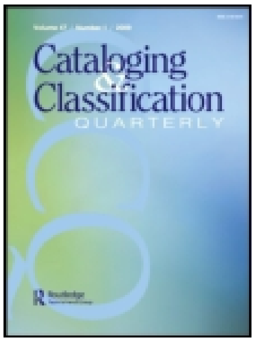

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FRBR and Linked Data: Connecting FRBR and Linked Data

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From the time of the earliest catalogs documenting private collections, to the present proliferation of repositories of material and digital objects, the bibliographic record as an aggregation of logical and physical characteristics of a resource has prevailed. The development of the Functional Requirements for Bibliographic Records (FRBR) conceptual model introduced a shift in focus away from the record as a whole to component pieces of data (or disaggregated data) where those data elements have the potential to be shared and used in diverse, even novel ways. Tim Berners-Lee's "rules" underlying the Open Linked Data Project offer an opportunity for FRBR-compliant, quality bibliographic data to be exposed to the digital universe via the Semantic Web. Context and potential for seizing this advantage are explored.

KEYWORDS *Functional Requirements for Bibliographic Records (FRBR), linked data, Semantic Web*

INTRODUCTION

In August 1990, the International Federation of Library Associations and Institutions (IFLA) Core Program for Universal Bibliographic Control and International MARC (UBCIM) and the IFLA Division of Bibliographic Control convened a seminar to examine the purpose and nature of bibliographic records. The following year, the IFLA-sponsored Study Group on Functional Requirements for Bibliographic Records was formed with objectives, "to delineate in clearly defined terms the functions performed by the bibliographic record with respect to various media,

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various applications, and various user needs."[1] The final report from the Study Group, Functional Requirements for Bibliographic Records (FRBR), was approved by the IFLA Standing Committee of the Section on Cataloguing in 1997, and FRBR was launched, subsequently spawning other entity-relationship modeling exercises for authority data (Functional Requirements for Authority Data [FRAD]; published in 2009),[2] and subject authority data (Functional Requirements for Subject Authority Data [FRSAD]; published in 2010).[3] All represent conceptual models of the bibliographic universe, and have subsequently informed other domains and disciplines within the cultural heritage communities and beyond.

In 2006, Tim Berners-Lee introduced a set of rules—later dubbed the "Linked Data Principles"—for publishing data on the World Wide Web as part of a global data space.[4] This space was intended to connect data from diverse and multiple domains, and, as the Open Linked Data Project, has afforded opportunities for supporting interoperability of highly structured and granular metadata. For the cataloging community, linked data offers to expose quality bibliographic data to the digital world, and that of other communities to library catalogs and digital repositories.

This article necessarily begins with a disclaimer. The "connecting" in the title, "Connecting FRBR and Linked Data" is not a literal intention. Rather, the word is used in a figurative sense to explore what kinds of associations might be envisioned between FRBR as a family of conceptual models, and linked data as a method of publishing structured data that can be shared and queried automatically by computers. In a sense, a consideration of dual abstractions and their respective relevance and possible relationship to one another provides the focus for arguing an inextricable link between the two in the emerging world of the Semantic Web, the "Web of Data," and Web 3.0, as all are identified, interchangeably. We begin with necessary historical context as prelude to offering some proposals and opportunities for a future that takes advantage of all that libraries and the bibliographic community have accomplished to-date.

FRBR, THE RECORD, AND BEYOND: SOME HISTORICAL CONTEXT

From the time of the earliest catalogs documenting private collections, to the present proliferation of repositories of material and digital objects, the bibliographic record as an aggregation of logical and physical characteristics of a resource has prevailed. Traditionally, encoding of bibliographic data, through such cataloging conventions as access points (main and added entries; subject headings), and communications formats, such as MARC 21 and UNIMARC, have enabled catalog users to search discrete elements of data relating to title, author, series, or subject of the resource. Current Web-enabled catalogs provide for retrieval of items by an even larger inventory of data elements, including date, physical media type, International Standard numbers, publisher, edition, language, and so on, or a combination of several characteristics related to a resource. Likewise, the revision of cataloging codes that guide the content and structure of elements of a bibliographic record, continues apace through manifestations of *RDA: Resource Description and Access*,[5] the International Standard Bibliographic Description (ISBD),[6] individual national cataloging codes, such as *Regole italiane di catalogazione* (REICAT),[7] and the overarching principles articulated in the IFLA *Statement of International Cataloguing Principles* (ICP), published in 2009.[8]

The FRBR offers a model that, in essence, disaggregates the components of the bibliographic record, delineating ten entities—work, expression, manifestation, item, person, corporate body, concept, object, event, place—the attributes associated with each of the entities, and the individual data elements associated with each of the attributes.[9] The relationships between specific instances of entities, and, finally, the relevance of attributes and relationships related to each entity to generic user tasks to find, identify, select, and obtain, are likewise modeled. Thus, each attribute and relationship can be mapped directly and systematically to the user tasks they support.[10] Rather than being parts of a record, elements and attributes are linked to specific entities with a kind of "free agent" status. In this respect, then, we begin to see the glimmer of the logic and process of linked data. The FRBR model disentangles data from records, and offers a possibility for "re-linking" individual data elements to other data sets or record structures once a mechanism for doing so is supported. Enter the Semantic Web and Linked Data. This thread will be explored in more detail later.

The favorable conditions for the development of a set of functional requirements for bibliographic records (FRBR), and subsequently for authority data (FRAD, 2009), and subject authority data (FRSAD, 2010), resulted from the concurrent evolution of computer technologies, and of data formats for structuring content for electronic communication and manipulation. The emergence of mainframe computers for large-scale data processing, seized upon by major private and public institutions, among them, the Library of Congress (LC) in the mid-1960s, moved information production and services from manual to automated processes. LC's design of the MARC (Machine Readable Cataloging) format in 1964 allowed for bibliographic records to be created and stored in a digital format supportive of data exchange (through early cooperative networks, such as OCLC, UTLAS, RLIN, WLN, etc.), and, across time, the manipulation of bibliographic and other data to produce products (catalog cards; book and microform catalogs). As computer technologies became price-accessible to libraries of all types and sizes, and software applications, such as integrated library systems (ILS) developed greater functionalities with a "user-friendly" design, collections could be searched and displayed through online public access catalogs (OPACs), then Web-enabled catalogs (WebPACs). "Liberating" bibliographic data from the physical confines of the card or book or even microform format, opened possibilities for using that same information more flexibly within digital environments.

Over the past twenty years, through increasingly ubiquitous access to the Internet, the emergence of highly sophisticated search engines (Google, Bing, etc.), and a veritable buffet of World Wide Web resources, individuals have realized an ability to have their immediate information needs met, not through institutional sources, such as libraries and library catalogs, so much as through handheld devices or similar personal computing technologies, accessing Wikipedia, downloading an e-Book from an online bookseller, or being entertained by or learning a skill from YouTube, as examples. The more recent evolution of social networking sites has likewise come to support peer to peer information access and sharing—a phenomenon that has been fostered by libraries adopting so-called Web 2.0 technologies for user input to institutional resources and services. Nonetheless, very real questioning of the ideas of library as storehouse of knowledge, and the online catalog as portal to that storehouse, is likewise challenging the relevance of library-as-information-provider in the contemporary context. More pertinent to a discussion of FRBR is the continuing relevance of, and need for cataloging and catalogers as the availability of information about an object—its metadata—moves upstream to the point of creation of a digital object. We will return to considering this in more detail later.

COMMERCIALIZATION AND EXPANSION

While the development of MARC, national derivatives (UKMARC, USMARC, FINMARC, etc.), individual formats (MARC Bibliographic; MARC Authorities; MARC Holdings: etc.), and later consolidations (MARC 21; UNIMARC), provided a record structure for encoding, storing, and exchanging/communicating data, continuous revision to bibliographic codes and standards proceeded apace. As the record created in one cataloging unit could increasingly be shared through a local network, then nationally, then internationally, the need for greater consistency in record content and the process of building it became more apparent. Conceptions of descriptive record structure and content internationally became the responsibility of the Cataloguing Section of the IFLA through the publication of a family of ISBDs. The Anglo-American Cataloguing community likewise engaged in code revision, issuing two editions of the *Anglo-American Cataloguing Rules*, and continuous updates, between 1967 and 2005, and a fully rethought and renamed *RDA: Resource Description and Access* in 2010. Similar ongoing code development occurred among national cataloging agencies, while a series of five meetings of cataloging experts held across the continents between 2003 and 2007, resulted in the publication of the *IFLA Cataloguing Principles* in 2009, thus replacing the 1961 "Paris Principles."[11]

Code revision and the development of new standards and principles were designed to focus on record content and structure independent of information technologies, or automated systems. The guidelines that emerged uniformly acknowledged the essential relationship and interdependency of what was recorded, and how that data might be communicated, stored, accessed, and displayed. Connecting FRBR entities and attributes to generic user tasks does not operationalize the requirements to find, identify, select, or obtain through a specific mechanism or tool, though we would all recognize an inherent—and implicit—appreciation for a computer-assisted means of doing so.

ENTER METADATA AND COGNATE DOMAINS

Mirroring standards development within the bibliographic community, cognate domains, such as archives/records management, publishing, education, and cultural heritage were likewise engaged in determining metadata content and mark-up structures appropriate to supporting the digitization of domain-specific objects. Mark-up of text for purposes of scholarly analysis and electronic publishing was enabled through the establishment of syntactic conventions in the Standard Generalized Mark-up Language (SGML) adopted as an international standard (ISO 8879:1986) in 1986. During the 1990s, and particularly corresponding with the emergence of the World Wide Web ("the Web"), there was a flurry of metadata standards creation—both syntactic and semantic metadata—relating to content description of, analytical access to, preservation of, and rights management for a range of digital objects, and domain-specific purposes. Encoded Archival Description (EAD), Text-Encoding Initiative (TEI) metadata, Content Description for Works of Art (CDWA), IEEE Learning Object Metadata (IEEE LOM), and Dublin Core (DC) metadata emerged from this period, along with countless others.

Extending the notion of "create once, share often," schema-to-schema mappings were undertaken, creating crosswalks for linking data elements across domains, and facilitating broad interoperability. Syntactic mark-up (XML) provided the technical underpinnings for data exchange; resolving issues of semantic compatibility between and among schemas offered other sets of challenges. For example, while one-to-one matches among schema elements were amenable to interoperability, one-to-many, many-to-one, or no matches offered particular challenges alleviated through appropriate workarounds.

THE SEMANTIC WEB AND LINKED DATA

In a design note discussing issues relating to the Semantic Web project, World Wide Web Consortium (W3C) Director, Time Berners-Lee (2006) first coined the term, "linked data" to refer to a method for publishing structured data that could be shared openly among producers and consumers of that data. In his design note, Berners-Lee outlined four "rules" or "expectations of behaviour" to facilitate interconnection of data.[12] These included:

- Using Uniform Resource Identifiers (URIs) to identify or "name" things (information) uniquely;
- Using Hypertext Transfer Protocol (HTTP) URIs so that people can look up ("dereference") those named things (information);
- Providing useful information about the URI-named thing (information) using standard formats (e.g., RDF/XML; SPARQL); and
- Including links to other URIs to enable discovery of related named things (information).

A URI, which is key to machine-level interconnection and sharing within the Linked Data framework, is comprised of a base (or "namespace") plus a unique, identifying suffix. Within the Resource Description Framework (RDF), a URI is required for the subject and predicate of the RDF triple, subject-predicate-object. The object may be a literal value or a URI. In Figure 1, Gordon Dunsire[13] offers an example to illustrate such a triple where "mlx:54321" is an abbreviated URI for the record number ID added to the unique http domain for the library, "rdarole:author" is the URI for the property, "author," in the RDA "rda" namespace (rdaxxx), and the value for the author's name is a URI from the Virtual International Authority File (VIAF).

This sample RDF triple which identifies one element of a bibliographic record—that is, this record in the library's collection (subject) has author (predicate) "Wythe, Deborah" (object)"—can be one piece of a whole, or may be seen as an independent "packet" of data to be linked to any other item/object or relationship with which the name, "Wythe," is associated. Assuming that this same individual has created or co-created other work, or has been the subject of a work, the URI, "viaf:31899419/#Wythe,+Deborah", can be incorporated as required. In such an environment, as Dunsire and Willer note:[14]

> Online catalogues in a linked data environment can assemble bibliographic descriptions from instance triples taken from all available sources, so there is no need for the library community to create its own triple if there is already one available from the publishing community. The archive, library, and museum communities can focus on maintaining

> metadata unique to the needs of their members, such as provenance, availability, suitability, and context. Metadata of more general interest, such as label, format, associated places and events, will be accessible as linked data from other communities.

Other data or instance triples, to which Dunsire and Willer refer, can be accessed similarly from appropriate sources represented in the linked data cloud. Figure 2 illustrates the status of sources and communities residing in that cloud as of September 2011.[15] With bibliographic information positioned among a vast array of data contributed by agencies and groups of individuals within, but not limited to scientific, historical, geographic, pharmaceutical, media, and government domains, the potential for *enriching* as well as sharing data is evident. The idea of "universal bibliographic control" has, across time, been fostered by international cooperation and manifested by the development of content standards, such as ISBD, and communications formats, such as MARC and UNIMARC. Within the digital realm, greater

mlx:54321	rdarole:author	viaf:31899419/#Wythe,+Deborah

FIGURE 1 Example of a Resource Description Framework (RDF) Triple.

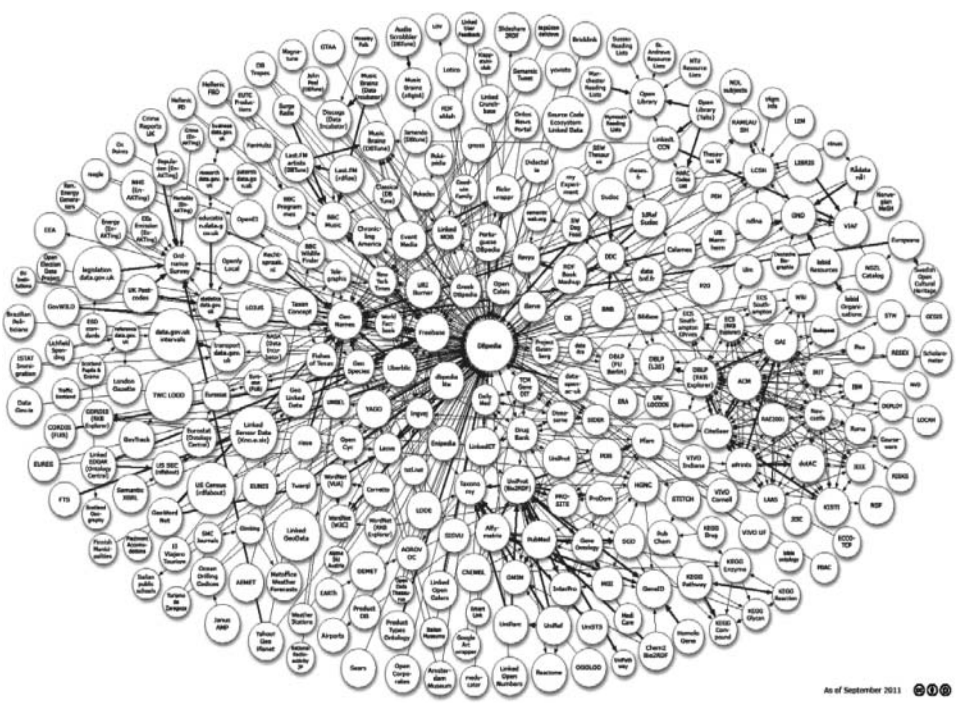

FIGURE 2 Linking Open Data (LOD) Cloud Diagram.

convergence and interoperability have been realized through international commitments to the creation and applications of metadata schemas, such as Dublin Core, and large-scale projects, such as Europeana, and the VIAF. In a sense, linked data, as an initiative, allows for the shift from convergence as supported by content and technical infrastructure, to that of *semantic* convergence. While clearly in the early stages of development, application, and implementation, with numerous problematic areas still to be resolved, the voluminous storehouses of bibliographic metadata that bridge national and linguistic boundaries can now be expressed as instance triples and exposed, literally, to the world through the Semantic Web. This, in turn, supplies an expanding range of data values to be extracted to create or enhance digital repositories in libraries.

Efforts to expose bibliographic data to the Semantic Web are currently well underway. As Haslhofer and Isaac note, "Soon after the first Linked Data sources went online, libraries and cultural institutions, such as the Library of Congress and the Swedish Union Catalogue, followed the Linked Data principles to publish their data. As a result, we can now access library resources and their descriptive metadata simply by dereferencing HTTP URIs, which facilitates data access and reuse."[16] The outer edges of the two o'clock position on Figure 2, show the addition of the Swedish National Union Catalogue, LIBRIS, *Library of Congress Subject Headings* (LCSH), Rameau (French subject headings), NDL Subjects and NDL Name Authorities (National Diet Library, Japan), Norwegian Medical Subject Headings (Norwegian MeSH), the NSZL Catalog (Hungarian National Library), and the VIAF—implemented and hosted by OCLC) among others within the bibliographic community to the Linking Open Data (LOD) cloud.

Dunsire and Willer also describe other initiatives to make standard library metadata models and structures available to the Semantic Web. In 2009, the IFLA established the IFLA Namespaces Task Group to focus on representing IFLA standards in formats suitable for use in the Semantic Web.[17,18] Since the IFLA namespaces domain, "iflastandards.info," was registered, a RDF/Simple Knowledge Organisation System (SKOS) representation of the *Multilingual Dictionary of Cataloguing* (MulDiCat) was published in November 2010 with the namespace base URI "http://iflastandards.info/ns/muldicat."[19] Dunsire and Willer also reported in August 2010 that, "The FRBR Review Group is currently developing representations of FRAD and the entity-relationship model of FRBR in resource description framework (RDF) applications, using a combination of RDF, RDF Schema (RDFS), SKOS and Web Ontology Language (OWL), cross-relating both models where appropriate."[20] As of the end of November 2011, element sets and RDF/XML files for the FRBRer, FRAD, and FRSAD models, and for ISBD had been published.[21] These and other RDF representations relating to linked library data are described at the W3C Semantic Web site, *LLD/Library Data Resources*.[22] Triples based on library metadata, and that generated by national cataloging agencies should be of considerable interest to the Semantic Web because, Willer, Dunsire, and Bosančić observe, "... they are likely to be of higher quality than those generated by machines and by untrained humans ... [and] are also, currently, likely to be of greater granularity and specificity than metadata derived from core or simple records."[23]

CONNECTING FRBR AND LINKED DATA: A CASE STUDY

The development of RDF representations of each of the Functional Requirements (FR) conceptual models (i.e., FRBR, FRAD, FRSAD) has been instrumental to informing current work on creating a single consolidated FR model. An approved RDF representation of the latter "is unlikely to be published until 2012."[24] This consolidation effort is not without precedence. As mentioned earlier in this article, the FRBR model was originally designed as an entity-relationship model and published in 1998. Quite independently, and beginning in March 1996, the ICOM-CIDOC (International Council for Museums—International Committee on Documentation) Documentation Standards Working Group shifted its data modeling efforts away from a relational to an object-oriented approach to museums information documentation and interchange. In 1999 the first complete edition of the *CIDOC Conceptual Reference Model (CRM)* was published, becoming an ISO Standard (ISO 21127) in 2006. While FRBRer and CIDOC-CRM were developed with reference to libraries and museums, respectively and uniquely, the idea that the two communities might benefit from bringing the two models together was first proposed in 2000, with the formation in 2003 of the International Working Group on FRBR/CIDOC CRM Harmonisation. The Working Group had two goals, namely, (1) to express the IFLA FRBR model with the concepts, tools, mechanisms, and notation conventions provided by the CIDOC CRM, and (2) to aligning (and possibly merge) the two object-oriented models thus obtained.[25] While a first draft of the object-oriented FRBR (or FRBRoo) was completed in 2006, version 1.0 of *FRBR object-oriented definition and mapping to FRBRer* was published in June 2009, with version 1.0.1 appearing in January 2010.

In conceptualizing FRBR using object-oriented, rather than entity-relationship methodology, the intention was not "... to force museums' concerns and viewpoints into the bibliographic universe, or libraries' concerns and viewpoints into the museum universe..." but, rather, (1) to come to a shared perspective regarding cultural heritage information with respect to modeling, standards, recommendations, and practices, (2) to verify the internal consistency of FRBR, (3) to enable information interoperability and integration, (4) to mutually enrich, and (5) extend the scope of FRBR and CIDOC CRM.[26] Thus, for example, temporal entities, events, and time processes that are important to CIDOC CRM, but were missing in FRBRer, needed to be added to FRBRoo. Likewise, "... the analysis provided for bibliographic processes in FRBRoo paved the way to the introduction of refinements into CIDOC CRM, so that the museum community's model could give a better account for mass production phenomena (such as the printing of engravings, for instance), or the relation between creating immaterial content and physical carrier."[27]

Another of the objectives underlying the FRBRoo initiative was to position FRBR to be exposed using RDF applications and technologies associated with the Semantic Web. A partial representation of CIDOC CRM in RDF Schema (RDFS) which did not include the FRBRoo extension was published in 2009,[28,29] followed, on August 11, 2010, by the publication of *FRBRoo v1.0.1 harmonised with CIDOC CRM v5.0.2 encoded in RDFS*. The latter's stated intention was: "... to capture and represent the underlying semantics of bibliographic information and to facilitate the integration, mediation, and interchange of bibliographic and museum information."[30] With all members of the "FR Family" now expressed in Semantic Web–compliant RDFS, the potential for any cultural heritage community that creates and uses standards based on the FR conceptual model to have its own data represented in RDF/XML can be realized readily. In the same way that CIDOC CRM served as an exemplar for FRBR in both modeling and RDFS encoding, FRBRoo can provide a case study for cooperation, mutual integration, and interoperability of data across diverse domains, as well as for further enhancement of the "Web of Data."

CONNECTING FRBR AND LINKED DATA: SOME THOUGHTS ON THE FUTURE

The expression of FRBR in RDFS, and its contribution to Linked Data initiatives and applications, results from, and can be contextualized within, a long history of standards development, the steady evolution of communications protocols and technologies, a commitment to fostering cooperation and building on common ground, supporting interoperability of information pertaining to objects whether physical or digital, and championing an open data environment. Within the library community, the aggregate of parts into the whole that was the bibliographic record predominated for many decades. While the introduction of the MARC format enabled different parts of the record to be extracted and manipulated to purpose, it was the systematic entity-relationship modeling associated with FRBR that opened the door to mapping individual attributes and relationships directly to whichever user tasks they support. Such an approach informed and provided structural rationale to rethinking the design of cataloging codes, notably *RDA: Resource Description and Access*, and more recently, *REICAT*. While bibliographic control initiatives have always had at their heart a focus on the user and usage (think Cutter's "objects" for the catalog), FRBR's entity-relationship model has brought systematic, conceptual focus to addressing specific user tasks (find, identify, select, obtain [with some adding "navigate," and, more recently, "explore"]), through the alignment of data attributes and relationships. With a shift in focus away from data aggregates—the bibliographic record as a whole—to component pieces of data (or disaggregated data), those data elements have the potential to be shared and used in diverse, even novel ways.

Within the world of linked open data, libraries and other cultural institutions emerge as strong and potentially important players bringing to the table storehouses of structured data that embody decades of history and standards compliance. Are these data of use to other domains and applications? To a world of physical and digital objects more broadly? It may be germane to consider, for example, the potential impact on social networking sites—of bringing "structured data" to unstructured data to enhance the integration of digital objects tagged by users with those residing in legacy collections. The use of structured subject vocabularies in LibraryThing,[31] self-described as "a cataloging and social networking site for book lovers," hints at such an example where, one might venture, traditional bibliographic data is brought into the realm of social data. The Commons on Flickr[32] likewise suggests applications for integrating "folk culture" with "formal material culture," where structured metadata—linked open data, such as that found in the VIAF, or in Europeana—could be harvested and applied to bring about greater consistency and integrity to identifying archival photographs, whether in a personal (informal) or an institutional (formal) collection.

The knowledge store is vast and growing as more participants engage in adding content to the Web. The FRBRoo exercise reminds us of benefits to be gained by exploring commonalities, and deriving opportunity from incorporating what is most useful from respective community applications. While an institutional repository can tap the knowledge and experience of individual taggers, those same contributors might find structured data freely available from the Web of Data (Semantic Web; Web 3.0) useful, not only to tagging their digital objects, but also to rendering them hospitable to integration within the larger spheres of both formal and informal knowledge. The lesson of FRBRoo lies in combining respective strengths to broader benefit, or in this case, of bringing into closer alignment the "hive mind"[33] or the "wisdom of crowds"[34] with the "wisdom of the ages."

Libraries familiar with the cooperative cataloging mindset are already recognizing the potential for RDFS and linked data to enhance workflow and the development of larger, richer knowledge repositories for universal access. Many libraries are investigating the transformation of their catalogs into RDF triples to contribute to, and take advantage of, the SemanticWeb. As Willer, Dunsire, and Bosančić have observed, "Such triples can be linked to triples from encyclopedias, dictionaries, and other reference works, booksellers, publishers, and other agents in the bibliographic universe to enhance information services."[35] These are triples that could likewise be harvested within social networking sites to harness the potential of structured data to disambiguate and more transparently integrate digital objects within diverse knowledge stores.

Liberating data from records can also work to the benefit of creating new *kinds of records* through new kinds of linked data. In essence, parts of the record structure, including aggregated and simple, individual statements can be re-used and mixed with other elements from related communities and their namespaces. Willer, Dunsire, and Bosančić also note that, "RDF properties can be used directly by other communities, aggregated into different forms of statement, and interlinked with their own namespaces for their own requirements."[36] This approach speaks to the power of building records that bring together, not only numerous pieces of structured data, but also different contexts and perspectives, enriching and enhancing the data pool through flexible and extensible metadata. A kind of strength through "biblio-diversity"!

This article has made the case that, by disaggregating component data from the record as a whole, the design of the FRBR conceptual model has created the conditions necessary to placing the bibliographic community within libraries as dynamic players on the threshold of the Semantic Web. With a "perfect storm" of historical standards development, technological evolution, and a cooperative mindset favoring opportunities through convergence, we seem poised to either ride the linked data wave,[37] or to be swept away in the deluge.

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