content files and their corresponding metadata are united, physically and/or logically, through the use of a digital wrapper'[34]. • 'a discrete unit of information in digital form. A Digital Object can be a Representation, File, Bitstream, or Filestream the PREMIS definition of Digital Object differs from the definition commonly used in the Digital Library community, which holds a Digital Object to be a combination of identifier, metadata, and data' (PREMIS, 2012:13). • 'Something (e.g. an image, an audio recording, a text document) that has been digitally encoded and integrated with metadata to support discovery, use, and storage of those objects'[35].
2.	Creation & technical aspects		
3.	Harvesting & ingestion		
4.	Aggregation		
5.	Access issues (ubiquitous, open, closed, etc.)		
6.	Sharing & re-use		
7.	Appraisal & selection for long-term		
8.	Trust (data integrity, sustainability, usability, persistent access, security, privacy) (APARSEN, 2012)		
9.	Trustworthiness & performance		
10.	Scalability		
11.	Transformation		
12.	Adding value & Digital Curation		
13.	Dissemination & use & discovery		
14.	Integration with (external) other objects		
15.	Interoperability		

Substantially, the cluster "Adding value & Digital Curation" (Giess et al., 2012) combines the potential of all the other clusters, as its goal is

> 'to provide a stable interpretive experience of a given noumenal unit of content across space and time. Ubiquitous connectivity has largely eliminated difficulties posed by spatial concerns, but the inherently corrosive effects of time on digital content remain problematic.' (UC Curation Center, 2015: 12).

[33] A Glossary of Archival and Records Terminology: http://www2.archivists.org/glossary
[34] CDL Glossary: http://www.cdlib.org/gateways/technology/glossary.html#d
[35] A Glossary of Archival and Records Terminology: http://www2.archivists.org/glossary

As it was already mentioned, there is a series of foundational theories (of the most prominent are 5Sframework and DELOS superseded by DL.org Reference Model), capturing and identifying the cornerstone concepts within DL (DL at a higher level, DL System, DL Management System) facilitating the integration of different types of DOs and proposing better ways of developing effective and sustanaible DL systems and services. Contextualizing ongoing challenges and processes regarding a well-structured integration of DOs into DL systems, it would be reasonable, first of all, to refer to a set of seven core concepts (Organization, Content, User, Functionality, Quality, Policy, Architecture, provided by the DL.org) underlying every system, that can be fulfilled through complying to a number of specific criteria[36]. Secondly, referring to a qualitative harvesting and integration of different DOs types within DL system, the Europeana Data Model (EDM)[37], developed to aggregate heterogeneous cultural heritage resources (manuscripts, documents, paintings, art and architecture objects, photos, videos, etc.) within EUROPEANA DL, is worth mentioning. The EDM has been succeeded in effective solving of puzzle regarding the contextualization of a great typological diversity of DOs (harvested from distributed digital repositories) in well-structured and highly interoperable digital collection structures. The EDM is based on the solid foundations of DCMI Metadata Terms[38], the most widely used metadata vocabularies providing the lowest common denominators to describe different types of resources and data (valued as "first-class citizens" of processes (D-Lib Magazine, 2015)) on the web. Moreover, the EDM model has adopted a number of more advanced metadata models, aiming to transcend domain-specific metadata standards and accommodate, though mappings, the range and richness of different community standards such as, LIDO for museums, EAD for archives, METS (a flexible XML framework for encapsulating and pointing to administrative, structural, and descriptive metadata) conveying complex DOs (Fox & Torres, 2014). The EMD facilitates also Europeana's participation in the Semantic Web, basing itself on an open, cross-domain, semantic web-based framework (Haslhofer & Isaac, 2011), that includes RDF, SKOS, OAI-ORE, CIDOC-CRM, FRBR schemes relevant for modeling different connections and for sharing data between different conceptual classes.

Such a modeling approach, provided by the EDM, leaves different data providers and aggregators – providing their contents to EUROPEANA through the Data Exchange Agreement[39] - free to use their preferred metadata schemas, chosen or elaborated according to the specific local needs (Peroni et al., 2013), with regard to exploiting and valuing the common metadata elements and controlled vocabularies of values through crosswalks (e.g., mapping from the CARARE schema to EDM[40]). Given this, the EDM architecture presents a best current practice for consistent metadata interoperability ans harmonization[41], at the same time preserving and enhancing semantics of DOs managing by systems from different application domains (libraries, museums, archives, audiovisual collections). Such an approach is setting off an efficient mechanism for interoperability among a variety of services or components supporting cultural heritage DOs and providing a solid base for collaborative DL, that allows public and research

[36] DL.org. 7 core concepts:http://www.dlorg.eu/index.php/outcomes/digital-library-manifesto/7-core-concepts
[37] The family of technical documents about EDM (in particular Definition, Primer, Guidelines): http://pro.europeana.eu/web/guest/edm-documentation
[38] Dublin Core Metadata Initiative: http://dublincore.org/documents/dcmi-terms/
[39] The Europeana Data Exchange Agreement (DEA): http://pro.europeana.eu/data-exchange-agreement
[40] Europeana Carare Project: http://www.carare.eu/eng/Resources/CARARE-Documentation/About-metadata-mapping
[41] DCMI Glossary: http://wiki.dublincore.org/index.php/Glossary/Metadata_Harmonization

libraries to form a network of digital information in response to the needs of the Information Society and research (Europeana, 2014).

Metadata And Object-Oriented Data In Tandem With Interoperability, Harmonization And Quality Issues

Considering that

> 'systems of all partners in a collaborative Digital Library must be able to interoperate […] in such a way that they are readily and economically available for use by a defined community or set of communities' (IFLA/UNESCO Manifesto),

it is worth stressing the importance of a capillary modeling of all processes existing among different entities involved in DO lifecycle management. In this view, there is an urgent need to move towards collaborative development and sharing of sustainable descriptive metadata models/schemas (e.g., DCMI, FRBR, MARC, MODS, TEI, LIDO, LOM, RDA, VRA -based metadata):

- empowered by cross-references/crosswalks (e.g., GETTY crosswalks[42], LODE-BD crosswalks (Subirats, Zeng, 2013);
- consolidated with efforts of preservation of DOs ensuring their long-term usability (e.g., OAIS reference model (ISO, 2012; CCSDS, 2012); PREservation Metadata Implementation Strategies/PREMIS Data Dictionary for Preservation Metadata in new Version 3.0[43]);
- mapped to administrative (included recordkeeping) standards (e.g., AGRkMS, SARKMS; ISO 30300 – 30301), in order to meet efficiently descriptive, search, preservation, management and interoperability solutions focused on needs of different systems and users.

The approach of exploiting common data elements, facilitating appropriate mappings among different application domains, has a goal to better articulate the overall, even if idealized (Patel, 2011), mission-specific objectives of DOs.

While modeling DL processes responsible for DO's lifecycle management, it would be also of benefit to take into account the series of ISO 23081 Standards, as they cover most of important principles that underpin and govern information objects and their metadata, all processes that affect them, any system in which they reside and any organization that is responsible for their management. Modeling methodologies provided by this Standard together with those ones provided by the already cited LODE-BD, DCC Lifecycle and FRBR frameworks, would be very helpful to design a

[42] GETTY Metadata Standards Crosswalk: http://www.getty.edu/research/publications/electronic_publications/intrometadata/crosswalks.html
[43] DCMI. Digital Preservation Metadata and Improvements to PREMIS in version 3.0. Webinar: http://dublincore.org/resources/training/#2015dappert

multi-Entity metadata schema (Figure 2) sufficient enough to represent (starting from clustering metadata in groups and entities) the complexity of different processes existing between information resources and their immediate context such as: Responsible Body (Agent, with awareness of the distinction between a person/organization and her/his/it role), Event (acquisition, selection, preservation, protection, evaluation, etc.), Policy (Standard, Law, Data Management Plan etc.) and cross-entity processes based on relations, usability and space-time considerations.

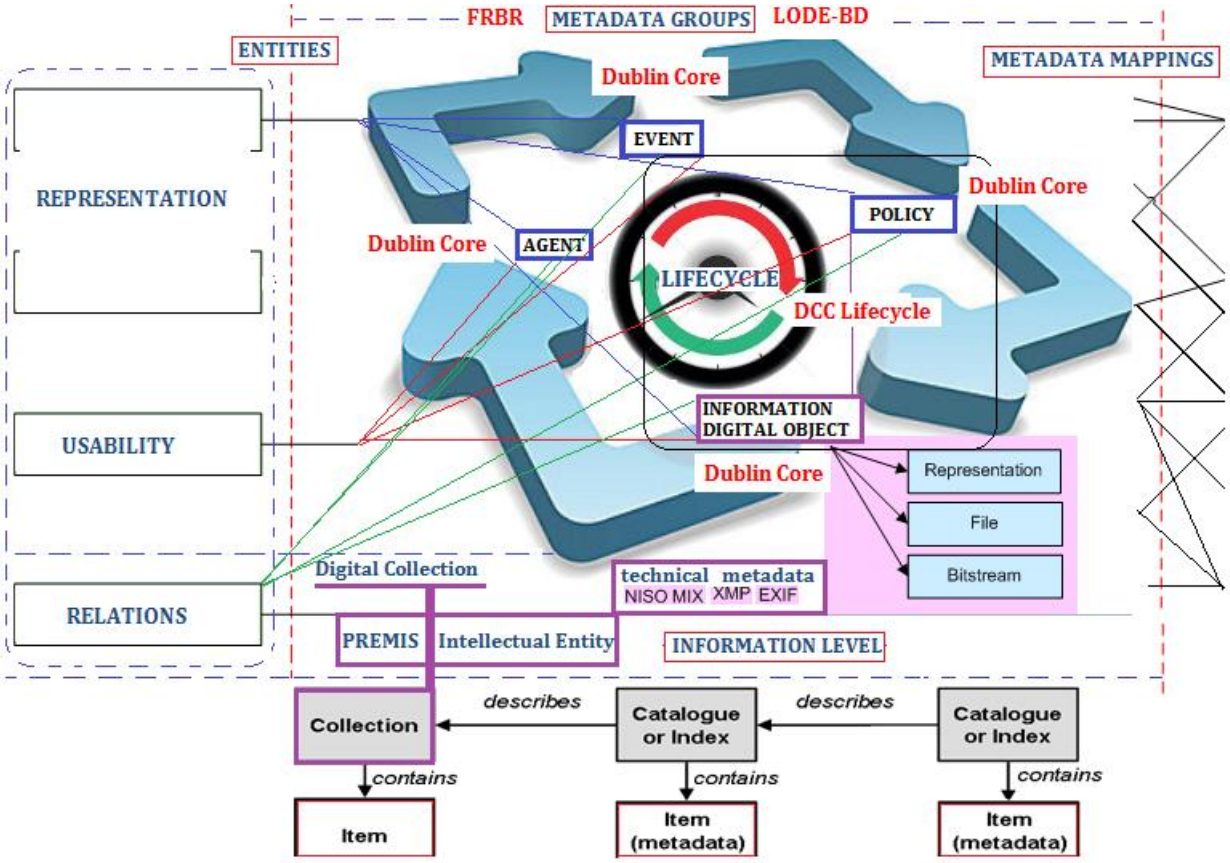


Figure 2. Clustering and aligning metadata on support of DL interoperability.

The graphical representation on Figure 2 shows basic building blocks tracing DO's lifecycle, that can accommodate numerous of other relations, matching them with interoperable and commonly accepted specification or standard.

To support such an evident need to model interoperability mechanisms among different information entities (comprised software and agents) involved in various phases governing DOs' management, the CERIF (Common European Research Information Format) data model - designed to support the storage of information about researchers, projects and organizations - is worth mentioning. Although the primary objective of CERIF model is to support CRIS (Current Research Information Systems), it can be also

> 'described using bibliographic standards and move those data to a data model of bibliographic standard […] This implies that […] CERIF model

> can be easily implemented within the existing Library infrastructure' (Ivanović et al., 2011).

A few years ago, the CERIF model has been also successfully engaged in VOA3R[44] (Diamantopoulos et al., 2011) and OpenAIRE CERIF-XML profile[45] in order to facilitate data exchange of different records on research projects in connection with result research publications and data, thus allowing the generation of complete reference DOs including semantic references to be used for different purposes (e.g. evaluation of scientific research results, generating bibliographies of researchers and institutions, citations).

Among ongoing challenges aimed at harmonizing and connecting various vocabularies, metadata schemas and object-oriented models, in order to bridge different DL (bibliographical and authority data) ecosystems, the recent NISO initiative on developing Standards for Bibliographic Vocabulary Exchange[46], LOD-LAM Project and FRBRoo (object-oriented definition and mapping from FRBRER, FRAD and FRSAD) are worth citing.

The LOD-LAM Project is focused on the whole range of LAM applications and tools in order to connect LAM (un)familiar data and metadata by means of LD (ISQ Information Standards Quarterly, 2012; Isaac et al., 2011; Babu et al., 2012; Baker, 2012; Hooland & Verborgh, 2014). This would be possible by analyzing and aligning (through semantic relationships) metadata elements (properties) used by different communities and data providers beyond LAM, by defining crosswalks from harmonized LAM (meta)data to some CKAN dataHub datasets.
The LOD-LAM Project aims also

> 'to develop an integrated tool [MV-Junction] to facilitate discovery of matched metadata terms, reorganization of metadata terms, and use of the selected metadata terms to link and aggregate useful data based on the needs'[47],

by making the best matches between various structured- and non structured-data and tapping into tap into the riches of LOD universe.
The recent FRBRoo document represents

> 'the definition of the object-oriented version of the FRBR family of conceptual models, harmonised with CIDOC CRM, hereafter referred to as FRBRoo, a formal ontology that captures and represents the underlying semantics of bibliographic information and therefore facilitates the integration, mediation, and interchange of bibliographic and museum information' (Bekiari et al.,2015).

Beside (meta)data harmonization, the next important prerogative to enhance the quality of communication between different expressions and manifestations of DOs from different DLs (thus also interoperability between DL systems that host these DOs) is to

[44] Using CERIF to describe Research Entities in a Virtual Network. http://aims.fao.org/news/using-cerif-describe-research-entities-virtual-network
[45] OpenAIRE Guidelines for CRIS Managers based on CERIF-XML. https://guidelines.openaire.eu/wiki/OpenAIRE_Guidelines:_For_CRIS
[46] NISO Launches New Projects to Develop Standards for Bibliographic Vocabulary Exchange (18 March 2015). http://www.niso.org/news/pr/view?item_key=0641282358290982226d2a535f1403ce877df9d7
[47] The LOD-LAM Project. Connecting libraries to the unfamiliar data and metadata resources in the Linked Open Data (LOD) Universe. http://lod-lam.slis.kent.edu/about.html

properly link metadata (properties) representing DOs with entities of authority KOSs (authority files, controlled vocabularies and other semantic schemes normalizing Responsible Body, Subject, Place headings)[48]. These KOSs should not be waivable in long-term perspective and be expressed and integrated on the Web by means of SKOS (Panzer & Zeng, 2009) and Linked Open Data (e.g., integrated classification system and thesaurus; cultural object name authority that link to various value vocabularies). By enabling metadata properties as LOD through KOS with non-literal data values, as it is recommended by (Subirats & Zeng, 2013; Subirats, 2014), DOs will be automatically connected to various collaborative authority platforms of trustworthy sources, contributing in this way to the cross-fertilization of metadata properties managed in different distributed DLs and Repositories on the global scale.

Last but not least. Each metadata schema that aims to achieve a certain level of acceptance by different stakeholders, should be trustworthy. To this end, to be recognized as a good practice for describing and managing DOs, every metadata schema should be sustainable in a long-term perspective and be conformant to widely shared community standards and quality criteria. These last, in turn, should be compliant with multiple level constructs reflecting feasibility and efficiency of metadata governing DO Lifecycle curation phases (Alemneh, 2009; Ochoa, Erik Duval, 2009).
It is worth noting that assessment of metadata quality

> is a delicate undertaking, as it tends to involve a reduction in diversity that implies a loss of information […] Simply meeting requirements is often hard because funding is unavailable or the original producer of the Digital Object cannot be reached. Hence, these specifications provide significant leeway in metadata and content file requirements, particularly for long-term preservation'. (CDL, 2011:3)

Evaluation of metadata quality should take place at multiple level constructs needed to assess quality assurance of different information packages conveying them. Below (Table 3) a number of Quality dimensions, mined from 5 S Digital Library Model, are presented. These dimensions represent the core blocks to assess the quality of the following DL concepts: DO, Metadata, Collection, Catalogue, Repository, Services.

Table 3. Quality core dimensions in relation to Digital Library Concepts (Fox, 2013).

DIGITAL LIBRARY Concept	Dimensions of QUALITY: Quality-Oriented Criteria
Digital Object	Accessibility – Pertinence - Preservability-Relevance Similarity - Significance - Timeliness
Collection	Completeness - Impact Factor
Catalogue	Completeness - Consistency
Repository	Completeness - Consistency

[48] The International UDC Seminar "Classification & Authority Control: Expanding Resource Discovery". (29-30 October 2015). The National Library of Portugal in Lisbon. http://seminar.udcc.org/2015/index.php. All International UDC Seminars. http://seminar.udcc.org/; ISKO UK BIENNIAL CONFERENCE "Promoting the theory and practice of organizing knowledge and information". (13/14 July 2015). London. http://www.iskouk.org/

Services	Composability – Efficiency - Effectiveness Extensibility - Reusability - Reliability
(META)DATA	Accuracy - Completeness - Conformance

The core dimensions, presented in Table 3, are key issues to evaluate both the Quality of DL structural dimensions and of its integration readiness level with other DL systems (Fox, 2012).

Frameworks To Program Some Technical Aspects

By focusing on DL interoperability issues, it is also worth noting a considerable and extensively use of protocols such as Z39.50, OAI-PMH, OAI-ORE, OData, supporting service, object and technical interoperability levels of DL architectures. Concerning DL data integration on Semantic Web, the extensively use of syntaxes, formalisms and ontological languages such as XML, RDF, OWL or JSON Object Notation for Linked Data should be mentioned.

In order to properly program, manage and curate data and processes (echoing 3rd LIBER Workshop on Digital Curation topics[49]), included those affecting the overall concept of trust (as defined in APARSEN, 2012) (authenticity of the digital objects and the metadata, rights, access, formats, security, long-tem preservation, documented processes and procedures for managing data storage) of digital information systems, it is also worth taking into consideration the following frameworks: ISO/IEC 27037:2012, ISO/IEC 29101:2013 regulating security and privacy; METS Rights; copyrightMD[50]; CDL Digital File Format (2011); NISO Recommended Practice Access and License Indicators; PREMIS. According to APARSEN, PREMIS semantic units (needed to model preservation processes of DOs over the long term) are very important components of every trusted digital information system. PREMIS units regard administrative metadata, generic technical metadata shared by all content types, specification of structural relationships relevant for preservation functions (ISQ Information Standards Quarterly, 2010).

To be recognized/approved as Trusted Digital Repository (TDR)[51], the modeling of all DL processes should be conformant to criteria of Open Archival Information System (OAIS) Standard (ISO 14721:2012; Lavoie, 2014; Data Seal of Approval Guidelines[52], TRAC superseded by ISO 16363:2012), that refers to a generic conceptual framework for building a complete TDR structure by identifying responsibilities and interactions between organization of people and systems accepted the responsibility to preserve information and make it available for a designated community. The OAIS provides a framework to terminology, concepts, strategies and techniques needed to describe properly lifecycle processes of information objects within a designated system. Moreover, the OAIS is being widely advocated by Digital Curation Center for the tasks of lifecycle planning for successful Digital Curation[53]. Digital Preservation, access management and content re-usability represent increasingly important topics within

[49] 3rd LIBER Workshop on Digital Curation. (19-20 May 2014). Keeping data: the process of data curation. Vienna. http://liber2014.univie.ac.at/

[50] CDL. Rights Management Group – copyrightMD: http://www.cdlib.org/groups/rmg/

[51] European Framework for Audit and Certification on Digital Repositories: http://www.trusteddigitalrepository.eu/Welcome.html

[52] Data Seal of Approval. The Guidelines 2014-2015: http://www.datasealofapproval.org/en/information/guidelines/

[53] Lifecycle Planning for Successful Digital Curation: http://www.dcc.ac.uk/resources/curation-reference-manual/chapters-production/lifecycle-planning; Using the OAIS Reference Model for Curation: http://www.dcc.ac.uk/resources/curation-reference-manual/chapters-production/using-oais-reference-model-curation

Digital Curation research field, with main objective to create new sustainable Digital Curation workflow models and tools (Weidner, Alemneh, 2013) supporting complex set of actions necessary for maintaining authenticity, reliability, usability and integrity of DOs in long-term perspective.

The completeness of the DO in terms of its preserved and secured (e.g., via encryption, digital signatures, public-key encryption techniques) integrity over time is good reflected in the concept trustworthy DO (Gladney, 2009). DO's integrity is

> 'measured in terms of content, fixity, reference, provenance, and context. [Nevertheless] it argued as well that the preservation of object integrity, though necessary, is not a sufficient condition of persistence. Persistence depends on other factors as well: organizational will, financial means, and the negotiation of legal rights' (Kresh, 2007: 7).

Persistence and the long-term preservation issues are core technical aspects regarding research data management, as "more and more universities and research centres are starting to build Research Data Repositories allowing permanent access to data sets in a trustworthy environment".[54]

Digital Library As A Collaborative Lab: Some Perspectives

The spread of new research and open web communities (e.g., Mozilla Science Lab, LinkingOpenData W3C SWEO Community[55]), together with recommendations, communications and best practices related to:

- Publication and usage of data on the Web (W3C Data on the Web Best Practices, 2015);
- (Research) data Lifecycle Management Curation[56] (Scholarly Communication and Research, 2014);
- Open Access and Open Data[57] as core areas in European Commission Recommendation on Access to and Preservation of scientific information and Digital Agenda for Europe;
- Linked Data (Hyland et al., 2014; W3C Best Practices for Publishing Linked Data),

accelerate international data-driven research innovation and discovery through facilitating data linking, exchange, harmonization, integration and discoverability.
In the last decade LD Semantic Web technology (i.e. a set of best practices for publishing and connecting structured data on the Web) has been widely fostered by the

[54] the re3data.org schema. Schema for the Description of Research Data Repositories: http://zenodo.org/record/11748#.VMQV3Gd0w5t
[55] Mozilla Science Lab: http://www.mozillascience.org/were-hiring/; LinkingOpenData W3C SWEO Community: http://www.w3.org/wiki/SweoIG/TaskForces/CommunityProjects/LinkingOpenData
[56] Research Data Management Forum (RDMF). DCC: http://www.dcc.ac.uk/events/research-data-management-forum-rdmf
[57] European Union Open Data Portal:https://open-data.europa.eu/en/data/

increasing adoption of Open Data poised to make a tremendous positive impact on how we can do research for the benefit of open collaborative (leveraging the power of Web 2.0) research value creation and commons-based property rights[58] (Sicilia, 2014; Tochtermann, 2014; Fox & Leidig, 2014; Assante et al., 2014, 2015).

A rich panorama of literature dedicated to LD (Bauer & Kaltenboeck, 2011; Martin Bojārs et al., 2013; Latif et al., 2014) offers different insights on how to incorporate LD data and tools into the daily workflow both of DL and its end user, and how to obtain new structured (meta)data that can be shared as LD, by providing recommendations of items from diverse domains (Figueroa et al., 2015). Beside the primary goal of Open Data combined with LD, which is to unlock and link data for creation of quality of services, applications over Linked APIs and Data[59] and "Knowledge out of Interlinked Data" (Auer et al., 2014), LOD has also a goal to improve technical and semantic interoperability (Zeng & Chan, 2015) of huge amounts of data (Big Data)[60] for beneficial of different cultural, research and industrial entities publishing their data on the Web.

Integrating DL content (e.g., pages about Authors, Works, Subjects as in The data.bnf.fr project use case[61]) and publishing services into the wider Web of Data (e.g., Library of Congress LD Service; LOD for Conferences in Computer Science project[62]) enriches (meta)data representing DO contents, linking them to other available data in the LOD Cloud (W3C Library Linked Data, 2011), thus improving interoperability, visibility of information resources on the Web and providing semantically searchable data.

> 'If all the data on the Web were Open and Linked, it would be easier to establish information systems combining different distributed Data Repositories. Consequently, the Web of Data would enable access and sharing of data and knowledge without barriers' (Subirats, 2014)

By integrating DLs with Semantic Web trustworthy resources by means of LOD, DLs will benefit in several aspects: high assurance of bibliographic control quality, reduction of redundancy of bibliographic descriptions on the Web, better data relatedness and machine readability, semantic enrichment and aggregation of additional information resources as well as semantic information retrieval. LOD is considered to be a milestone not only to increase the geospatial visibility of research outputs, but also the number of their statistics and semantic annotations.

Different DLs (e.g., OAPENlibrary[63]; Open Library[64]; Pakistan National DL[65]), in order to increase the visibility (more eyes - more downloads - more citation impact[66]) of their resources, are fully adhering to the principles of openness and transparency conveyed by Open Data in tandem with Open Access movements for Science and Humanities (Sula, 2013; Eve, 2014; IFLA Statement on Open Access).

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[58] Big Data & Linked Data: http://www.semantic-web.at/big-data-linked-data
[59] 4th workshop on Services and Applications over Linked APIs and Data, SALAD2015: http://salad2015.linked.services; 2nd Workshop on Linked Data Quality, ESWC 2015: http://ldq.semanticmultimedia.org/
[60] Big Data Public Private Forum: http://www.big-project.eu/; Big Data & Linked Data: http://www.semantic-web.at/big-data-linked-data; New H2020 project Big Data Europe. http://big-data-europe.eu
[61] The Bibliothèque nationale de France. http://data.bnf.fr/semanticweb-en
[62] LOD for Conferences in Computer Science project: http://lod.springer.com/wiki/bin/view/Springer+LOD/About
[63] OAPENlibrary: http://www.oapen.org/home
[64] Open Library: https://openlibrary.org/
[65] Pakistan National DL: http://www.digitallibrary.edu.pk/open.htm
[66] OpCit Project (The Open Citation Project - Reference Linking and Citation Analysis for Open Archives): http://opcit.eprints.org/oacitation-biblio.html

. Moreover, together within Digital Humanities[67] (Shaffner & Erway, 2014). DLs can enlarge and enhance their collaborative directions for research as never before, advancing in sharing of research knowledge through participatory Digital Humanities Infrastructures worldwide.

Conclusions. Towards A Central Collaborative Digital Library Knowledge Space

The state-of-the art (obviously not exhaustive), presented in previous sections, has shown a great vastness of different aspects and their varied facets involved to represent, manage and sustain over time structures and systems of Digital Library universe. The article has also introduced different initiatives (models, frameworks, projects, recommendations, best practices) underpinned by a number of communities uniting their collaborative efforts to create different community knowledge bases in order to provide timely support to information workers about common vision of different tools and resources that can be applied to the specific DL information management context.
On the road to a Global Digital Library it is quite necessary not only to have a common vision, though from different paths, but also a central common Virtual collaborative DL Knowledge Space welcoming dynamically all interested parties to exchange and to promote openly their proposals, questions and solutions on support of quality and harmonization of DL services. DL services should be aligned through interoperable Policies and Data Management Plans, as a global vision requires

> ‘the increasing need for "building by re-use" and "sharing" [while considering that] The lack of a systematic approach on the one hand and scarce knowledge of current solutions adopted on the other are among the main impediments to interoperability. What's more, solutions are all too often confined to the systems they have been designed for.’ (DL.org Cookbook)

Following the last research trends on support of DL universe, it would be appropriate, as a first step, to take into consideration the already mentioned seven core DL concepts (Organization, Content, User, Functionality, Quality, Policy, Architecture)[68] provided by DL.org project. These concepts can be chosen as main Knowledge pillars on which the central collaborative Digital Library Knowledge Space can be established (Figure 3).

[67] What is Digital Humanities? http://www.library.illinois.edu/sc/services/Digital_Humanities/index.html
[68] Dl.org. 7 conceps: http://www.dlorg.eu/index.php/outcomes/digital-library-manifesto/7-core-concepts

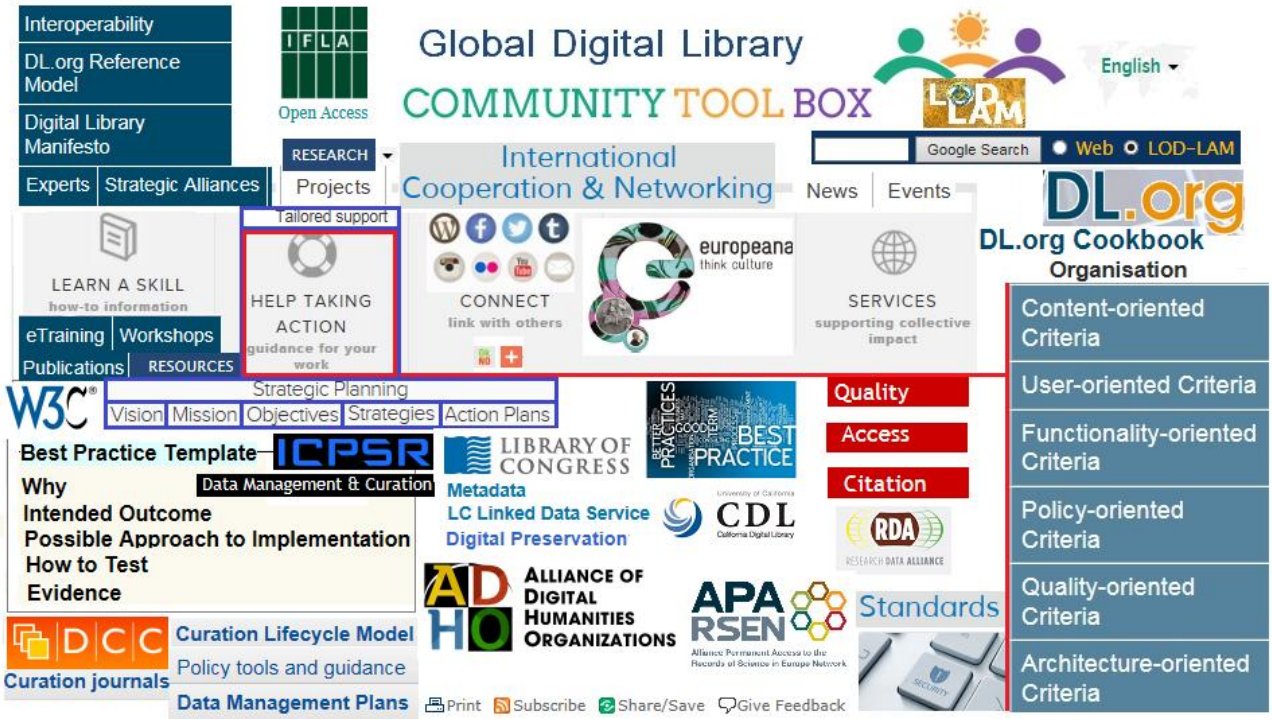

Figure 3. Pillars and clusters for a collaborative Digital Library Knowledge Space.

To design a collaborative Digital Library Knowledge Space ("Global Digital Library Community Tool Box", as showed in the Figure 3) different approaches can be undertaken.

The main goal of such a virtual common DL Knowledge Space is to aggregate different practical approaches of excellence to addressing common DL information management issues and needs.

The representation on the Figure 3 proposes to put together and to link know-how (structure, content) of a number of most significant open international communities, whose methodologies and best practices are being widely adopted on support of DL universe. Besides DL.org Community, IFLA, DCC, EUROPEANA, Library of Congress, California DL, LOD-LAM, APARSEN, W3C, Research Data Alliance, ICPSR communities are considered. Other collaborative Open Communities can be retrieved through the "International and Cooperation Networking" search box. The box "Learn a skill" can aggregate different international case studies from early adopters of information and data approaches concerned with scalability, flexibility and robustness of DL management systems, designed to help support a self-sustaining DL ecosystem. Knowledge sharing, adoption, enhancement and reuse of new trends provided by different participating entities (communities) through a central Digital Library Knowledge Space can be of a great benefit both for building a robust Global DL infrastructure and for communities themselves, as new virtuous research directions can be traced and connected, and collaborative forces to pursue common goals advancing research on DLs can be strengthen as never before.

Collaboratively shared ideas, solutions and activities will give any participating entity an opportunity to develop its vision and mission in close professional contact with others. That means that each contribution will be much more likely to address the community's real needs, rather than what a single participating entity think they might be. It will also mean DL Knowledge community ownership of the common vision and mission, while putting each single contribute on the same level of importance, as it can

greatly increase the chances that common efforts to build a Global Digital Library will be successful.

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