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Abstract. Quality is the most dynamic aspect of DLs, and becomes even more complex with respect to interoperability. This paper formalizes the research motivations and hypotheses on quality interoperability conducted by the Quality Working Group within the EU-funded project DL.org (http://www.dlorg.eu/). After providing a multi-level interoperability framework – adopted by DL.org - the authors illustrate key-research points and approaches on the way to the interoperability of DLs quality, grounding them in the DELOS Reference Model. By applying the DELOS Reference Model Quality Concept Map to their interoperability motivating scenario, the authors subsequently present the two main research outcomes of their investigation - the Quality Core Model and the Quality Interoperability Survey.

Keywords: Interoperability; Quality; Digital Libraries; Digital Repositories; Quality Core Model; DELOS Reference Model; DL.org

1 Introduction

Among the conclusions of a pioneering paper on DLs interoperability emerged "an urgent need to solve the problems hindering true interoperability on national and international scales" [1, p. 43], and the necessity to investigate this complex issue from cross-domain perspectives. Twelve years after that paper, these two needs are still crucial, and represent the research motivations of the EU-funded DL.org project (http://www.dlorg.eu).

DL.org is aiming to identify requirements, solutions and future challenges for achieving DL interoperability by adopting a cross-domain and multi-layered approach investigating the six core domains (Content, Functionality, Policy, Quality, User, Architecture) captured by the DELOS Digital Library Reference Model [2], which correspond to six dedicated working groups.

This paper focuses on the research analysis on quality interoperability developed within the DL.org Quality Working Group, and illustrates the two main research outcomes of its investigation - the Quality Core Model and the Quality Interoperability Survey.

2 A multi-level approach to interoperability

Digital libraries are complex systems, intrinsically interdisciplinary. They involve collaboration support, digital preservation, digital rights management, distributed data management, hypertext, information retrieval, human-computer interaction, library automation, publishing [3, 4].

The most crucial issue involved in the integration of heterogeneous DLs is interoperability. The IEEE defines interoperability as "the ability of two or more systems or components to exchange information and to use the information that has been exchanged" [5, p. 114]; the ISO/IEC 2382-2001 Information Technology Vocabulary, Fundamental Terms defines interoperability as "the capability to communicate, execute programs, or transfer data among various functional units in a manner that requires minimal knowledge of the unique characteristics of those units" [6].

As you can note, the ISO definition contains all the main features needed to characterize interoperability from a general point of view but, as a consequence, it lacks the contextualization necessary to apply it to a specific domain, as the DLs one can be. On the other hand, the IEEE definition takes into account a more functional perspective and it is mainly focused on the exchange of information resources, which represents only one of the facets of interoperability.

In order to achieve interoperability, in fact, DLs need to cooperate and agree at three different levels. Technical agreements cover formats, protocols, security systems, so that messages can be exchanged; content agreements cover the data and metadata, and include semantic agreements on the interpretation of the information; organisational agreements cover the ground rules for access, preservation of collections and services, payments, authentication, etc. [7, 8].

This three-tier interoperability classification (*organizational*, *semantic*, *technical*) has been used in 2004 within the European Commission by the Interoperable Delivery of European eGovernment Services to public Administrations, Businesses and Citizens (IDABC), which developed a European Interoperability Framework for eGovernment services [9], and has been adopted by DL.org in order to address the interoperability issue exhaustively. *Organisational interoperability* – concerned with defining business goals, modelling business processes – involves in particular the role of policy makers. Their part in allowing interoperability has been stressed in the last years [10, 11], to the extent that the European Interoperability Framework 2.0 will also include a *political context* (cooperating partners having compatible visions, and focusing on the same things) and a *legal interoperability* (appropriate synchronization of the legislations) level [11].

3 Towards quality interoperability: context and key-issues

A small fraction of works on DLs is dedicated to quality: those that do often focus on the establishment, adoption and measurement of quality requirements and performance indicators. However, the manner in which these quality indicators can interoperate is still under-researched.

The investigation of the DL.org Quality Working Group aims to gain insight into this area, underpinning work on other aspects of interoperability addressed by DL.org (Content, Architecture, Policy, Quality, Functionality, User), according to the DELOS Reference Model [2].

Quality is the degree that the DL conforms to the specified policy that expresses what the goal of a DL is. The policy can cover from very general guidelines to very technical issues, like the maximum response time of a system.

The ISO standard 8402-1994 defines quality as "the totality of characteristics of an entity that bear on its ability to satisfy stated and implied needs" [12]. This definition has been further refined in the ISO standards about quality "the degree to which a set of inherent characteristics fulfils requirements" [13], where requirements are needs or expectations that are stated, generally implied or obligatory while characteristics are distinguishing features of a product, process, or system.

Both definitions highlight how quality can be applied to either overall or single aspects of any products, services and processes, and is "usually defined in relation to a set of guidelines or criteria" [14, p. 33].

A quality model for DLs was elaborated in 2007 within the 5S (Streams, Structures, Spaces, Scenarios, and Societies) theoretical framework [15, 16]: the model was addressed to digital library managers, designers and system developers, and defined a number of dimensions which were illustrated with real case studies.

Within the DELOS Digital Library Reference Model [2], quality is described as one of the six core domains of the Digital Library Universe as follows: "The Quality concept represents the parameters that can be used to characterize and evaluate the content and behavior of a Digital Library. Quality can be associated not only with each class of content or functionality but also with specific information objects or services" [2, p. 20] In Section II of the DELOS Reference Model, a further elaboration is given: "The Quality Domain represents the aspects that permit considering digital library systems from a quality point of view, with the goal of judging and evaluating them with respect to specific facets [2, p. 48].

Overall, the DELOS Reference Model embraces the ISO 9000:2005 definition of quality, discussed above, and defines the *Quality parameter* as a resource that indicates, or is linked to, performance or fulfilment of requirements by another resource. A quality parameter is evaluated by a measure and expresses the assessment of a user. With respect to the ISO definition, we can note that: the "set of inherent characteristics" corresponds to the pair (resource, quality parameter); the "degree of … fulfilment" fits in with the concept of measure; finally, the "requirements" are taken into consideration by the assessment expressed by a user.

Moreover, the representation of the quality parameter provided by the DELOS Reference Model is extensible with respect to the several quality dimensions each institution would like to model.

The relationships and the interdependencies among quality and interoperability can be extremely complex. Quality and interoperability can highly affect each other: offering high quality services can require a high degree of interoperability among the different components of a system; similarly, poorly designed or low quality services can affect the degree of interoperability among different components that can be achieved, thus preventing the successful cooperation among different systems.

The previous considerations mainly concern a functional perspective but the distributed nature and the composition of different services in a user-centered perspective impacts also different dimensions of the quality of a digital library. Consider, for example, the possibility of adding user generated content to the information resources managed by a digital library: this basically breaks the traditional curatorial and selection process that, for example, distinguishes digital libraries from the Web, ensures the quality and reliability of the managed information resources, and keeps a digital library updated and fitting to the needs of one or more user communities. Indeed, the quality of the content added by users may be varying and it may not match the level and the requirements adopted when selecting the information resources to be managed by the digital library. This impacts not only the overall perceived quality of the digital library but also the policies adopted and enforced by the digital library: for example, a moderation step could be envisioned to review users' content before accepting and publishing it in a digital library, but this requires to have specific policies concerning the staff responsible for moderating annotations, the rules of which define when an annotation can be accepted or not, the procedures and functionalities for the ingestion of new content and so on. As a consequence, the quality of the policies themselves adopted by the digital library is concerned in this scenario, since they need to prove to be exhaustive, flexible, and powerful enough to be able to deal with the creation and the addition of new content by users [17].

Quality is still a low-priority issue with regards to DLs interoperability. Quality is not on the same level with the other interoperability issues. There are specific metrics for estimating content quality, functionality quality, architecture quality, user interface quality, etc. For example, content quality could be expressed by the completeness and the accuracy of the content. The overall quality of a digital library – which is a most challenging issue - could deal with the combined quality of all the issues involved, and the effects of the individual quality factors to it. For example, how the timeouts (from the system architecture - that make some of the results inaccessible), the content quality, and the sources functionality affect the quality of the search results.

The DL.org Quality Working Group defined *quality interoperability* as "the possibility for digital libraries to share a common quality framework", and is investigating both the research areas and the real-world cases in which quality issues have been developed.

Quality interoperability is a decentralised paradigm that poses the question of how to link very heterogeneous and dispersed resources from all around the world keeping the reliability of services and data precision. When building systems and operating on data in a distributed infrastructure, for example, each system needs to rely on every part and considerable effort is needed to arrange all the filters to ensure the end user has a homogeneous experience in working with such diverse sources. Quality must thus be provided in a decentralised manner, which requires standards.

One of the main obstacles towards the identification of quality interoperability solutions within the DL field is that often quality is not formally described but implied or "hidden" as a background degree of excellence, compliance to standards, effectiveness, performance, etc. which is not anyhow formally specified. That's why

quality aspects can be found e.g. within content, policy or functionality interoperability solutions.

Upon the agreement to adopt the DELOS Reference Model as the conceptual framework, the Quality Working Group analysed its "Three-tier Framework" [2, p. 17] and suggested to consider an additional level termed "Organisation", over-arching the existing levels of Digital Library (DL), Digital Library System (DLS) and Digital Library Management System (DLMS). The underlying rationale of this extension is that the concept "Digital Library" on its own may not be sufficient to address all interoperability issues that are under investigation in DL.org, in particular the organisational interoperability issues. It is considered that there is an organisation beyond a DL which defines the policy of the overall system in which the DL is operating. As an example, this organisation might be a subject community, a university, or a library steering committee that does not consider the DL itself the primary objective of a policy and might not even be termed 'library' at all.

4   The DL.org Quality Core Model

Upon the agreement that - from a system perspective - the core business of DLs resides in the management of their collections, the Quality Working Group identified a quality pattern that is thought to be most characteristic for DLs and that shall help DLs to interoperate in the quality domain. This pattern is grounded on the DELOS Reference Model Quality Concept Map [2, p. 191], where *Generic parameter*, *Content parameter* and *Policy parameter* express three of the six different facets (including also *Functionality*, *User* and *Architecture* parameters) of the *Quality parameter*. The pattern includes the three *Quality parameter* facets which have been considered crucial to allow interoperability, and has been thus called the "Quality Core Model" (Fig. 1).

The Quality Core Model's motivating scenario considers that representatives of two (or more) DLs have a round table to negotiate a service level agreement (SLA) defining their interoperability requirements and for this establish a quality threshold that each individual DL has to meet or exceed; in this case, "Quality" would provide transparent qualitative or quantitative parameters for defining the threshold.
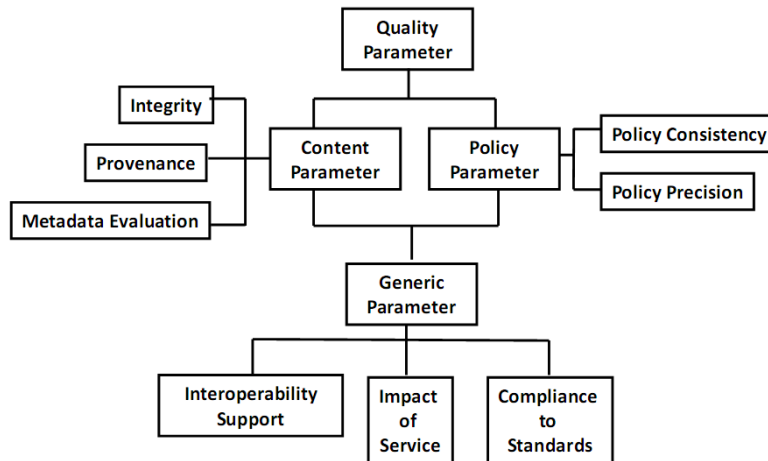
Fig. 1. The DL.org Quality Core Model

As facets of the *Quality parameter*, the *Generic*, *Content* and *Policy* parameters includes specific sub-parameters. The DELOS Reference Model Concept Map [2, p. 191] comprehensively lists forty-two sub-parameters, distributed within the six *Quality parameter*'s facets.

The sub-parameters that are currently included in the Quality Core Model are:

- *Compliance to standards*: the degree to which standards have been adopted in developing, managing and delivering a digital library service [2]
- *Impact of service*: the influence that a digital library service has on the users' knowledge and behaviour [2]
- *Interoperability support*: the capability of a digital library to interoperate with other digital libraries as well as the ability to integrate with legacy systems and solutions
- *Integrity*: the quality of being whole and unaltered through loss, tampering, or corruption [18]
- *Metadata evaluation*: the measurements of metadata schemas and their individual fields to support the collection, management, discovery and preservation of digital library content [2]
- *Provenance*: information regarding the origins, custody, and ownership of an item or collection [18]
- *Policy consistency*: the extent to which a policy or a set of policies are free of contradictions [2]

− *Policy precision*: the extent to which a set of policies have defined impacts and do not have unintended consequences [2]

The Quality Working Group investigated the Quality Core Model parameters' definitions and relationships – referring to The Society of American Archivists' definitions [18] when it was felt the DELOS Reference Model ones would still need to be enhanced, and producing related real user scenarios. As an example, we present here a user scenario from DRIVER (http://www.driver-community.eu/) on *Policy consistency*:

− *Check consistency between the DRIVER primate of fulltext exposure (content policy: DRIVER Guidelines) and DRIVER repository registration policy.*
The DRIVER repository network has guidelines for content providers that define how to expose fulltexts with OAI-PMH. This is to make clear that DRIVER expects repositories to expose fulltexts rather than catalogue entries. At the same time DRIVER has registration policies for including repositories in the network. Consistency can be checked by whether or not the content policy is reflected in the registration policy. During registration DRIVER offers repositories a validator tool to check their compliance with the DRIVER- Guidelines. However, for logical and technical reasons a binary decision for or against compliance cannot be made and repositories (and therefore also DRIVER) may still offer records to users that do not lead to a full text. As a consequence, an inconsistency between content policy and registration policy could be stated. However, DRIVER applies a quantitative compliance rate. This simplified example makes clear that an actual application of the DELOS Reference Model to a real user scenario may pose numerous challenges in the modelling relations provided by the DELOS RM, e.g. the relation between Policy by compliance and Policy consistency.

The selection of quality parameters for the "Quality Core Model" is not intended to alter the DELOS Reference Model Quality Concept Map, or to ignore quality aspects such as the functionality or the user ones; it arose, instead, from the application of the Quality Concept Map to a specific interoperability scenario, and from the need to identify - with a practical approach - core quality aspects that real-world DLs should take into account and measure in view of interoperability.

5   The Quality Interoperability Survey

The Quality Working Group is currently working on implementing the "Quality Core Model" by creating and running a Quality Interoperability Survey.
Digital repositories are included in the Quality Working Group's survey in the same way as DLs because they can be considered as the most dynamic example of information systems [19].
The results will help to understand what the professional community understands by quality interoperability issues, how it responds to them and from this to identify best practices in this area.

The Quality Working Group successfully completed the survey pilot and recently produced and distributed its official online version. The survey was organised in order to gather information on quality requirements regarding the different quality facets and asked specific questions on quality interoperability, focusing on the Quality Core Model parameters.

One of the main results of the survey pilot was that "quality" is considered as a subjective and dynamic entity, and that a common understanding even on the basic terms used is needed. In response, the Quality Working Group has prepared a glossary of terms that has been integrated with the survey's official version. In addition, comments from the pilot participants enabled the Group to simplify and improve the structure of the questionnaire (see Appendix, Table 1).

Among the specific best practices and recommendations, it is expected that a key-role will be played by certifications, checklists, validators and standards. These are typically quality areas in which digital libraries seeking to interoperate and negotiating a service level agreement (as postulated in the Quality Working group's motivation scenario) will need to define their approaches as a means to set their interoperability requirements and establish the quality threshold for their respective services.

A high level set of practical recommendations based on the Quality Core Model parameters and the Quality Interoperability Survey results will be then produced and presented as a checklist. It is hoped that the checklist will enable institutions to prepare the ground for interoperability discussions on quality but also that it may suggest areas in which institutions may / should be checking the quality of their data or services.

The checklist will first enable institutions to list areas that may be checked for quality in their own individual repositories / digital libraries taking into account that within one institution there may be a number of these with different responses. For each element examples will be provided based on the responses from the survey. Areas covered are:

- Formats
- Format compliance checking tools (and results)
- Metadata standards
- Metadata compliance checking tools (and results)
- Communication protocols
- Communication protocol compliance checking tools (and results)
- Web guidelines / standards in the areas of accessibility, usability, multilingualism
- Legal obligations *e.g.* for web standards

A second level will enable institutions to indicate whether and with what results they have already followed multi-level guidelines such as the DRIVER ones [20], taken part in certification processes such as DINI [21], monitored user satisfaction, and to check current policy for interoperation if such exists.

Together these first two areas will enable evaluation of the DL concerned according to the *generic quality* parameters of the Quality Core Model (*Interoperability support*, *Impact of service*, and *Compliance to standards*).

The central part of the checklist covers the parameters identified by the group as the most crucial for interoperability between digital collections/libraries. These points cover the following areas:

- Content
  - identifiers
  - metadata (type, compulsory elements, checking, use of ontologies etc., completeness)
  - identity authentication
  - provenance
  - tracking /recording changes
  - preservation

These areas cover the integrity, provenance and metadata parameters of the model.

Finally, a checklist of areas in which an institution may/should have policy guidelines (*e.g* for user access, preservation, metadata, networks, authentication, and service level agreements) recaps the areas above and covers the *policy quality* parameter section of the model.

An institution that completes the list and brings together the different documents pertaining to these parameters will not only be in an excellent position to analyse its own quality of system and service but also be well placed to compare and adjust in negotiation with other institutions as hypothesised in the group's motivating scenario.

6   Conclusions and Future Work

Quality is the most dynamic aspect of DLs, and becomes even more complex with respect to interoperability. By grounding its research on the DELOS Reference Model, analysing its Quality Concept Map, providing additional definitions and real user scenarios, the DL.org Quality Working Group identified a core selection of parameters that are considered to be essential to achieve interoperability.

The simplified pattern – called the "Quality Core Model" - has been implemented by developing and running an online survey on quality interoperability of current DLs and digital repositories. It is expected that the survey results will give an overview of best practices and adopted solutions towards DLs quality interoperability, by testing the feasibility of the Quality Core Model.

The survey will also lead DLs and digital repositories managers to identify core quality aspects with regards to interoperability, providing them with a first quality interoperability checklist.

In parallel, the DL.org Quality Working Group will elaborate further the definition of *quality interoperability*, by instantiating it at a technical, semantic and organisational level, providing examples of how it can be achieved.

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Appendix

Table 1. The Quality Interoperability Survey's questionnaire*

A.	QUALITY
1	Which type of digital objects are included in/collected by the DL/digital collection eg texts, images, audio, etc. (please separate names by commas)?
2	Do you have any guidelines on formats for these objects?
2a	If yes, which?
3	Do you use any validation tools to check the format compliance?
3a	If yes, which?
4	Which are the metadata standards in place?
5	Do you use any validation tools to check the metadata compliance?
5a	If yes, which?
6	Which are the communication protocols standards in place?
7	Do you use any validation tools to check the compliance to the communication protocols standards?
7a	If yes, which?
8	For which aspect(s) do you have guidelines or standards for the Web interface? [ ] Accessibility [ ] Usability [ ] Multilingualism
8a	Please specify which guidelines
9	Do you have any specific legal obligations on the Web interface?
9a	If yes, which?
10	Do you follow multi-level guidelines eg DRIVER 2.0, national association or institutional guidelines?
10a	If yes, which?
11	Have you ever been involved in a certification process eg with TRAC, DRAMBORA, DINI?
11a	If yes, please provide details
12	Do you monitor user satisfaction?
12a	If yes, by which method(s)?
13	Do you have collection(s) that need to interoperate with collection(s) from other institutions?
13a	If yes, please check the appropriate box(es) [ ] Academic institutions [ ] Private institutions [ ] Public institutions [ ] Research institutions [ ] Other

13b	If Other, please specify
13c	Please indicate any written/publicly available policy on each interoperation
B.	QUALITY AND INTEROPERABILITY
14	Is the DL/ digital collection interoperating as part of a network eg DRIVER, TEL, etc.?
14a	If yes, which?
15	Are persistent identifiers mandatory for the collection?
15a	If not, what percentage has them?
16	What percentage of those resources that do have a persistent identifier still resolve correctly?
17	Which standard(s) are used for the persistent identifiers?
18	To what extent do you use Dublin Core metadata?
19	Does the DL system define authorization for identities that have been authenticated by identity federations?
19a	If yes, please specify
20	Do you measure the impact of your DL services?
20a	If yes, please detail
21	Do you record/track changes to data items?
21a	If yes, please detail
22	Do you modify the content for preservation purposes?
22a	If yes, please detail
23	Please describe any actions you take concerning the tracking of provenance at a collection and/or an item level
24	Is there a minimum set of metadata fields which are compulsory when a new item is submitted?
25	How do you ensure consistent metadata values eg data values, subject terms, etc.?
26	Do you use thesauri, word lists, ontologies or authority files
26a	If yes, please detail
27	Do you use automation tools for technical metadata creation?
27a	If yes, please detail
28	Do you monitor updates, additions and changes to community practice for any standards you use?
29	On a scale 1-5 [1 very incomplete; 2 incomplete; 3 sufficient; 4 complete; 5 very complete], how complete is your metadata?
30	In your opinion, what is the single greatest barrier to metadata creation?
31	Please indicate if your organisation or the DL itself follows written policies or some other statement(s) that guide its development and maintenance [ ] User access [ ] Preservation [ ] Metadata [ ] Networks [ ] Online collections and services [ ] Intellectual property [ ] Authentication

	[ ] Service Level Agreements [ ] Other
31a	If Other, please specify
32	Please provide the URL of any publicly available policies according to the following areas Please indicate if your organisation or the DL itself follows written policies or some other statement(s) that guide its development and maintenance *Same categories of 31*
33	Do you know of any inconsistencies between the above policies?
33a	If yes, please detail
34	Are there any procedures in place to check how well a policy is implemented?
34a	If yes, please specify
35	In your opinion, are there any crucial quality aspects for interoperability that are not covered by part B of this survey (14-36)?
35a	If yes, please specify
36	Please tick the appropriate box(es) *1. Successful interoperability is largely a technical issue* ( ) Strongly disagree ( ) Disagree ( ) Neutral ( ) Agree ( ) Strongly agree *2. Quality aspects are crucial for successful interoperability* *3. We considered quality aspects for improving our interoperability within our organization*
C.	FINAL QUESTIONS
37	What do you consider to be a "good quality" Digital Library (DL)?
38	Are you familiar with the DELOS Reference Model?
38a	If yes, to what extent the models plays/played a role in the design and operation of your DL?

* Questions 2, 3, 5, 7, 9, 10, 11, 12 13, 14, 15, 19, 20, 21, 22, 24, 26, 27, 28, 33, 34 allow Yes/No/Don't know answers, while questions 35 and 38 allow Yes/No answers only. Answer options for sentence 1 in question 36 are repeated for sentence 2 and 3.