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Interoperability and Semantics in RDF representations of FRBR, FRAD and FRSAD

Abstract: This paper describes recent work on registering Resource Description Framework (RDF) versions of the entities and relationships from the Functional Requirements for Bibliographic Records (FRBR) and Functional Requirements for Authority Data (FRAD) models developed by the International Federation of Library Associations and Institutions (IFLA). FRBR was developed several years before FRAD, and is under-developed in areas which FRAD was expected to cover; FRAD therefore makes significance reference to FRBR. Similarly, FRAD leaves a full treatment of subject authority data to the ongoing development of Functional Requirements for Subject Authority Data (FRSAD) which was finalised during 2010. Although the FRBR Review Group is charged with consolidating all three models in due course, the RDF versions of FRBR, FRAD, and FRSAD are being created in separate namespaces, with a separate Web Ontology Language (OWL) ontology to connect the three models. The paper discusses interoperability issues arising from this work. Such issues include class definitions and sub-classes, reciprocal properties, and disjoint classes and properties. The paper discusses similar work on the International Standard Bibliographic Description (ISBD), also maintained by IFLA, and related issues arising from the RDF representation of the metadata element set of RDA: resource description and access, which is based on the FRBR and FRAD models. The work is ongoing, and the paper updates the original conference presentation to the end of October 2010.

1. Background

In September 1997, the International Federation of Library Associations and Institutions (IFLA) produced *Functional requirements for bibliographic records*, the final report of the IFLA Study Group on the Functional Requirements for Bibliographic Records approved by the Standing Committee of the IFLA Section on Cataloguing. FRBR, as the report has come to be known, was published in 1998 by K.G. Saur[1]. The purpose of the study leading to FRBR was "to delineate in clearly defined terms the functions performed by the bibliographic record with respect to various media, various applications, and various user needs [covering] the full range of functions ... that encompasses not only descriptive elements, but access points (name, title, subject, etc.), other 'organizing' elements (classification, etc.), and annotations."[2] The study used an entity-relationship approach, identifying entities that are of key interest to users, attributes of those entities, and relationships between entities that are the most important in bibliographic resource discovery. The intention of the work was to develop "a conceptual model that would serve as the basis for relating specific attributes and relationships (reflected in the record as discrete data elements) to the various tasks that users perform when consulting bibliographic records."[3] However, the study did "not cover the extended range of attributes and relationships that are normally reflected in authority records"

[1] IFLA Study Group on the Functional Requirements for Bibliographic Records 1998.
[2] Ibid. P. 2.
[3] Ibid. P. 3.

and "recognized that an extended level of analysis would be necessary for a fully developed conceptual model"[4].

Accordingly, the Working Group on Functional Requirements and Numbering of Authority Records (FRANAR) was established in April 1999 by the IFLA Division of Bibliographic Control and the IFLA Universal Bibliographic Control and International MARC Programme (UBCIM). *Functional requirements for authority data: a conceptual model* (known as FRAD), the final report of FRANAR, was approved by the Standing Committees of the IFLA Cataloguing Section and IFLA Classification and Indexing Section in March 2009, and subsequently published by K.G. Saur[5]. There was thus a gap of some 12 years between FRBR and FRAD. Furthermore, FRAD noted that while FRANAR "included some aspects of subject authorities in the authorities model, it has not undertaken the full analysis that the FRBR Study Group envisioned."[6] Instead, that task was assigned to the IFLA Working Group on the Functional Requirements for Subject Authority Records (FRSAR) formed in 2005. FRANAR and FRSAR thus worked in parallel from 2005, with FRSAR releasing a draft report for world-wide review by the time FRAD was published in 2009. *Functional requirements for subject authority data: a conceptual model* (known as FRSAD) was approved by the Standing Committee of the Classification and Indexing Section in June 2010[7].

IFLA's FRBR Review Group took on the task of reviewing and maintaining FRBR, FRAD, and FRSAD as the "FRBR family of models"[8] in 2009, and in 2010 agreed to develop a consolidated model for the family. This process is now underway, and is being informed by the work of the FRBR Namespace Project.

This project was initiated during the World Library and Information Congress 73rd IFLA General Conference held in Durban, South Africa, in August 2007. The task of the project was "to define appropriate namespaces for FRBR (entity-relationship) in RDF and other appropriate syntaxes"[9]. The creation of the project was stimulated by the Data Model meeting[10] held at the British Library in London on 31 May and 1 April 2007 between representatives of the Joint Steering Committee for Development of RDA (JSC)[11], the Dublin Core Metadata Initiative (DCMI)[12], and various other Semantic Web communities. This meeting had resulted in the creation of the DCMI RDA Task Group[13] to investigate options for representing bibliographic concepts and metadata in Resource Description Framework (RDF)[14], the data model of the Semantic Web. *RDA: resource description and access*[15] provides a set of guidelines and instructions on formulating data to support resource discovery." FRBR and FRAD are the conceptual models underlying RDA, and the FRBR Review Group realized that RDF representations of the models would be required for the work of the DCMI RDA Task Group.

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[4] Ibid. P. 4.
[5] IFLA Working Group on Functional Requirements and Numbering of Authority Records (FRANAR) 2009.
[6] Ibid. P. 1.
[7] IFLA Working Group on the Functional Requirements for Subject Authority Records (FRSAR). 2010.
[8] Cf. the website of the FRBR Review Group: Functional requirements: the FRBR family of models. Available at: http://www.ifla.org/node/2016.
[9] Dunsire 2008. P. 1
[10] Cf. the notes on the website of the British Library. Bibliographic Standards. Data Model Meeting. Available at: http://www.bl.uk/bibliographic/meeting.html.
[11] Cf. the website of the Joint Steering Group for Development of RDA. Available at: http://www.rda-jsc.org/rda.html.
[12] Cf. the website of Dublin Core Metadata Initiative. Available at: http://dublincore.org/.
[13] Cf. the DCMI/RDA Task Group wiki. Available at: http://dublincore.org/dcmirdataskgroup/.
[14] Cf. RDF Working Group (2004)
[15] Cf. the website of the Joint Steering Group for Development of RDA. Available at: http://www.rda-jsc.org/rda.html.

At around the same time, the Material Designation Study Group of IFLA's ISBD Review Group, which was developing a consolidated edition of *International standard bibliographic description* (ISBD), recommended the development of an XML schema for ISBD. This resulted in the creation of the ISBD/XML Study Group[16] in 2008. The Study Group agreed during the World Library and Information Congress 74th IFLA General Conference, held in Québec City, Canada, in August 2008, not to spend time on a general XML schema, but instead create RDF representations of the ISBD elements that could be expressed in RDF/XML.

The surge of activity by the IFLA groups and the need for IFLA-controlled namespaces to contain RDF representations led to the formation of the IFLA Namespaces Task Group in late 2009 to identify requirements and propose options for the development, support, and promotion of IFLA standards in the Semantic Web. The Group's report was submitted in May 2010 to IFLA's Professional Committee[17], which accepted a recommendation to create an IFLA Namespaces Technical Group which would carry out work on the other recommendations concerning requirements and options, and report to the new IFLA Bibliographic Standards Program (Core Activity) which was approved at the same time. A paper discussing IFLA's activities in relation to the Semantic Web[18] was presented at the World Library and Information Congress 76th IFLA General Conference, held in Gothenburg, Sweden, in August 2010.

2. Methodology

The DCMI RDA Task Group had decided to use the NSDL Metadata Registry, now the Open Metadata Registry (OMR)[19], to create basic RDF representations of RDA elements and vocabularies, including uniform resource identifiers (URIs), labels, definitions and scope notes. This has proved successful, so the FRBR Namespace Project and ISBD/XML Study Group are using the same infrastructure. In addition to the RDA vocabularies[20], the OMR currently contains RDF element sets for the FRAD model, FRBRer model, FRSAD model, and ISBD elements, and RDF vocabularies for FRAD user tasks, FRBRer user tasks, FRSAD user tasks, ISBD content form, ISBD content qualification of dimensionality, ISBD content qualification of motion, ISBD content qualification of sensory specification, ISBD content qualification of type, ISBD media type.

All three of the FR family models are based on entity-relationship analyses which can be readily mapped into the basic RDF entities of class and property.

Each "entity" identified in an FR model becomes an RDF class. For example, the FRBR Group 1 entities (work, expression, manifestation, and item) are represented as the RDF classes Work, Expression, Manifestation, and Item respectively. Note that class labels are capitalized according to an RDF labelling convention which is reflected in this paper; for example, "work" refers to an entity name and "Work" to a class label.

Attributes assigned to each FR entity become RDF properties. For example, the logical attribute "intended audience" assigned to the FRBR entity work is represented by an RDF property with the label "has intended audience". Relationships between FR entities also become RDF properties. The

[16] Cf. the website of the ISBD/XML Study Group. Available at: http://www.ifla.org/en/node/1795.
[17] Cf. the website of the IFLA Professional Committee. Available at: http://www.ifla.org/en/professional-committee.
[18] Dunsire, Willer 2010.
[19] Cf. the website of the Open metadata registry. Available at: http://metadataregistry.org/.
[20] Cf. the RDA (resource description and access) vocabularies. Available at: http://metadataregistry.org/rdabrowse.htm.

high-level structural relationship between the FRBR entities work and expression is represented by an RDF property with the label "is realized through".

2.1 Terminology

The terminology used for class and property labels, definitions and scope notes is based as closely as possible on the relevant source documentation; for the FR models this consists of the published reports. Minor adjustments have been made to improve consistency, but otherwise it should be possible to match the RDF representations with the original text. This is intended to make it easier to relate the source documentation to the RDF text and use it for further information about the context and background of the models. A standard approach has been adopted to create human-readable labels for the RDF properties based on attributes: the label consists of the attribute name preceded by the word "has", as shown in the example for the attribute "intended audience" given above. This results in a "verbal" label which can be interpreted in near-natural language when an RDF instance triple based on the property is labelled for human readability. Instance triples consist of three parts: the subject of a metadata statement based on an RDF property; the RDF property itself; and the object or value of the property. The first two parts must be expressed as machine-readable URIs, but the corresponding labels can be substituted to give a human-readable version, for example "this work:has intended audience:adult". The structure of a triple is based on concepts from logic and linguistics. The middle part of a triple, an RDF property, is technically a predicate in descriptive logic, equivalent to a verb phrase in natural language.

Some attributes are assigned to more than one entity. In some cases, the name of the attribute is explicitly distinct in the documentation. For example, "form of expression" is an attribute of the FRBR expression entity and "form of work" is an attribute of the work entity. The corresponding property labels can be created in the standard way and remain distinguishable: "has form of expression" and "has form of work". In other cases, the documented attribute name is not distinct. For example, FRAD assigns the attribute "address" to both the person and corporate body entities. The standard RDF property label for both would be "has address", and a user would have to check the RDF definition to determine which property to use. Identical property labels might also be confusing and misleading, so in these cases the entity name is added to the label to give distinctive labels, for example, "has address (person)" and "has address (corporate body)". This approach has been used throughout the RDF representations, where applicable, to ensure that all property labels are unique within the namespace.

Definitions for the RDF classes are generally derived directly from definitions in the source documentation. Definitions for attribute properties usually consist of the definition in the source documentation preceded by the standard phrase "Relates a ... to" with the name of the class to which the attribute is assigned inserted in the placeholder. For example, the definition of the property "has intended audience" is "Relates a work to the class of user for which the work is intended, as defined by age group, educational level, or other categorization." Definitions for relationship properties similarly start with the phrase "Relates a ... to a ..." followed by a phrase based on the definition of the relationship taken from the documentation, with the names of the related classes inserted in the placeholders. For example, the definition of the relationship property "is realized through" is "Relates a work to an expression that is the realization of the work." The wording of the source documentation may be rearranged to create consistent phrasing in the definition.

Examples embedded in the definition of a property or class in the documentation are removed and used to form a scope note for the property or class, where appropriate. For example, "E.g., sound cassette, videodisc, microfilm cartridge, transparency, etc." is the scope note for the FRBR property labelled "has form of carrier". Explanatory "includes" notes in the documentation are also treated as scope notes. For example "Includes real individuals" is one of several notes attached to the definition of the FRAD entity person. Each class and property has at most one scope note which may concatenate several sets of examples and "includes" notes from the documentation.

2.2 Related namespaces

Each of the FR models has been given its own namespace, although classes and properties represented in a prior model are re-used where indicated in the documentation: FRSAD and FRAD use classes and properties from FRBR, where those classes and properties are identical in definition. In some instances a later model redefines an earlier class or property, in which case a new RDF representation is made. For example, FRAD uses the FRBR class Expression and FRBR property "has form of carrier", but redefines the FRBR class Corporate Body by restricting it to a corporate body with a name, resulting in a separate FRAD class for Corporate Body. RDF properties relating such redefined entities will be made available as extensions to the relevant namespaces.

The principle reason for keeping the FR namespaces separate is the length of time between publication of FRBR and FRAD, during which FRBR has been used in applications without reference to FRAD, and the parallel but independent development of FRAD and FRSAD. The separate namespaces ensure that the integrity of any application of one of the models remains intact and self-contained, without being influenced by the others.

Generally, there is no re-use of RDF resources from external community namespaces such as DCMI metadata terms[21], although the use of some FOAF[22] properties for FRAD is under investigation. Again, this ensures that there is no unintended influence on the integrity of the models. Equivalences between the FR (and ISBD) namespaces and appropriate external namespaces are likely to be established after the RDF representations are completed.

2.3 Inferencing

An RDF property may be declared with a domain or range. A domain is class which is intended to be the subject of the property, while a range is intended to be the object or value of the property. This allows inferences to be made when the property is used in an instance triple. For example, if a property has a domain, then it can be inferred that the subject of a corresponding instance triple must be a member of the class given by the domain.

All properties based on FR attributes have a domain but no range. The FR models deliberately avoid specifying what type of value should be assigned to an attribute, to allow any application based on the model to be extended to suit its needs. Thus no inferences about the object value can be made from triples based on FR properties. The domain of the attribute properties is the class to which the attribute is assigned. For example, the FRBR property "has form of carrier" is declared to have the domain of FRBR class Manifestation, because "form of carrier" is an attribute of the entity "manifestation". It can therefore be inferred from the instance triple "this:has form of carrier:DVD" that "this" is a manifestation.

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[21] Cf. the DCMI metadata terms. Available at: http://dublincore.org/documents/dcmi-terms/.
[22] Cf. the FOAF vocabulary specification. Version 0.98. Available at: http://xmlns.com/foaf/spec.

All properties based on an FR entity relationship have both a domain and a range based on the classes representing the related entities. For example, the FRBR property "is realized through" has domain FRBR Work and range FRBR Expression. It can be inferred from the instance triple "this:is realized through:that" that "this" is a FRBR work, and "that" is a FRBR expression. Such inferencing is a powerful tool when instance triples are created from legacy bibliographic records which may be duplicates describing the same resource, or incomplete or of otherwise low quality.

3. Interoperability

3.1 General issues

It has not always been easy to create consistent RDF labels or definitions based on the source documentation for the FR family. The text of the original reports was written for human consumption, and there is some evidence of deliberate variation in phrasing to make it more readable. For example, the terms "prior", "preceding", and "first" are used in an apparent interchangeable way in FRBR. There are also minor inconsistencies in the use of indefinite articles in relationship phrases. Most include an indefinite article ("a" or "an"), but some do not; for example “has a reproduction” and “has reconfiguration”. The appropriate article has been added to the RDF labels to remove inconsistencies, so the label in this example becomes "has a reconfiguration". A comment has been added to the RDF property when such amendments have been made, to alert users to resulting inconsistencies between the RDF representation and the source documentation. Although each report uses a generally consistent layout, there is much less consistency between the reports.

A specific issue was encountered in interpreting the FRBR model. The source documentation for FRBR refers to sub-types of entities, for example "musical work" and "serial". Specific attributes are assigned to these sub-types. For example, "key" is an attribute of "musical work" which is not applicable to other sub-types of the entity work. The first draft of the RDF representation treated these sub-types as sub-classes so, for example, a FRBR class for Musical Work was created and a property added to indicate that it was a sub-class of the FRBR class Work. The documentation does not, however, give formal definitions of these sub-types, and further discussion with the FRBR Review Group showed that there could be significant overlap and mixing of any definition that might be constructed for the RDF representations; for example a musical work can also be a serial. The Group agreed that the sub-types were not intended to be sub-classes, so they were subsequently removed from the OMR. This leaves it open to applications of FRBR to model the documented sub-types as well as others to suit their needs, if any. The RDF property labels for such attributes contain the sub-type, for example "has key (musical work)", but the property domain is the class for the main entity which in this example is Work.

3.2 Opaque URIs

Opaque URIs are used for FR and ISBD classes and properties, for example "http://iflastandards.info/ns/fr/frbr/frbrer/C1001" rather than "http://iflastandards.info/ns/fr/frbr/frbrer/Work". This results in abbreviated references, using XML namespace declarations or qualified names (qnames), such as frbrer:C1001 instead of frbrer:Work. In this syntax, the qname "frbrer" is substituted automatically during machine-processing by the equivalent namespace "http://iflastandards.info/ns/fr/frbr/frbrer/", and the linking colon removed. The computer treats a URI as a text string which uniquely identifies a class or property, and does

not parse the string to extract any other "meaning". Such opaque URIs have no human-readable semantic content and must be de-referenced to the corresponding label for presentation to human users. But IFLA operates in a multilingual environment, and the use of such opaque URIs avoids Anglophone or any other natural language bias; an English label may be just as difficult to read for a Russian user as a Russian label for an English user. Multiple RDF labels in different languages can easily be associated with a single opaque URI (using the @language-code syntax), and there are many translations of the FR and ISBD source documents into non-English languages available for such purposes. The URI must be persistent and not change. The de-coupling of label from URI allows subsequent changes to labels without causing confusion. If, for example, indefinite articles were to be removed from the labels in the consolidation of the FR family to shorten their length, there would be no resulting issues such as articles remaining embedded in the URIs.

3.3 Semantic issues

Variations in the text of the FR family source documentation beg the question: do differences in documentation reflect real semantic differences? Close examination of the text and detailed discussion with the FRBR Review Group are required to determine this. A minor example is found with the FRBR entity work, which is defined as "A distinct intellectual or artistic creation." However, FRAD claims it uses the FRBR entity "as modified in the ICP Glossary" (that is, *Statement of international cataloguing principles*[23]) and therefore defines it as "A distinct intellectual or artistic creation (i.e., the intellectual or artistic content)." The FRBR Review Group has agreed that there is no real semantic difference between these definitions, so FRAD can safely re-use the FRBR class Work. An explanatory comment is added to the RDF representation.

A major example of variation between FRBR and FRAD is found with the entity person. The FRBR definition is "An individual" while that for FRAD is "An individual or a persona or identity established or adopted by an individual or group." FRAD states that this is also modified from FRBR, but gives no additional information. The FRBR Review Group agrees that the different definitions are sufficiently great to require FRAD to create its own class for Person. The situation is further complicated by the semantic relationship between an object-oriented version of FRBR, known as FRBRoo[24], and the *CIDOC conceptual reference model* (CIDOC CRM)[25] which introduces yet another apparently distinct definition for person. As noted above with reference to the entity corporate body, it is intended to represent the semantic relationships between such different classes using RDF properties; in this case it will be challenging exercise.

3.4 Ontological issues

The FR source documentation identifies pairs of inverse relationships. For example, FRBR states that the relationship "is realization of" is the inverse of "is realized through": an expression is a realization of a work, and a work is realized through an expression. These are represented in RDF as inverse properties with the OWL statement "frbrer:P2001 owl:inverseOf frbrer:P2002".

RDF properties based on attributes have no inverses because they have no ranges. When a property is inverted, its domain becomes the range of the inverse property, and the range becomes the domain. Properties with no domains can weaken the integrity of the model and remove the ability to

[23] IFLA, 2009. Available at: www.ifla.org/files/cataloguing/icp/icp_2009-en.pdf.
[24] International Working Group on FRBR and CIDOC CRM Harmonisation 2008 .
[25] Cf. the website of the International Council of Museums. The CIDOC conceptual reference model. Available at: http://www.cidoc-crm.org/.

apply inferencing to instance triples. The FR models are ontologically rich; this intrinsic value can be made explicit by using OWL to define relationships between properties and classes in addition to the inverse pairs given in the source documentation. The OWL transitive, asymmetric, and disjoint relationships are particularly important for the FR models, requiring a careful analysis of the source documentation to determine their applicability.

For example, the FRBR property labelled "has an alternate" has the class Manifestation as both its domain and range, and FRBR explicitly gives an inverse property labelled "is an alternate to", also with domain and range of Manifestation. But any two instances of Manifestation to which the property applies are mutually alternate: they can be swapped as domain and range in the property and its inverse. One of the properties is therefore ontologically redundant, and the model can be represented more elegantly by declaring the remaining property as symmetric. That is, "has an alternate" is symmetric, allowing the inference that "this manifestation:has an alternate:that manifestation" implies "that manifestation:has an alternate:this manifestation", which is identical in meaning to "that manifestation:is an alternate to:this manifestation". The property labelled "is an alternate to" can therefore be dropped from the FRBR namespace, and its explicit reference in the source documentation can be represented as an alternate label to the property labelled "has an alternate". This property is also transitive: "this manifestation:has an alternate:that manifestation" and "that manifestation:has an alternate:another manifestation" implies "this manifestation:has an alternate:another manifestation".

All FRBR classes are mutually disjoint. That is, a value which appears to be both an instance of a Work and an Expression (or Person, or Place, etc.) is inferred to be representing different entities. Similarly, many FRBR properties are disjoint, so the value "1900" appearing as the title of a manifestation and as the date of publication of the same manifestation is inferred to be referring to two distinct things (a title, and a date).

Ontological properties will be used to represent relationships between entities in the separate FR models. For example, the FRAD class Corporate Body is likely to be related to the FRBR class Corporate Body using the rdfs:subClassOf property. Such linking properties may be published as an addendum to the existing FR models, and will have a significant role in informing the development of the consolidated model. The consolidated FR model may also require additional classes and properties, and some classes and properties from the separate models may be deprecated. It is worth noting that redundant classes and properties will not be removed from the separate namespaces; their URIs must be permanent, although their future use will be discouraged.

3.5 RDA

The DCMI RDA Task Group has created its own FRBR classes within the RDA namespace in order to avoid any delays waiting for the FRBR namespace versions to be approved. The original timescale for final approval of the RDA classes and properties was well in advance of that for the FRBR equivalents; as it happened, delays in producing the final draft of RDA and development of the RDA Toolkit have resulted in the FRBR classes and properties being approved first, in September 2010. The RDA equivalents are still in "new-unapproved" status. JSC and the Task Group have yet to determine whether to substitute the FRBR namespace classes in RDA, or declare equivalence with the RDA versions.

There is a potential conflict with FRBR in the RDA database implementation scenarios[26]. In RDA, the Manifestation class is linked to both the Work and Expression classes via the "embodies" relationship, while in FRBR only the Expression class can be linked. While it is possible to create a non-FRBR property for the Manifestation-Work link in RDA, further investigation is required to determine whether this would result in a semantic reasoning collision if the FRBR classes are used instead of the RDA equivalents.

FRBR identifies sets of entities (represented as RDF classes) as Groups 1, 2 and 3, but these were not intended to be interpreted as RDF super-classes. Instead, they simplify the entity-relationship diagrams by collapsing multiple relationships into a single generic relationship between groups. But those relationships are to be interpreted as being between individual entities and not groups, and represented in RDF as a set of multiple properties between classes and not a single property between super-classes, as reflected in the FRBR namespace. For example, there are distinct FRBR properties with the labels "is subject (item) of", "is subject (person) of", "is subject (place) of", etc., instead of a single generic property with the label "is subject of". JSC and the DCMI RDA Task Group are discussing the utility of declaring such super-classes in the RDA namespace to simplify and reduce the corresponding properties. This approach was taken by an earlier RDF representation of FRBR, *Expression of core FRBR concepts in RDF*[27], which was not approved by IFLA.

3.6 ISBD

ISBD is a data model for representing bibliographic metadata records, rather than a conceptual model such as the FR family. ISBD has only one class, Resource, which is implied in the source documentation. Further investigation is required to determine if this is a super-class of FRBR Work, Expression, Manifestation, and Item. If so, it would be equivalent to the concept of FRBR Group 1, even though that is not intended to be a class.

There are no relationship properties in ISBD because it only addresses a single Resource. ISBD does not specify any relationships between bibliographic resources or between a resource and associated authority records. All ISBD RDF properties are based on attributes. All properties have a domain of ISBD Resource, but there are no ranges because ISBD does not specify what types of value an attribute can have. As a result, there are no inverse properties in the ISBD namespace. Further work is required to map ISBD properties to FRBR properties; preliminary analysis suggests there is significant overlap.

As such, it has been easier to develop the ISBD namespace than the FR namespaces. The balance of complexity is restored, however, because ISBD specifies a sequence for attributes within a bibliographic record, and indicates whether an attribute is mandatory or repeatable within a record, unlike the FR models which have nothing to say about these qualities. The ISBD/XML Study Group is representing these aspects of ISBD in a Dublin Core application profile (as is the DCMI RDA Task Group with RDA); the interoperability of application profiles remains the subject of intense discussion with Semantic Web communities, as, for example, in a recent meeting at the DC-2010 conference[28].

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[26] Cf. notes to the Joint Steering Committee for Development of RDA. RDA database implementation scenarios. 2009. Available at: http://www.rda-jsc.org/docs/5editor2rev.pdf.

[27] Cf.. Davis, Ian, and Richard Newman. Expression of core FRBR concepts in RDF. Available at: http://vocab.org/frbr/core.html.

[28] Agenda, notes and related material available at: http://www.w3.org/2001/sw/wiki/JointMeeting2010.

Like RDA, and unlike the FR family, ISBD specifies some controlled vocabularies for the values of its content and carrier attributes. A draft mapping[29] of ISBD Content form and media type descriptors (assembled from the controlled vocabularies which have been represented in RDF/SKOS in the OMR) to the RDA content and carrier type controlled vocabularies has been created by mapping the ISBD and RDA terms to the RDA/ONIX framework for resource categorization[30], which is intended to act as the hub for interoperability between bibliographic content and carrier terminologies. The draft mapping is under consideration by the ISBD Review Group as part of the development of the final consolidated edition of ISBD.

4. Conclusion: Improving interoperability

There are therefore at least 3 namespaces relevant to bibliographic resources in development: FR family (comprising the 3 original models plus the consolidated model), ISBD, and RDA. There is likely to be significant overlap in the semantics of their individual classes and properties, so any interoperability between the namespaces will improve the quality and quantity (through inferencing) of linked-data instance triples based on these properties.

There are several current opportunities for improving interoperability in bibliographic metadata created by libraries.

The Vocabulary Mapping Framework (VMF) matrix[31] is based on an analysis of resource, role and relator terms used in several publisher and library models and encoding schemes, including FRBR, FRAD, ISBD, and RDA. The matrix exhausts a "relational space" for resources and the agents associated with them in various roles, and enables a hub-and-spoke mapping, in RDF, between any pair of models or applications. A class or property URI is declared as equivalent to the nearest VMF node, independently of any relationship it may have to other classes or properties within its own namespace. All nodes are connected within the matrix, so any external URI attached to a node is therefore connected to any external URI attached to another node; the two URIs do not have to belong to the same external namespace. Significant further work is required to compute minimum pathways between nodes within the matrix to produce efficient and effective interoperability, as there will usually be multiple connecting pathways between any two nodes.

The coherent and consistent management environment of IFLA namespaces envisaged in the report of the IFLA Namespaces Task Group will improve interoperability between classes and properties derived from IFLA standards, and encourage interoperability with external communities. One of the activities envisaged is the RDF representation of relationships between classes and properties from different IFLA namespaces, and with appropriate external namespaces such as FOAF.

The deliverables and other outputs of the W3C Library Linked Data Incubator Group[32] should also help to improve interoperability between library namespaces and those of other communities. The

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[29] Cf. the Draft Minutes by Dunsire, Gordon. Analysis of content and carrier designators in the ISBD consolidated edition with respect to the RDA/ONIX framework. 2010. Available at: http://www.ifla.org/files/cataloguing/isbdrg/area-0-analysis.pdf.

[30] RDA/ONIX framework for resource categorization, version 1.0 (ROF). Available at: http://www.loc.gov/marbi/2007/5chair10.pdf.

[31] Cf. the website Vocabulary Mapping Framework (VMF) matrix. Available at: http://cdlr.strath.ac.uk/VMF/documents.htm.

[32] Cf. W3C Library Linked Data Incubator Group. Available at: http://www.w3.org/2005/Incubator/lld/.

Group's mission is "to help increase global interoperability of library data on the Web"[33]. The Group has had extensive discussions about the IFLA models, RDA, and other bibliographic namespaces, most recently at a face-to-face meeting[34] held at the end of the DC-2010 conference in Pittsburgh, USA.

Interoperability of these models for bibliographic metadata is essential for supporting the interoperability of value vocabularies for subjects in knowledge organization schemes, by supplying context and ontologies for inferencing rules that can be used to determine the appropriate use of such vocabularies in library linked data triples and thus enriching the Semantic Web.

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[33] Cf. W3C. Library Linked Data Incubator Group. Charter. Available at: http://www.w3.org/2005/Incubator/lld/charter.
[34] Agenda, notes and related material available at: http://www.w3.org/2005/Incubator/lld/wiki/F2F_Pittsburgh.