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2014

## The 1: 1 Principle in the Age of Linked Data

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## The 1:1 Principle in the Age of Linked Data

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### Abstract

This paper explores the origins of the *1:1 Principle* within Dublin Core Metadata Initiative (DCMI). It finds that the need for the *1:1 Principle* emerged from prior work among cultural heritage professionals responsible for describing reproductions and surrogate resources using traditional cataloging methods. As the solutions to these problems encountered new ways to model semantic data that emerged outside of libraries, archives, and museums, tensions arose within DCMI community. This paper aims to fill the gaps in our understanding of the *1:1 Principle* by outlining the conceptual foundations that led to its inclusion in DCMI documentation, how the *Principle* has been (mis)understood in practice, how violations of the *Principle* have been operationalized, and how the fundamental issues raised by the *Principle* continue to challenge us today. This discussion situates the *1:1 Principle* within larger discussions about cataloging practice and emerging Linked Data approaches.

**Keywords:** 1:1 Principle, RDF, Abstract Model,

### 1. Introduction

In general, Dublin Core metadata describes one manifestation or version of a resource, rather than assuming that manifestations stand in for one another. For instance, a jpeg image of the *Mona Lisa* has much in common with the original painting, but it is not the same as the painting. As such the digital image should be described as itself, most likely with the creator of the digital image included as a Creator or Contributor, rather than just the painter of the original *Mona Lisa*. The relationship between the metadata for the original and the reproduction is part of the metadata description, and assists the user in determining whether he or she needs to go to the Louvre for the original, or whether his/her need can be met by a reproduction (Hillmann, 2003).

The Dublin Core Metadata Initiative (DCMI) *1:1 Principle* appears to offer a simple dictum: “metadata is about one, and only one, resource” (Powell, Nilsson, Naeve, Johnston, & Baker, 2007).<sup>1</sup> Yet despite its apparent simplicity, “one to one...is a many headed snake, and it has bitten us often over the years.” (Weibel, 2010). Metadata creators find the *Principle* confusing or, at best, routinely ignore it because it remains unsupported by digital library software and exchange protocols (Han, Cho, Cole, & Jackson, 2009; Hutt & Riley, 2005; S. J. Miller, 2010; Park & Childress, 2009; Park, 2009; Shreeves et al., 2005; Stvilia, et al., 2004; Urban, 2012). Although the specific definition provided in Hillmann’s (2003) *Using Dublin Core* (and the “one-to-one” label itself) has fallen out of favor, the fundamental questions embodied in the *Principle* continue to animate debates and discussions about the DCMI Abstract Model and DCMI’s relationship to the Resource Description Framework (RDF).

This paper aims to fill the gaps in our understanding of the *1:1 Principle* by outlining the conceptual foundations that led to its inclusion in DCMI documentation, how the *Principle* has been (mis)understood in practice, how violations of the *Principle* have been operationalized, and how the fundamental issues raised by the *Principle* continue to challenge us today. This

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<sup>1</sup> For consistency, I use *1:1 Principle* except when variants are used in direct quotes. i.e. “one-to-one,” etc.

discussion situates the *1:1 Principle* within larger discussions about cataloging practice and semantic knowledge representations.

## 2. Background

While the specifics of the *1:1 Principle* are directly tied to the development of Dublin Core (DC), the general problem that it references — how to model the description of original resources and their associated reproductions or surrogates in various formats — is one that has plagued cataloging standards since reproductive technologies (such as photography, microfilm, and microfiche) became widely available in the mid-20<sup>th</sup> century. At the heart of these discussions are ontological distinctions among different kinds of bibliographic entities (e.g. multiple versions, electronic resources, non-book resources). But is also an account of how flat bibliographic records have struggled to represent the complex relationships among these entities. At the time that DC was being defined in the mid-1990s, many of the key stakeholders in its development had already been wrestling with these issues for more than a decade.

### 2.1. Describing Reproductions, Multiple Versions, and Electronic Resources

From the earliest cataloging guidelines, concerns about representing “reproductions” of bibliographic materials complicated emerging descriptive standards. As libraries began collecting an increasing number of different reproductive media (microfilms and microfiche), or multiple versions of the same work (i.e. a musical recording released simultaneously on vinyl, cassette, and/or compact disc), the problems began to multiply (Graham, 1992; Knowlton, 2009). Simonton’s report (1962), commissioned by the Association of Research Libraries (ARL), defined two solutions to the problem that serve as the foundations for current practice:

- The *Facsimile Theory* privileged the intellectual content of an item by making the “original” resource the focus of the record representing a reproduction. Following the long-standing practice of dash entries, a description of the reproduction itself would be included as a note.
- The *Edition Theory* required a record to represent the physical features of the reproduction, using a note to provide a description of the “original” resource.

The first edition of the *Anglo-American Cataloging Rules (AACR1)* used the facsimile theory and dashed entries to continue a common practice. However, *AACR2*’s cardinal principle required a shift in cataloging rules towards an edition theory (item-at-hand) perspective (Graham, 1992).<sup>2</sup>

This shift was not welcomed by the cataloging community who “assailed [it] as ‘an obsession with principle to the exclusion of common sense’” (Graham, 1992). Most vocal in their opposition to the rule change were libraries and information centers that dealt in large numbers of “reproduction” records, such as the Library of Congress (LOC), the National Library of Medicine (NLM), and academic libraries participating in the NEH-funded U.S. Newspaper Program (USNP). In response, the LOC issued a rule interpretation upholding a facsimile theory approach (Graham, 1992; Library of Congress, 2010). While some bibliographic services, such as the Research Libraries Group (RLG) RLIN, adapted to these rule interpretations, many cataloging services could not take full advantage of them, leaving “a fractured set of approaches” in place (Jones, 1997). Following the precedent set with microfilm reproductions, the Library of Congress applied the same rule interpretation to the digitization of its photography collections (Arms, 1999). “The records describe the intellectual expression and the original form of the material and provide a link to the corresponding digital reproductions” (Library of Congress, 2010).

Many of the arguments about which theory should be used center around user needs and the functions of information retrieval systems. For example, an advantage of the facsimile theory is that it allowed records about originals and reproductions to co-locate in the catalog, thereby

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<sup>2</sup> “The starting point for description is the physical form of the item at hand, not the original or any previous form in which the work has been published” (American Library Association, et al., 1988).

saving the time of the user. The facsimile theory also had economic advantages. Under an edition theory approach (*AACR2*), a cataloger had to “start over” to create a new record for the reproduction. The facsimile theory (*AACRI/LOC 1.11*) allowed catalogers to quickly clone an existing description and append a reproduction note, saving significant costs. (Graham, 1992).

## 2.2. Beyond the Book: The Description of Art, Visual Resources, and Archival Materials

At the same time that cataloging standards struggled with reproductions a parallel conversation was taking place about the representation of surrogates for non-book visual materials, such as artworks, photography, and archival materials. Members of this community drew careful distinctions between a reproduction that fully represented an original object and surrogates which merely stood-in for the object, i.e. a photograph of a 3-dimensional sculpture does not reproduce the sculpture, but does allow us to represent it in an information system. This community included professionals responsible for managing visual resource collections (art and architectural slide collections) and museum collections (the Getty’s Art History Information Program, later the Getty Information Institute – GII) (Fink, 1999; McRae & White, 1998). Until the advent of centralized online catalogs, the distinction between originals and surrogates was handled by establishing physically separate card catalogs. However, in a MARC-based catalog what kind of resource a record represented was less clear. In order to make this more explicit, the MARC Visual Materials (MARC-VM) and Archival Materials Control (MARC-AMC) formats introduced new control fields that made the “type of record” explicit (Dooley & Zinham, 1990; Evans & Will, 1988). In discussing the need for these new features, we see examples that would later be revisited to illustrate the need for the *1:1 Principle*:

The [*Art and Architecture Thesaurus*] considers reproductions of works of art to be surrogates for original works and will recommend that they be indexed in a similar fashion. For example, PAINTING (655) would be used to describe both Leonardo's *Mona Lisa* and a slide reproduction; SLIDE (655) would also be used in the latter case. This holds serious implications for effective retrieval...In an integrated database containing both of these media, searchers interested only in examples of actual paintings might have to learn to exclude slides, microfilm, and other reproduction media in their search queries to retrieve only records for original paintings. . . . One solution might be the addition of a “reproduction” facet to indexing strings for object surrogates so that they would be differentiated from “originals” in a browse display (Dooley & Zinham, 1990).

The ability to distinguish between descriptions of originals and surrogates in various analog and digital formats was a key component of emerging standards for describing information about artworks and museum objects. Both the Categories for the Description of Works of Art (CDWA) and the Visual Resource Association’s VRACore included structures that enabled the separation of information about different kinds of resources (Baca, 2002; Harpring & Baca, 2009; Visual Resources Association & Whiteside, 1999).

## 2.3. A Principle is Born

When the DCMI began, it had an explicit goal to describe “document-like objects” (DLO) found on the World Wide Web (Weibel, 1995). The development of this new standard soon came to the attention of several organizations interested in developing online representations for their collections, including RLG, the Getty Information Institute (GII), and the UKOLN Arts and Humanities Data Service (AHDS) (Erway, 1996; Fink, 1999; P. Miller & Greenstein, 1997). Advocating for the needs of library, archive, and museum (LAM) collections, RLG argued that DC could be used to describe offline physical collections and that the definition of DLOs should extend to images (Erway, 1996). The *Guidelines for Extending the Use of Dublin Core Elements* grounded its recommendations for a “record type” indicator or element refinements on earlier

work for reproduction/surrogate descriptions (Research Libraries Group, 1997a, Research Libraries Group, 1997b).

The RLG proposal became a central point of discussion at the 1997 DC-4 Workshop in Helsinki, Finland. Rather than adopt the proposed changes in the RLG *Guidelines*, workshop participants discussed the relationship between “logical clusters of metadata...that reference one, and only one, state of the information resource,” which became the nucleus of the *1:1 Principle* (Bearman, 1999; Weibel & Hakala, 1998).

Following the Helsinki meeting, *1:1 Principle* issues emerged in several working groups (One-to-One, Relations, and Data Model). The discussions were frequently contentious debates between members in different camps. Cultural heritage professionals' concerns with the *1:1 Principle* primarily focused on the kinds of resources that could be described using DC. Drawing on their experiences with previous standardization efforts, this camp felt it necessary to provide guidance for different types of materials. However, there was a strong resistance to DCMI getting into the cataloging rules business, especially ones that needed to deal with complexities of different ontological kinds. The members of this group preferred to let Dublin Core remain a simple vocabulary for resource discovery. Acknowledging the concerns of cultural heritage professionals, the latter group argued that the kind of discrimination sought for cultural materials could be handled by more robust local standards (P. Miller & Greenstein, 1997). Furthermore, discussions on the dc-one2one listserv:

. . . made absolutely clear that there is no consensus on what 1:1 really means in practice. In the end, people will describe what \*they\* want to describe, for their purposes and the purposes of their user community. That means they may describe a TIFF of an Ansel Adams photograph as having been created by Ansel Adams. Who's to say they're wrong? (Wendler, 1999)

By the end of 1999, discussion in the One-to-One group dwindled without having reached a clear consensus on the *Principle*. It was formally combined with other task groups into the DC-Architecture working group which attacked the problem from a different perspective.

Discussions in the Relation working group focused more on developing logical clusters of metadata that could be linked together. The discussions echoed concerns found in earlier MARC-based solutions to representing originals and reproductions. In particular, there were concerns that separating descriptions into distinct records could result in a loss of information when shared outside of an application. The suggestion of separate records also raised concerns about how to display them to users, with a sense that independent representations of originals and reproductions would make the task harder. Proponents of “keeping Dublin Core simple” suggested that atomic statements about resources enabled better discovery of resources without the additional complexity of resource type-based models. Instead, statements about resources could be dynamically organized into logical packages for particular uses such as retrieval or display for a user (Lagoze, 1997, 2001a).

### 3. From Principle to Abstract Model

Thus far, the story of the *1:1 Principle* has been about cataloging practices in a cultural heritage community concerned with ontological distinctions and relationships among resources. The introduction of these concerns into the development of DC metadata brought these practices into contact with fundamentally different theories of description that emerged from formal knowledge representation (KR) approaches. KR semantics were not merely concerned with fixing the meaning of individual vocabulary terms, but how descriptions could consistently refer to described resources (Urban, 2012).

This was of little concern when Dublin Core was created as embedded metadata within a document-like object, such as a HTML page. In this case the metadata described the resource that it was embedded within. A desire to describe non-textual resources meant developing a

standalone Standard Generalized Markup Language (SGML) syntax that would provide “explicit semantics of each Dublin Core element”; however, “discrete packages of metadata cannot be identified and the semantics of repeated elements are not specified” (Burnard, Miller, Quin, & Sperberg-McQueen, 1996). These conversations resulted in the emergence of the Warwick Framework that would allow for the creation and exchange of metadata containers (Dempsey & Weibel, 1996; Lagoze, 1996). A package might include DC metadata, or metadata in other formats.

The Warwick Framework became one of several alternative metadata proposals submitted to the World Wide Web Consortium (W3C) in order to address laws aimed at filtering adult content on the Web. Among the others were the Platform for Internet Content Selection (PICS), Microsoft’s XML Web Collections (XMLWC), and Apple’s Meta Content Framework (MCF). Rather than developing each of these recommendations separately, the W3C rolled them together into a new initiative known as the Resource Description Framework (RDF) (E. Miller, 1998).

As a model for expressing a formal semantics for metadata, RDF owes a great deal to earlier artificial intelligence and knowledge representation research that took place before the advent of the World Wide Web (Halpin, 2004). In addition to fixing the meaning of properties used to describe resources, researchers in this area quickly realized that referent tracking was essential to the development of computational reasoning (Lenat & Guha, 1990). Guha would add features originally developed for the Cyc project to MCF and ultimately to RDF (Halpin, 2004). In the context of the RDF model, the relationship between a metadata statement and a resource is established through the consistent assignment of a URI (Berners-Lee, 2002; Hayes, 2004). In theory, if all the objects of description are supplied with a URI, statements about those resources will naturally organize themselves around these identifiers, fulfilling the main objectives of the *1:1 Principle*.

The development of RDF and eXtensible Markup Language (XML) specifications encouraged DCMI to begin work on a more formal data model for Dublin Core (Baker, 2012; Weibel & Hakala, 1998; Weibel, 2010). Initially, this work expressed DC descriptions as a variant of RDF. However, within the implementer community, there was a great deal of initial resistance to RDF in favor of simpler “plain” XML representations. This was due in part to a lack of practice and software tools that could understand RDF, and to fundamental misunderstandings within the Dublin Core implementer community that saw RDF as an overly complex XML syntax (Baker & Johnston, 2011; Baker, 2012). Because the XML serialization of RDF represented a graph structure, it was also less human-readable than a document-like encoding of element/value pairs. Resistance to RDF also came from the Open Archives Initiative (OAI) community, which was developing a protocol for exchanging “packages” of metadata along the lines of the Warwick Framework. “It may be that the vast majority of data providers don't need (or even understand) RDF and are mainly interested in exposing metadata as simple attribute-value pairs or simple trees for which XML is perfectly appropriate” (Lagoze, 2001b). In order to conform to the simple DC and to provide a low barrier to use (i.e., by using well-supported technologies), OAI-PMH initially required a minimal DC XML schema (later versions of OAI-PMH referenced official DCMI XML syntax recommendations) (Lagoze, Van de Sompel, Nelson, & Warner, 2008). As a container architecture, OAI-PMH left the aboutness of a record to the enclosed metadata specification.

The intersection of XML and RDF models for DC metadata created some inherent tensions. Although DCMI developed an implicit grammar for statements, it was intentionally scruffy in order to accommodate the broad diversity emerging on the Web (Baker, 2000, 2012; Johnston, 2006). Addressing calls for more guidance, DCMI released official recommendations for encoding Dublin Core in XML and RDF that included rudimentary definitions of an abstract model. This initial model specified a one-to-one relationship between a record and a resource at the same time recognizing that “there is no formal linkage between a simple DC record and the resource being described. Such a linkage may be made by encoding the URI of the resource as the value of the DC Identifier element, however this is not mandatory” (Powell &

Johnston, 2002). Because of implementation confusions about this early model, a more formal recommendation was published as the DCMI Abstract Model (DCAM) (Powell, Nilsson, Naeve, Johnston, & Baker, 2005). Although DCAM borrowed some concepts from RDF, “DCAM was meant to provide a basis for guidelines that would allow metadata records to be encoded using XML, HTML, and in principle, any concrete implementation syntax...” (Baker, 2012, p. 121). Although DCAM enabled syntaxes to include “slots” for URIs to reference a resource, it also continued to support *1:1 Principle* concepts:

The abstract model described above indicates that each DCMI metadata description describes one, and only one, resource. This is commonly referred to as the one-to-one principle...However, real-world metadata applications tend to be based on loosely grouped sets of descriptions (where the described resources are typically related in some way), known here as description sets. For example, a description set might comprise descriptions of both a painting and the artist...(Powell et al., 2005)

Unfortunately, DCAM failed to achieve widespread adoption within the Dublin Core implementer community, especially among LAMs that are the focus of this discussion. Instead of resolving the tensions between RDF and XML approaches, the DCAM “fell between two stools,” leaving neither group invested in applying it to their data (Baker & Johnston, 2011).

#### **4. 1:1 Principle Violations and Metadata Quality**

Because one of the fundamental objectives of Dublin Core is to enable to exchange of interoperable metadata, studying metadata quality has been an important activity. Among studies that examine DC metadata for cultural heritage resources, failure to comply with the *1:1 Principle* has been identified as cause for many quality problems (Han et al., 2009; Hutt & Riley, 2005; S. J. Miller, 2010; Park & Childress, 2009; Park, 2005; Shreeves et al., 2005; Stvilia et al., 2004).

For Shreeves, et al (2005), the *1:1 Principle* is related to the internal cohesiveness of a metadata record and the degree to which it represents related resources. In examining an aggregation of cultural heritage metadata, they found that “...no collection maintained a consistent one-to-one mapping between the metadata and a single resource...” Within an individual collection, “between 57% and 100% of records in their sample included properties for both physical and digital manifestations of a resource” (Shreeves et al., 2005). These findings were later confirmed by Hutt & Riley (2005), Han, et al (2009) and again by S. J. Miller (2010).

S.J. Miller (2010) notes that *1:1 Principle* problems result from “database and user interface systems [that] do not have the capacity to adequately link separate records and to display them together in a clear and meaningful way for end users.” Systems, such as CONTENTdm, base their primary information models around digital assets, making it difficult to independently represent non-digital source resources (Han et al., 2009). These systems also enable metadata creators to add specialized, locally defined metadata elements on a collection-by-collection or project-by-project basis. The ease with which these systems allow the addition of new properties encourages ad-hoc modeling optimized for display in one local context, rather than more formal and rigorous methods of modeling on at Web scale.

##### **4.1. Limitations of Violations**

In light of the debates that brought the *1:1 Principle* into existence, it is necessary to question many of the assumptions that have gone into quality studies. First, the studies themselves demonstrate that the *1:1 Principle* was not necessarily a concern among metadata creators. Instead, conforming to cataloging rules for reproductions and/or surrogate resources provided the context for descriptions. Regardless of whether an record uses facsimile (*AACR1*) or edition (*AACR2*) theory approaches, MARC inherently describes more than one resource. While local practices for Dublin Core may not alter the definition of DC terms, they implicitly changed the referent to a different resource (i.e. the prevalence of `date.original`, `date.digital`). The adoption of

these rules in association with Dublin Core, particularly within the library community, is often justified by user convenience and economics (Cronin, 2008; S. J. Miller, 2010).

Secondly, most of these studies use a “record” as the unit of analysis for assessing metadata quality, especially the set of DC elements provided by an OAI-PMH DC record. As noted above, `oai_dc` is based on a 2002 XML schema recommendation that pre-dates DCAM (Lagoze, Van de Sompel, Nelson, & Warner, 2002; Lagoze et al., 2008). Neither the OAI-PMH container architecture nor this Dublin Core schema enable DCAM-like description sets that would comply with the *1:1 Principle*. These problems are further compounded by the limitations of data representations within commonly used digital repository systems like ContentDM (Han, et al., 2009, S. J. Miller, 2010).

Furthermore, these studies are only able to detect a limited set of *1:1 Principle* violations. Most operationalize violations of the *1:1 Principle* through a conjunction of `oai_dc` statements (i.e., the resource hasFormat “image/jpeg” AND hasFormat “oil on board”). Although the informal definition of a *1:1 Principle* licenses such an assumption, it is not supported formally by the XML semantics or the DCAM. The detection of *1:1 Principle* violations has hinged on format and date elements that supply ontological absurdities. Being aware that metadata represents cultural heritage resources heightens our awareness of incoherent format statements that describe the properties of both physical and digital resources. In a heuristic evaluation of metadata records, qualitative researchers bring a great deal of background knowledge to their assessments. They may intuitively understand that terms like image/jpeg and glass plate negative are properties that are unlikely to be shared by the same resource. They also may understand that JPEGs are the kinds of the resource that “reproduce” something like a glass plate negative, but rarely will glass plate negatives “reproduce” a JPEG. They understand that JPEGs are the kind of resource that can be associated with “2008” and are not resources that could have been created in “1901.” These kinds of inferences are difficult to automate even when using robust taxonomies because they require integrating and aligning knowledge from across multiple sources (for example, *AAT* knows little about specific file formats described in a resource such as the Unified Digital Format Registry (UDFR)). Even accepting these limitations, these automated approaches fail to identify violations when DC records appear to be internally coherent. For example a DC description of a microfilm that merely uses a URL to link to a digitized version of the resource.

## 5. Would RDF save us from *1:1 Principle* Violations?

The studies discussed above all took OAI-PMH XML as their focus, leaving an important question unanswered: Would an RDF-based approach save us from rampant violations of the *1:1 Principle*? Debates from within the Semantic Web/Linked Data community suggest that RDF alone does not solve the problems inherent in the *1:1 Principle* but rather shifts the burden onto URIs. Known as the Semantic Web Identity Crisis or http range-14 problem, the debates on this issue closely parallel *1:1 Principle* problems (Halpin, 2011; Hayes & Halpin, 2008). At the heart of the problem is the question of whether a URI can refer to both an information object that describes an entity (i.e., a surrogate representation) and the entity being described. Hayes and Halpin (2008) provide the example of a URI that may refer to the Eiffel Tower itself (the structure in Paris designed by Gustave Eiffel) and a photograph of the Eiffel Tower (or equally, a set of RDF statements about the Eiffel Tower). According to Hayes & Halpin, what a URI refers to may be specified by the formal interpretation associated with it. In one interpretation, the URI may refer to the surrogate representation (the photo); in another, it may refer to the entity the surrogate stands for (the Eiffel Tower itself). In contrast, Berners-Lee (2002) argues that URIs refer to one, and only one, resource, as determined by the agent responsible for “minting” the URI (in part through the authority bestowed by the owner of a domain name). To date, World Wide Web Consortium (W3C) recommendations support Berners-Lee's approach (Sauermann & Cyganiak, 2008). However in a study of available Linked Data, Halpin, et al (2010) found that the same Linked Data URI was being used to refer to distinct entities in different contexts (for example, the city of Paris as a political entity vs. Paris as a geographic location). Within the



present metadata quality literature, the question of whether a URI successfully refers to the described resource is left unmeasured, especially for the use of URIs that do not provide access to offline resources, but may successfully refer to them. While identifiers found in OAI-PMH records had a high degree of uniqueness, this does not entail that any identifier refers uniquely to one, and only one, resource. This suggests that another kind of *1:1 Principle* violation may occur if a URI is used to refer to more than one resource (Stvilia et al., 2004; Stvilia & Gasser, 2008).

## 6. Conclusion

The developers of Dublin Core intended it to be a simple vocabulary that could be broadly applied to emerging Internet resources. The introduction of cultural heritage material introduced more complex kinds of relationships between online and offline resources or “originals” and “reproductions.” Faced with this problem, the cultural heritage community proposed solutions based on many years of practice using document surrogates in information retrieval systems. However, users of traditional cataloging systems also struggled with defining best practices for describing reproductions and multiple versions. Conflicting interpretations meant that document surrogates could appear in two forms based on the object of description (i.e., facsimile/edition theory approaches). Within the DCMI, these developments in descriptive cataloging encountered new approaches to representing descriptions as “metadata.” While emerging technologies such as XML enabled the creation of document-like data models, the development of DC was also influenced by more formal modeling techniques, such as RDF, that required a one-to-one relationship between entities and their descriptions. Because this requirement conflicted with the cultural heritage community's recommendations for handling reproductions, it was necessary to articulate it in DCMI documentation as the *1:1 Principle*. However, these recommendations failed to overcome the limitations the cultural heritage community's pragmatic understanding of the relationship between descriptions and resources. While the limitations of systems for storing and exchanging DC metadata are implicated in the prevalence of *1:1 Principle* problems, there also seemed to be little desire from within the community for more formal representation models, such as RDF. However, it is important to recognize that RDF, in and of itself, is insufficient to solve fundamental identity issues embodied by the *1:1 Principle*. The more recent development of complex bibliographic models, such as Functional Requirements for Bibliographic Records (FRBR), and their implementation as Linked Data, suggest opportunities to reformulate our ability to detect whether a description is about “one and only one resource.”

## References

- American Library Association, Australian Committee on Cataloguing, Canadian Committee on Cataloguing, British Library, & Library of Congress. (1988). *Anglo-American Cataloging Rules*. (M. Gorman & P. W. Winkler, Eds.) (2nd Edition revised.). Chicago: American Library Association.
- Arms, C. R. (1999). Getting the picture: Observations from the library of congress on providing online access to pictorial images. *Library Trends*, 48(2), 379–409.
- Baca, M. (Ed.). (2002). *Introduction to Art Image Access: Issues, Tools, Standards, Strategies*. Los Angeles: Getty Research Institute. Retrieved from [http://www.getty.edu/research/conducting\\_research/standards/intro\\_aia/](http://www.getty.edu/research/conducting_research/standards/intro_aia/)
- Baker, T. (2000). A grammar of Dublin Core. *D-Lib Magazine*, 6(10). Retrieved from <http://www.dlib.org/dlib/october00/baker/10baker.html>
- Baker, T. (2012). Libraries, languages of description, and linked data: a Dublin Core perspective. *Library Hi Tech*, 30(1), 116–133.
- Baker, T., & Johnston, P. (2011, May 13). Review of DCMI Abstract Model. Dublin Core Metadata Initiative. Retrieved from [http://wiki.dublincore.org/index.php/Review\\_of\\_DCMI\\_Abstract\\_Model](http://wiki.dublincore.org/index.php/Review_of_DCMI_Abstract_Model)
- Bearman, D. (1999, January). A common model to support interoperable metadata: Progress report on reconciling metadata requirements from the Dublin Core and INDECS/DOI Communities. *D-Lib Magazine*, 5(1). Retrieved from <http://www.dlib.org/dlib/january99/bearman/01bearman.html>
- Berners-Lee, T. (2002, July 27). What do URIs identify? W3C. Retrieved from <http://www.w3.org/DesignIssues/HTTP-URI.html>

- Burnard, L., Miller, E., Quin, L., & Sperberg-McQueen, C. M. (1996, April 1). A syntax for Dublin Core Metadata. Dublin Core Metadata Initiative. Retrieved from <http://dublincore.org/workshops/dc2/report-19960401.shtml>
- Cronin, C. (2008). Metadata provision and standards development at the Collaborative Digitization Program (CDP): A history. *First Monday*, 13(5). Retrieved from <http://firstmonday.org/htbin/cgiwrap/bin/ojs/index.php/fm/article/view/2085/1957>
- Dempsey, L., & Weibel, S. L. (1996). The Warwick Metadata Workshop: A framework for the deployment of resource description. *D-Lib Magazine*. Retrieved from <http://www.dlib.org/dlib/july96/07weibel.html>
- Dooley, J. M., & Zinham, H. (1990). The object as “subject”: Providing access to genres, forms of materials, and physical characteristics. In P. Molholt & T. Petersen (Eds.), *Beyond the Book: Extending MARC for Subject Access* (pp. 43–80). Boston, MA: G.K. Hall & Co.
- Erway, R. (1996). Digital initiatives of the Research Libraries Group. *D-Lib Magazine*. Retrieved from <http://www.dlib.org/dlib/december96/rlg/12erway.html>
- Evans, L. J., & Will, M. O. (1988). *MARC for Archival Visual Materials*. Chicago: Chicago Historical Society.
- Fink, E. (1999). The Getty Information Institute: A retrospective. *D-Lib Magazine*, 5(3). Retrieved from <http://www.dlib.org/dlib/march99/fink/03fink.html>
- Graham, C. (1992). Microform reproductions and multiple versions. *The Serials Librarian*, 22(1), 213–234. doi:10.1300/J123v22n01\_14
- Halpin, H. (2004). The Semantic Web: The origins of artificial intelligence redux. Presented at the Third International Workshop on the History and Philosophy of Logic, Mathematics, and Computation (HPLMC-04 2005), Donostia San Sebastian, Spain. Retrieved from <http://www.ibiblio.org/hhalpin/homepage/publications/airedux.pdf>
- Halpin, H. (2011). Sense and reference on the Web. *Minds and Machines*, 21(2), 153–178. doi:10.1007/s11023-011-9230-6
- Halpin, H., Hayes, P. J., McCusker, J. P., McGuinness, D. L., & Thompson, H. S. (2010). When owl:sameAs isn't the same: An analysis of identity in Linked Data. In P. F. Patel-Schneider, Y. Pan, P. Hitzler, P. Mika, L. Zhang, J. Z. Pan, ... B. Glimm (Eds.), *The Semantic Web – ISWC 2010* (Vol. 6496, pp. 305–320). Berlin, Heidelberg: Springer Berlin Heidelberg. Retrieved from <http://www.springerlink.com/content/v24433851k747864/>
- Han, M.-J., Cho, C., Cole, T., & Jackson, A. (2009). Metadata for special collections in CONTENTdm: How to improve interoperability of unique fields through OAI-PMH. *Journal of Library Metadata*, 9(3), 213–238. doi:10.1080/19386380903405124
- Harpring, P., & Baca, M. (Eds.). (2009). Categories for the Description of Works of Art. J. Paul Getty Trust. Retrieved from [http://www.getty.edu/research/conducting\\_research/standards/cdwa/](http://www.getty.edu/research/conducting_research/standards/cdwa/)
- Hayes, P. J. (2004). RDF Semantics. W3C. Retrieved from <http://www.w3.org/TR/2004/REC-rdf-mt-20040210/>
- Hayes, P. J., & Halpin, H. (2008). In defense of ambiguity. *International Journal on Semantic Web and Information Systems*, 4(2), 1–18.
- Hillmann, D. (2003, August 26). Using Dublin Core. Dublin Core Metadata Initiative. Retrieved from <http://dublincore.org/documents/2003/08/26/usageguide/>
- Hutt, A., & Riley, J. (2005). Semantics and syntax of Dublin Core usage in Open Archives Initiative data providers of cultural heritage materials. In *Proceedings of the 5th ACM/IEEE-CS joint conference on Digital libraries* (p. 270).
- Johnston, P. (2006, November 28). Why an abstract model for Dublin Core metadata? *eFoundations*. Retrieved from [http://efoundations.typepad.com/efoundations/2006/11/why\\_an\\_abstract.html](http://efoundations.typepad.com/efoundations/2006/11/why_an_abstract.html)
- Jones, E. (1997). Multiple Versions Revisited. *The Serials Librarian*, 32(1), 177–198. doi:10.1300/J123v32n01\_14
- Knowlton, S. A. (2009). How the current draft of RDA addresses the cataloging of reproductions, facsimiles, and microforms. *Library Resources and Technical Services*, 53(3), 159–165.
- Lagoze, C. (1996). The Warwick Framework: A container architecture for diverse sets of metadata. *D-Lib Magazine*. Retrieved from <http://www.dlib.org/dlib/july96/lagoze/07lagoze.html>
- Lagoze, C. (1997). From static to dynamic surrogates: Resource discovery in the digital age. *D-Lib Magazine*. Retrieved from <http://www.dlib.org/dlib/june97/06lagoze.html>
- Lagoze, C. (2001a). Keeping Dublin Core simple: Cross-domain discovery or resource description? *D-Lib Magazine*, 7(1). Retrieved from <http://dlib.anu.edu.au/dlib/january01/lagoze/01lagoze.html>
- Lagoze, C. (2001b, May 17). RE: RDF, OAI, and application within libraries.
- Lagoze, C., & Van de Sompel, H. (2008, October 17). ORE Specification - Abstract Data Model. Open Archives Initiative. Retrieved from <http://www.openarchives.org/ore/1.0/datamodel#Foundations>
- Lagoze, C., Van de Sompel, H., Nelson, M., & Warner, S. (2002). Implementation guidelines for the Open Archives Initiative Protocol for Metadata Harvesting. Open Archives Initiative. Retrieved from <http://www.openarchives.org/OAI/2.0/guidelines.htm>

- Lagoze, C., Van de Sompel, H., Nelson, M., & Warner, S. (2008). Open Archives Initiative Protocol for Metadata Harvesting. (OAI Executive & OAI Technical Committee, Eds.). Open Archives Initiative. Retrieved from <http://www.openarchives.org/OAI/openarchivesprotocol.html>
- Lenat, D. B., & Guha, R. V. (1990). *Building Large Knowledge-based Systems: Representation and Inference in the Cyc Project*. Reading, MA: Addison-Wesley Publishing Company.
- Library of Congress. (2010). 1.11A Facsimiles, Photocopies, and Other Reproductions. Library of Congress. Retrieved from [http://www.loc.gov/cds/PDFdownloads/lcri/LCRI\\_2010-03.pdf](http://www.loc.gov/cds/PDFdownloads/lcri/LCRI_2010-03.pdf)
- McRae, L., & White, L. S. (Eds.). (1998). *ArtMARC Sourcebook: Cataloging Art, Architecture and their Visual Images*. Chicago, IL: American Library Association.
- Miller, E. (1998). An introduction to the Resource Description Framework. *D-Lib Magazine*. Retrieved from <http://www.dlib.org/dlib/may98/miller/05miller.html>
- Miller, P., & Greenstein, D. (Eds.). (1997). *Discovering Online Resources Across the Humanities: A Practical Implementation of Dublin Core*. London: UKOLN.
- Miller, S. J. (2010). The One-to-One Principle: Challenges in Current Practice. *International Conference on Dublin Core and Metadata Applications*. Retrieved from <http://dcpapers.dublincore.org/ojs/pubs/article/view/1043/992>.
- Park, J. (2005). Semantic interoperability across digital image collections: a pilot study on metadata mapping. *Lecture Notes in Computer Science*, 3237, 621–630.
- Park, J. (2009). Metadata quality in digital repositories: A survey of the current state of the art. *Cataloging & Classification Quarterly*, 47(3), 213–228. doi:10.1080/01639370902737240
- Park, J., & Childress, E. (2009). Dublin Core metadata semantics: An analysis of the perspectives of information professionals. *Journal of Information Science*, XX(X), 1–13. doi:10.1177/0165551509337871
- Powell, A., & Johnston, P. (2002, January 31). Guidelines for implementing Dublin Core in XML. UKOLN. Retrieved from <http://www.ukoln.ac.uk/metadata/dcmi/dc-xml-guidelines/2002-01-31/#DCARCH>
- Powell, A., Nilsson, M., Naeve, A., Johnston, P., & Baker, T. (2005, March 7). DCMI Abstract Model. Dublin Core Metadata Initiative. Retrieved from <http://dublincore.org/documents/2005/03/07/abstract-model/>
- Powell, A., Nilsson, M., Naeve, A., Johnston, P., & Baker, T. (2007). DCMI Abstract Model. Dublin Core Metadata Initiative. Retrieved from <http://dublincore.org/documents/abstract-model/>
- Research Libraries Group. (1997a). Guidelines for extending the use of Dublin Core Elements. Retrieved October 1, 2010, from <http://www.oclc.org/research/activities/past/rlg/dcmetadata/guidelines.htm>
- Research Libraries Group. (1997b). Metadata Summit summary. Retrieved October 1, 2010, from <http://www.oclc.org/research/activities/past/rlg/dcmetadata/summit.htm>
- Sauermann, L., & Cyganiak, R. (2008, November 3). Cool URIs for the Semantic Web. W3C. Retrieved from <http://www.w3.org/TR/cooluris/>
- Shreeves, S. L., Knutson, E. M., Stvilia, B., Palmer, C. L., Twidale, M. B., & Cole, T. W. (2005). Is “quality” metadata “shareable” Metadata? The implications of local metadata practices for federated collections. In *Currents and convergence: navigating the rivers of change: proceedings of the Twelfth National Conference of the Association of College and Research Libraries April 7-10, 2005, Minneapolis, Minnesota* (p. 223).
- Simonton, W. (1962). The bibliographic control of microforms. *Library Resources & Technical Services*, 6(1), 29–40.
- Stvilia, B., & Gasser, L. (2008). Value-based metadata quality assessment. *Library and Information Science Research*, 30(1), 67–74.
- Stvilia, B., Gasser, L., Twidale, M., Shreeves, S. L., & Cole, T. W. (2004). Metadata quality for federated collections. In *Proceedings of ICIQ04-9th International Conference on Information Quality* (pp. 111–125).
- Urban, R. J. (2012). *Principle paradigms: Revisiting the Dublin Core 1:1 Principle* (Dissertation). University of Illinois at Urbana-Champaign, Urbana, IL. Retrieved from <http://hdl.handle.net/2142/31109>
- Visual Resources Association, & Whiteside, A. (1999, December 1). The core categories for visual resources - introduction. Retrieved September 26, 2010, from <http://web.archive.org/web/20010306092716/www.gsd.harvard.edu/~staffaw3/vra/coreintro.htm>
- Weibel, S. L. (1995). Metadata: the foundations of resource description. *D-Lib Magazine*. Retrieved from <http://www.dlib.org/dlib/July95/07weibel.html>
- Weibel, S. L. (2010). Dublin Core Metadata Initiative (DCMI): A personal history. In *Encyclopedia of Library and Information Sciences*.
- Weibel, S. L., & Hakala, J. (1998, February). DC-5: The Helsinki Metadata Workshop; A Report on the workshop and subsequent developments. *D-Lib Magazine*. Retrieved from <http://www.dlib.org/dlib/february98/02weibel.html>
- Wendler, R. (1999, April 14). Re: 1:1 debate: What’s the goal? *dc-one2one*. Retrieved from <http://dublincore.org/groups/one2one/>