Applying the Levels of Conceptual Interoperability Model to a Digital Library Ecosystem – a Case Study

Charlotte Kostelic
Library of Congress, USA
ckos@loc.gov

Abstract

This paper applies the Levels of Conceptual Interoperability Model to a case study of two cultural heritage institutions with disparate but related collections in an effort to define a maturity model for interoperability between presentations of digitized cultural heritage materials. The Levels of Conceptual Interoperability Model (LCIM) is a progressive model developed by Dr. Andreas Tolk within the field of Modeling and Simulation and systems engineering to be used in determining potential for interoperability between systems. This paper applies the LCIM through a descriptive model to a digital library ecosystem that includes digital collections, digital libraries, and meta-aggregators. This paper seeks to determine if this model is sufficient as a method of measuring the potential for interoperation between systems, metadata, and collections within a digital cultural heritage ecosystem. A maturity model for interoperability within a digital library ecosystem can aid metadata operations specialists in determining the potential for interoperability between systems and collections.

Keywords: Levels of Conceptual Interoperability Model; Linked Open Data; metadata interoperability; cultural heritage, maturity model

1. Introduction

The development of digital collections and digital libraries that has occurred over the last two decades has been characterized by rapid development of new technologies and standards. The adoption of new standards and implementation of new technologies can be limited by the human and monetary resources available within individual institutions. Providing access to digital surrogates and metadata for cultural heritage collections is inherently a project that seeks to transform access to collections. The examination of interoperability for digital collections is an exploration that seeks to enhance access to online collections by making connections between cultural heritage materials.

The case study for this paper explores how two institutions with metadata and digitization standards that have developed over time may be able to measure their potential for interoperability between their collections. The two institutions are the Library of Congress and Royal Collection Trust. These institutions have formed a partnership through which they will explore shared access to collections held at each institution related to Early American history and the Georgian period in the United Kingdom. In order to better serve their users – some of whom may wish to consult collections at both institutions – and to enrich public enjoyment of their collections, the Library of Congress and Royal Collection Trust have sought to explore the potential for interoperability between their collections.

In order to better understand interoperability between systems that provide access to digital collections, a clear definition of interoperability is needed. The Oxford English Dictionary defines interoperability as "the ability of two of more computer systems or pieces of software to exchange and subsequently make use of data," although this definition may not adequately express the complexity within the concept. Digital library ecosystems can include not only collections within an individual institution, but also related collections in other institutions or dispersed collections around the world. Online users of cultural heritage collections may view

materials around the world through individual institutions' websites or through aggregators. This complex ecosystem requires a more complex understanding of interoperability than the one provided by the Oxford English Dictionary.

An underlying idea of this paper is that cataloging and description in cultural heritage institutions are constantly evolving and improving with a goal of improving access. Within the Library of Congress and Royal Collection Trust this evolution has led to metadata being created, edited, enhanced, and amended as standards change and users request different methods of access. This evolution has resulted in rich metadata records in various formats, accessible in different ways, and presented in different locations. With these different records in many locations there is a need to determine how to employ data from all of them in order to enhance use of the data. Interoperability, access, and understanding are inherently linked in a digital library ecosystem because of need for composability of digital objects within an online presentation setting. Although the ability to compose digital objects online can allow for users to access collections without a level of interoperability there may be a low level of understanding of the collections. The Levels of Conceptual Interoperability Model can serve as a maturity model for interoperability within the digital cultural heritage sector that can help to measure access, interoperability, and understanding.

2. Methods of exploring interoperability

2.1 Traditional Methods of Developing Interoperability

In a digital cultural heritage ecosystem, interoperability can be explored through different approaches. Digital objects within this ecosystem can contain many different components including one or more metadata record and one or more digital surrogates for the object. In an online presentation of a digital collection both the digital surrogate and the metadata record for each digital object must conform to the expectations of the presentation system.

Rachel Heery (2004) focuses on interoperability through the lens of the Semantic Web and its potential for use in digital libraries. Her exploration of the take-up for new technologies in libraries highlights the difficulties that libraries face in deciding whether or not to implement new technologies. Heery highlights that the tradition of work with technology in libraries is characterized by collaboration, exchange, and consensus. Further, this tradition of collaboration and consensus can aid the library community when determining how to implement semantic web technologies. Heery outlines the difficulties associated with trying to implement semantic web technologies but asserts that this culture of collaboration and consensus can aid in implementation at a small scale through interworking within the library community. This means that implementation of semantic web technologies (an example of a way to level up in interoperability) could be done through community building, furthering the potential for interoperability.

Van de Sompel & Nelson (2015) present the opinions of two practitioners working for over fifteen years on efforts to improve interoperability within the realm of scholarly communication. While not specifically outlining a model for interoperability, Van de Sompel & Nelson (2015) highlight the distinctions between repository-centric and web-centric approaches to interoperability, noting the need to focus on web-centric approaches in order to meet user needs rather than repository-centric approaches that better serve machines. This emphasis on user-needs is significant as systems used to support scholarly communication – in the case of Van de Sompel & Nelson – or digital libraries – in the case of the Georgian Papers Programme – are ultimately only successful if they support research conducted by humans. Van de Sompel & Nelson focus on systems interaction – specifically REST/HATEOAS principles – in their definitions of interoperability rather than the metadata-specific approach to interoperability which I hope to define in this paper. Alipour-Hafezi et al. (2010) also highlight models of interoperability with an emphasis on how systems interact. Alipour-Hafezi note three models for interoperability in digital libraries: federated, harvesting, and gathering. Specific metadata schema and data formats that are

applicable to interoperability protocols are highlighted, but the article places less of an emphasis on the underlying data that is harvested by the protocols and more of an emphasis on how the systems interact in order to share and transfer data.

Metadata interoperability in a digital library environment has been explored in a tiered approach by Jian Qin and Marcia Lei Zeng (2016). Qin & Zeng (2016) organize these levels based on "the point at which interoperability efforts are initiated" meaning that a different level of interoperability may be possible depending on whether the choice to make metadata records interoperable was made before or after cataloging guidelines were created, repositories were chosen, or records were created. This model was first introduced by Marcia Lei Zeng in Chan & Zeng (2006) where three levels of interoperability – schema, record, and repository – are highlighted. Chan & Zeng note the definition of interoperability within digital libraries highlighted in Tennant (2001) which helpfully defines interoperability as the ability for users to use one search to recall objects from many databases without needing to search each collection individually. Tennant's (2001) basic definition is expanded by Chan & Zang through their three levels. These three levels are not mutually exclusive and each requires data manipulation at different times in order to develop metadata records that conform to the expectations of the system. At each of Qin and Zeng's three levels – schema, record, and repository – the methods of achieving interoperability are limited by the need to achieve conformity using legacy metadata. This approach is both limiting – because understanding the metadata is limited to the description that already exists rather than future cataloging projects – and practical – because these approaches allow librarians and information professionals to use their existing data rather than use resources to create new data.

Nilsson et al. (2009) also published a set of levels that mark interoperability, although in this case the levels specifically related to compatibility with Dublin Core metadata within a specific application or specification. This "ladder of interoperability" contains four levels at which an institution can measure their compatibility and the levels present simple questions that serve as tests for with which to measure compatibility. Nilsson (2010) further reviews approaches to metadata interoperability and presents harmonization as the method of achieving interoperability between distinct metadata specifications. The five key components of harmonization within Nilsson's (2010) thesis are: syntaxes for metadata exchange, semantics to interpret metadata correctly, abstract models for designing standards, vocabularies as carriers of meaning, and application profiles used to combine standards. Nilsson (2010) applies definitions of metadata and interoperability to define the concept of metadata interoperability as "the ability of two or more systems or components to exchange descriptive data about things, and to interpret the descriptive data that has been exchanged in a way that is consistent with the interpretation of the creator of the data." The inclusion of a consistent interpretation of the data is a significant part of this definition. Nilsson (2010) highlights a model defined in Haslhofer & Klas (2010) made up of four levels with which to define a metadata model. This four-level model allows for different levels of interoperability to be defined based on the case study.

The purpose of creating a maturity model for interoperability within a digital library environment or digital cultural heritage ecosystem is to highlight ways in which access to digital cultural heritage materials may be improved. Nilsson (2010) and Haslhofer & Klas (2010) and their abstract metadata models are more aspirational than Qin & Zang (2016) because of the focus on legacy data presented in Qin & Zang (2016). The models presented by Nilsson (2010) and Haslhofer & Klas (2010) as well as their definitions of syntax and semantics can be combined to present a more detailed maturity model. The highest level within these models may not be practical for some institutions but it is a goal to work toward in order to improve access to cultural heritage materials.

2.2 Levels of Conceptual Interoperability Model

Applying an existing model for interoperability to the digital cultural heritage ecosystem will allow for a structured and consistent approach to interoperability. The Levels of Conceptual

Interoperability Model (LCIM) was developed by Dr. Andreas Tolk within the Modeling and Simulation discipline of systems engineering in order to recommend the use of "rigorous engineering methods and principles and replace ad-hoc approaches" to the development of interoperability (Tolk et al. 2009). The framework, as described by Tolk et al. (2009), has both descriptive and prescriptive uses in systems engineering. This paper will give focus to the descriptive uses of this model and will recommend equivalent examples of each level that exist in current practices and recommendations for the future. Tolk et al. (2009) assert that the purpose of the LCIM descriptive model is to "depict or analyze the ability, properties, characteristics and the levels of conceptual interoperability of an existing system or system of systems…" Thus one can evaluate the interaction between two systems and inform users of current interoperability potential.

TABLE 1: Levels of Conceptual Interoperability Model – Descriptive Model (Tolk et al., 2009)

Level	Layer Name	Description of level
L6	Conceptual	Interoperating systems at this level are completely aware of each other's information, processes, contexts, and modeling assumptions.
L5	Dynamic	Interoperating systems are able to re-orient information production and consumption based on understood changes to meaning, due to changing contexts.
L4	Pragmatic	Interoperating systems will be aware of the context (system states and processes) and meaning of information being exchanged.
L3	Semantic	Interoperating systems are exchanging a set of terms that they can semantically parse.
L2	Syntactic	Have an agreed protocol to exchange the right forms of data in the right order, but the meaning of data elements is not established.
L1	Technical	Have technical connection(s) and can exchange data between systems
L0	No	NA

Tolk et al. (2009) associate the different levels of their model with different concepts that describe how systems interact. The lower levels are concerned with integrability – meaning the ability for systems' hardware and protocols to interact. This is less complex than the middle levels' concern with interoperability – meaning the ability for systems to exchange data. The highest levels are concerned with composability – meaning the ability for systems to consistently represent data in context. In some ways the LCIM is misnamed because, while interoperability is a goal, the overall goal is for composability. Interoperability is merely one aspect of composability.

The LCIM in its descriptive role serves as a maturity model for interoperability within modeling and simulation. This means that each subsequent level must fulfill the requirements of all levels preceding levels. Tolk et al. (2009) note that the purpose of this descriptive model is to "describe how existing systems are interoperating and what level of conceptual interoperability can be reached by user's specific approaches without prescription." A digital library-specific application of the LCIM will be outlined in more detail in Table 4. The outcome of descriptive role can be used to evaluate the interoperability of existing systems and inform the users of the current properties and capabilities of interoperability. The flexibility of the descriptive model also allows for it to be applied to fields outside of the modeling and simulation field that are also concerned with the ability for systems to interact, share data, and maintain context.

3. Case Study – Georgian Papers Programme

3.1 Georgian Papers Programme

Beginning in 2015, the Georgian Papers Programme is a collaborative project within the Royal Collection Trust that aims to transform scholarly access to and personal enjoyment of the papers

of the Hanoverian monarchs ("About Georgian Papers Online," 2017). Over the course of the five-year program the Georgian Papers will be cataloged and scanned by the Royal Archives and Royal Library – two divisions under the umbrella of the Royal Collection Trust – with regular batches of papers being made available online. This artificial collection of papers has been assembled through a series of accessions to the Royal Archives and includes the official and private papers of King George I, II, III, and IV as well as other members of the Royal Family and Royal Household of the United Kingdom from the 18th and early 19th century ("What's in the catalogue?," 2017). To the end of transforming access to collections, the Royal Collection Trust partnered with institutions in the United Kingdom and United States in order to sponsor academic research fellowships and technical exploration. The Library of Congress has partnered with the Georgian Papers Programme in order to add context to its own early American collections some of which, such as the George Washington Papers (1592-1943), were created or accumulated while America was still a colonial holding of the United Kingdom under King George III. The Library of Congress and Royal Collection Trust have jointly sponsored a National Digital Stewardship Resident who will explore the potential for interoperability between the Georgian Papers housed at the Royal Collection Trust and related early American manuscript, bibliographic, print, and map collections housed at the Library of Congress.

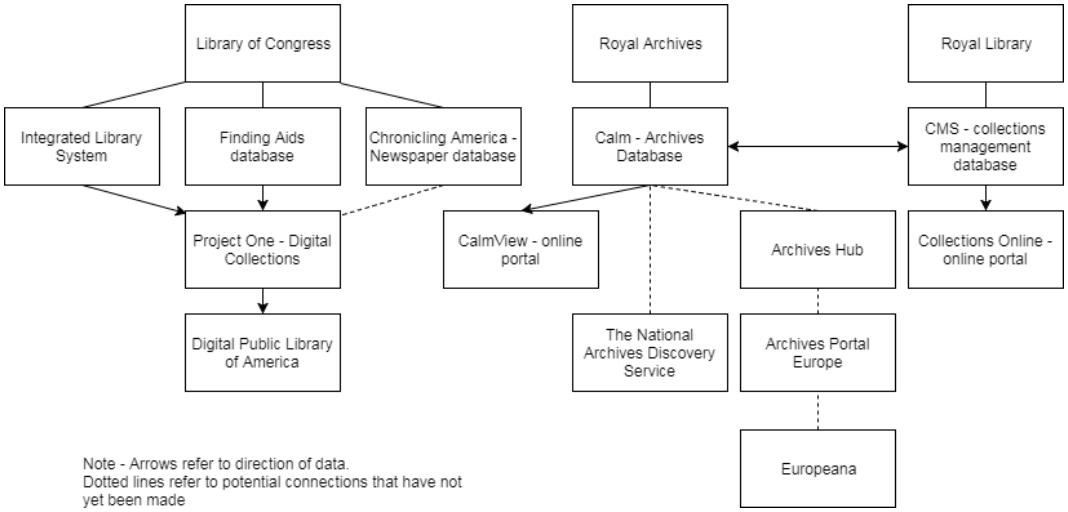
Both institutions have aspirations and plans to improve access to their collections online. Some collections are already accessible through online portals but further explorations could determine how these collections interact online with other collections and systems. While the impetus for the partnership between the two institutions was to make connections between collections related to the United Kingdom and its former colony, in order to make these connections there must be a way for users to examine materials across all collections. This exploration requires analyzing the individual institutions, their systems and metadata standards as well as the ways in which these systems and metadata standards may be interoperable.

While each of the partners involved in the project recognize the potential for improved access to their collections, there is not a universal definition of interoperability for its application to digital cultural heritage materials. Developing a definition of interoperability that will allow for the institutions to determine their potential will allow for partners to make it easier to determine what the goals are for the each of the partners individually as well as give them the potential to make decisions for collaborative projects related to interoperability of their collections. Each of the institutions is limited in their potential for interoperability based on practical limitations – such as levels of funding or staffing for further metadata enrichment projects – but the purpose of this exploration is to develop documentation and to describe the potential for interoperability rather than to try make recommendations for interoperable access for all of the collections.

3.2 Digital ecosystem for case study

The digital library ecosystem that is represented in this case study includes digital library systems, databases, and meta-aggregators. Figure 2 represents the digital ecosystem for the Georgian Papers Programme and the Library of Congress as it is explored through this interoperability project. Platforms that are not yet connected but may be in the future are noted with dotted lines. In particular, the Royal Archives has not yet established partnerships with Archives Hub or other meta-aggregators, but may establish these partnerships in the future. Data transfer is noted with arrows.

FIG. 2. Digital Ecosystem for Georgian Papers Programme



3.3 Current state of collections

In order to determine the potential of future interoperability between the collections, the current state of the collections, their metadata, and other components of their digital objects must be defined. Although there is an emphasis on interoperability between descriptive metadata for the collections, this analysis is concerned more broadly with interoperability between the collections and their components as well as the potential for interoperability between systems that deliver access to digital collections. Table 3 outlines the descriptive standards, syntaxes, and schemas used by the institutions to catalog their collections.

Table 3: Collection metadata schemas and syntaxes

Collection	Descriptive Standard	Schema	Syntax
George Washington Papers	Describing Archives: a Content Standard	EAD 2002 MARC21 MODS METS Project One Element Set	XML XML XML XML JSON
Benjamin Franklin Papers	Describing Archives: a Content Standard	EAD 2002 MARC21 MODS METS Project One Element Set	XML XML XML XML JSON
British Cartoon Prints	AACR2	MARC21 Dublin Core MODS Project One Element Set	XML XML XML JSON
American Revolutionary War Era Maps	AACR2	MARC21 Dublin Core MODS Project One Element Set	XML XML XML JSON
Early American Newspapers	AACR2	MARC21	XML
Georgian Papers (Archives)	ISAD(G)	EAD 2002 Calm Element Set	XML XML
Georgian Papers (Library)	N/A	RCT Element Set	[expressed in CSV]

The manuscript collections within the Georgian Papers Programme at the Royal Collection Trust are described using cataloging guidelines developed in-house. These guidelines are documented and available internally. The guidelines are an interpretation of ISAD(G) and the resulting records can be expressed in EAD 2002. The Royal Library collections have been described using a schema developed for the Royal Collection Trust to be used within its bespoke database. This schema captures key data for the objects within the library collections including creators, date created, physical descriptions, and other data points. The data can be exported from the database to CSV and Word documents using report formats created by internal developers but the metadata does not comply with any international standard descriptive practices or any metadata schema.

A select number of collections held by the Library of Congress have been selected for inclusion in this analysis due to their thematic similarities to the Georgian Papers including the George Washington Papers, Benjamin Franklin Papers, British Cartoon Prints, an assembled collection of American Revolutionary War era maps, and select early American newspapers. These collections have been cataloged and will all be accessible online by the end of 2017 although most collections are currently accessible online.

The collections are described using cataloging guidelines consistent with practices for each discipline. The George Washington and Benjamin Franklin Papers are both described at the object level in finding aids that are compliant with Describing Archives: a Content Standard (DACS). Select portions of the George Washington Papers have full-text transcriptions. These finding aids can be expressed in EAD 2002 and the data has also been mapped to MODS, METS, and MARC which can all be expressed in XML. The British Cartoon Prints and American Revolutionary War Era maps collections are both described at the item level in MARC records. These records have also been mapped to Dublin Core and MODS and are expressed in XML. All of the metadata records for the manuscript, print, and map collections have also been transformed into a data model for the Library of Congress Digital Library platform Project One. This data set is expressed in JSON. The Early American newspaper collections have minimal metadata records for their online presentation – containing only titles, dates, and page numbers – but have associated MARC records that describe the newspaper as a whole. These newspapers have been transcribed using optical character recognition (OCR) and are full-text searchable.

3.3 Current sharing capabilities and functions

Both the Library of Congress and the Royal Collection Trust currently have multiple online portals through which users are able to access collections. These systems have differing levels of data export capabilities. These systems serve as access portals for the various collections and some can also export data to specific formats. There are additional formats available for export directly from databases rather than from the online portals.

The Library of Congress collections are published through a finding aid database, an integrated library system that supports MARC records, and a digital library system that publishes digital collections. The integrated library system is able to export records to MARC and the finding aids database is able to export records to EAD 2002, MODS, and METS. These databases do not currently have connections to other systems outside of the Library of Congress but the data within these databases are transformed into records within the digital library system, Project One.

The digital library system, Project One, provides access to all digital collections with collection metadata mapped from existing descriptive metadata. Project One can be accessed through an online interface or via API. The Library of Congress is also a Content Hub for the Digital Public Library of America (DPLA) with the Project One API serving as the point from which data is shared with the meta-aggregator. The Project One element set has been mapped to the DPLA Metadata Application Profile for collections that have been provided to DPLA. Library of Congress collections that have been made accessible in DPLA can also be accessed using the DPLA API.

As separate divisions within the Royal Collection Trust, the Royal Archives and Royal Library each have separate online access platforms where Georgian Papers collections have been made accessible. Royal Library collections, including the Georgian collection, can be made accessible through Collections Online, the Royal Collection Trust online collections portal. This platform provides access to collections related to all of the different divisions of the Royal Collection Trust. The Royal Archives collections are currently accessible through a public viewer – CalmView – that is published from their database. These public access portals do not allow users to export data to any standardized formats and the formats noted in Table 3 are only able to be exported from internal databases by staff.

In order for archival collections from the Royal Archives to be made accessible in a meta-aggregator such as Archives Hub or Archives Portal Europe, the data must be exported from the database rather than be made accessible through the online view of the collections. Archives Hub requires data to be provided in EAD 2002 in order to be made available through their aggregator. In order to make this data accessible to Archives Hub or any other aggregator, the Royal Archives would need to export the data directly from their database. While the Royal Collection Trust has aspirations to provide data to meta-aggregators such as Archives Hub in the future, they have not formalized a partnership with any of the meta-aggregators noted in Figure 2 at time of publication.

4. Levels of Conceptual Interoperability Model and Georgian Papers Programme

4.1 Applying the LCIM to digital libraries

In order to determine the level of interoperability that may be possible for the institutions currently and to determine what might be possible with additional work, the LCIM is expressed with examples from digital library environments. These are not meant to be a prescriptive or a complete list of possible applications but to provide select common examples.

Table 4: LCIM applied to a digital library ecosystem (Tolk et al. 2009)

Level	Layer Name	Contents clearly defined	Description of level	Examples of level in cultural heritage institutions
L6	Conceptual	Documented conceptual model	Interoperating systems at this level are completely aware of each other's information, processes, contexts, and modeling assumptions.	
L5	Dynamic	Effect of information exchanged	Interoperating systems are able to re-orient information production and consumption based on understood changes to meaning, due to changing contexts.	PERICLES project
L4	Pragmatic	Context of information exchanged	Interoperating systems will be aware of the context (system states and processes) and meaning of information being exchanged.	ontologies
L3	Semantic	Content of information exchanged	Interoperating systems are exchanging a set of terms that they can semantically parse.	common semantic model
L2	Syntactic	Format of information exchanged	Have an agreed protocol to exchange the right forms of data in the right order, but the meaning of data elements is not established.	common syntax within systems (i.e. XML, JSON)
L1	Technical	Symbols of information	Have technical connection(s) and can exchange data between systems	HTTP, FTP connection within

		exchanged		system
L0	No	NA	NA	

Beginning at the L1, the LCIM can be explored through common methods of connecting data and systems within a digital library ecosystem. Level 0 outlines systems and methods that are not connected. Level 1 allows for systems that are connected through a shared protocol such as HTTP or FTP. The data can be copied or shared from one system to another but additional information about the data that was shared may not be understood after transfer. This is expanded in L2 by allowing for a shared formatting of data between systems that are connected via a shared protocol. By employing a common syntax, the data is better understood, although context may still be lost during transfer. By employing shared semantics in L3, the systems are better able to understand the content that has been exchanged. Common semantics expressed using the same data exchange format allows for this level of interoperability. L4 expands this to include an understanding of the context of the information that is exchanged. A common ontology can allow the systems to better understand the structure of the data. The terms are enriched through greater context allowing for shared terms to be better understood by distinct systems.

In order to achieve L5, systems would need to be able to capture information that aids in the understanding of metadata within the systems through time. While not applied to metadata specifically but to digital preservation and linked data more broadly, the PERICLES Project (2017) aimed to develop tools that could be used to document evolution in a digital ecosystem. The project uses linked open data technologies to capture information about digital objects in the environment in which they exist as well as changes to this environment and the digital objects. This example is the most closely related to L5 of the LCIM, but further exploration may elicit other examples of projects that capture changes to context in metadata through time. L6 requires a shared conceptual model that allows for systems to understand each other's processes, assumptions, and constraints. This level is still aspirational within a digital library ecosystem and does not have any examples in production. Systems for maintaining awareness of processes, contexts, and assumptions in a digital library environment are not yet available, but this level can still serve as a goal to work toward when developing systems.

While the goal of this maturity model is to measure metadata interoperability, it is not possible to measure metadata interoperability without also recognizing the potential for systems interoperability. A key requirement within Nilsson's (2010) definition of metadata interoperability is that it exists within the context of data transferred between two or more systems. So, while L6 is seemingly concerned with systems more than the underlying data, the systems and their capabilities must be required when determining the level of interoperability.

4.2 Interoperability between the Georgian Papers Programme and Library of Congress

Within the digital library ecosystem of the Georgian Papers Programme and the Library of Congress different levels within the LCIM can be achieved depending on the amount of resources that could be applied to a data transformation project. All collections can be exchanged at L1 or L2 without any additional changes made. All collections can be represented through XML and the systems are able to employ common protocols for data transfer. L3 could be achievable through the development or application of a crosswalk to a single metadata schema. As all collections have metadata expressed in XML this metadata can be transformed from many schemas into one allowing for L3 interoperability. L4 could be achievable through a shared ontology to which existing metadata could be mapped.

L4 may be the highest level which the selected collections may be able to achieve in this model, although even achieving L4 would require significant data transformations. While the Library of Congress has documented descriptive practices, the Royal Collection Trust collections may be more difficult to transform because not all of their descriptive practices follow

documented guidelines. Mapping all of these collections to a shared ontology would require a significant amount of effort to recreate the context in which the collections were originally cataloged.

5. Conclusions

The Levels of Conceptual Interoperability Model can serve as a maturity model for digital libraries that seek to improve their access to collections. Providing a leveled approach to interoperability and highlighting key improvements for each subsequent level can provide institutions with incremental changes that they may be able to complete in order to increase access. Using the examples set forth, the LCIM can be applied to current practices in digital libraries and can be used to measure the potential for interoperability between collections.

While overall a useful model for understanding and marking interoperability between digital library systems, the application of the LCIM may be limited because of the confusion that could arise from terms used to describe it. L3 is labeled "Semantic Interoperability" yet the description of the level is less complex than the understanding of semantic interoperability that information professionals may have already. In fact, semantic interoperability, a concept that stems from the development of the Semantic Web, is more similar to what the LCIM labels as Conceptual Interoperability or L6 of the model.

This analysis focused specifically on metadata interoperability although that is only one part of a digital library ecosystem. With the development of the International Image Interoperability Framework (IIIF), image interoperability in a digital library setting is a potential place of further exploration for this analysis. Additionally, further exploration of interoperability between specific systems that are commonly used in cultural heritage materials would provide a wider view of the potential for interoperability within a digital cultural heritage ecosystem.

An important aspect of this approach to interoperability research is that collection materials should be analyzed through the framework of a model that does not limit the potential for interoperability. Level Six of this model should not be thought of as the upper limit for composability or interoperability. As technology continues to develop and allow for further markers of interoperability, the LCIM should be expanded to include subsequent levels.

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