A Survey of FRBRization Techniques

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Abstract. The Functional Requirements for Bibliographic Records (FRBR), an emerging model in the bibliographic domain, provide interesting possibilities in terms of cataloguing, representation and semantic enrichment of bibliographic data. However, the automated transformation of existing catalogs to fit this model is a requirement towards a wide adoption of FRBR in libraries. The cultural heritage community proposed a notable amount of FRBRization tools and projects, thus making it difficult for practitioners to compare and evaluate them. In this paper, we propose a synthetic and relevant classification of the FRBRization techniques according to specific criteria of comparison such as model expressiveness or specific enhancements.

1 Introduction

A large majority of current IT systems used by librarians to manage their bibliographic records are based on old standards like the well-known MAchine Readable Cataloguing (MARC) format, designed in 1965 and used around the world in different versions like MARC21 or UNIMARC. Although these formats are references in libraries, they suffer from many fields with ambiguous semantic (e.g. 7xx fields in MARC21) and from a lack of mechanisms to represent complex relationships between records, i.e., bibliographic families composed by different executions and many related works. Furthermore, librarians nowadays have to deal with a large amount of storage formats (e.g., ebook, streams) and new data sources. This may result in bad cataloguing practices, numerous typing errors and finally increasing cataloguing costs [12]. However, best practices from Semantic Web encourage the reuse of data which implies, in the context of cultural heritage data, to improve interoperability of bibliographic catalogs [3].

In response to the discussions around major librarian's topics such as reducing cataloguing costs and enhancing the representation of bibliographic families, the IFLA Study Group published, in 1998, new recommendations for cataloguing and a set of concepts to represent bibliographic data in the context of the Functional Requirements for Bibliographic Records (FRBR) [20]. FRBR offers a

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flexible framework to represent any cultural content in library [18], new benefits for improving searching and visualization [13] and new possibilities for semantic enrichment of cultural entities [8]. The adoption of FRBR in cultural institutions requires different issues to be solved like the transformation of legacy data into the new entity-relationship model, a process mainly called **FRBRization** [31, 1]. The last decade has seen the emergence of a significant amount of FRBRization tools and projects, thus making it difficult for practitioners to gather relevant information [34].

This paper presents a survey of FRBRization techniques, both research projects and full commercial tools. To the best of our knowledge, our work is the first classification of these techniques according to criteria such as the type of transformation, the model expressiveness and its enhancements (see Section 4). This classification is useful for practitioners who need the keys to quickly understand and identify suitable techniques w.r.t. their requirements. The rest of the paper is organized as follows: Section 2 introduces preliminaries about FRBR and FRBRization, then we present the related work in Section 3. Our classification is detailed in Section 4. Section 5 concludes the article.

2 Preliminaries about FRBR and FRBRization

FRBR provides a set of concepts organized in an entity-relationship structure to represent bibliographic families and subject authority data of any cultural material with no ambiguity [10]. The main contribution of FRBR is that it deeply redefines the notion of what an intellectual work is and its representation [5]. Entities are divided into three groups: the first group focuses on the record's representation, the second one is about related persons or corporate body and the third group represents what a work is about. Contrary to legacy models, several levels of metadata can be used to describe each bibliographic record [23].

As illustrated in Figure 1, the first group is composed of entities **Work** (the most abstract object which represents an intellectual or artistic idea), **Expression** (the realization of a Work in various intellectual forms, such as a translation), **Manifestation** (the physical representation of an Expression in terms of material attributes) and **Item** (a single example of a Manifestation, for example a single book on a library's shelf). The components of the second group represent humans, groups or organizations and have been later gathered under the **Agent** name. In Figure 1, each entity from the first group has a link with an Agent. The third and last group of the FRBR model concerns the subject relation of a work. It allows the model to answer the question of what a Work is about and to align several Works according to specific criteria (e.g., same topic, review of).

The Functional Requirements for Authority Data (FRAD) [24] and the Functional Requirements for Subject Authority Data (FRSAD) [32] have later been added to FRBR to cover authority data and complex relationships between enti-

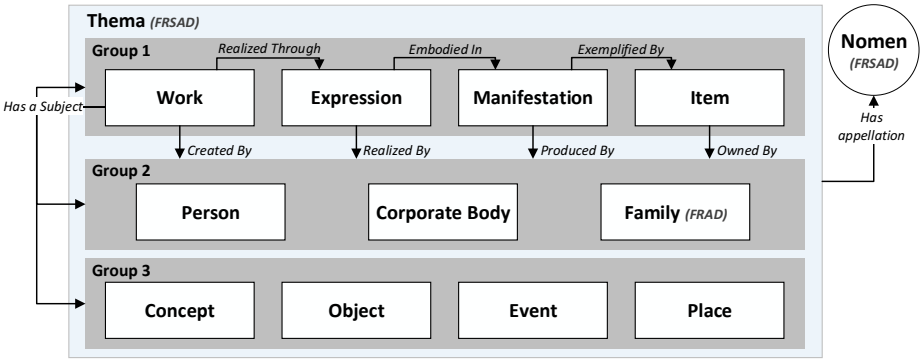

Fig. 1. Conceptual representation of the FRBR Family Model

ties respectively. For instance, Figure 1 depicts examples of these improvements like the new entity Family from FRAD or the new concepts of Thema and Nomen from FRSAD. These three functional requirements, FRBR, FRAD and FRSAD are called the FRBR Family and must be seen as a single architecture for the new cataloguing concepts. Because the FRBR model have been created regardless of technological constraints a large amount of provided concepts covers a too large scope for being used in practical implementations. In other words, FRBR must not be used directly as a final object model. Thus, there is a branch of the FRBR researches which is focused on modelling practical ontologies based on FRBR but adapted to the user needs [27, 11].

The adoption of a FRBR-based model in existing systems is known as the FRBRization process. Such a transformation relates to the well known challenges of data integration and data conversion [2]. This study focuses on a specific part of the process which aims at identifying, creating and connecting FRBR entities from existing records. In this context, FRBRization is widely regarded as a complete metadata migration framework rather than a simple algorithm [15]. The initial phases of a FRBRization process have been formalized as follows: pre-processing to harvest and normalize the input catalog, extraction to generate the FRBR entities and relationships and post-processing with deduplication and adaptation of data for visualization [1]. The next section presents the different attempts of surveys and classifications for FRBRization techniques.

3 Related Work

One of the earliest survey about FRBRization was conducted at the Online Computer Library Center (OCLC) [13]. Although focused on the benefits of FRBR cataloguing, it also reviews the major solutions which implemented this model. However, the projects are simply listed along with their properties and available technical details to mainly illustrate the contrast between a growing interest in FRBRization and the lack of successful tools.

Another notable work is the observation of the whole landscape of FRBR implementations in libraries by Zhang & Salaba [33]. The existing implementations have been classified according to the following categories: the full-scale systems (i.e., that are mainly FRBRized systems), the prototypes or experimental systems and the algorithms and software that are essentially tools to FRBRize catalogs. The scope of the study is large since all kinds of FRBR-related projects are covered. Although exhaustive (at that time), such a broad classification is not sufficient to understand technical features between two different FRBRization approaches.
Researchers from the TelPlus[1] project have also worked on a survey to introduce and list FRBR experiments [30]. They have presented, with a rich description, all the relevant projects related to FRBR ordered in high level sections. The conversion tools are introduced under a Research section and presented as a list. More recently, Aalberg et al. presented a list of FRBRization projects [2]. For each project, they studied the possible issues raised during the transformation of records, and more specifically in terms of common structures. The authors were able to propose solutions for interpreting these structures and to FRBRize them correctly. However, the list of projects is not exhaustive since it mainly aims at illustrating structural problems.

To summarize, existing surveys presented the state of the art of FRBRization techniques, but mainly as an unsorted list. In addition, the techniques can be described with a specific goal in mind (e.g., illustrating problems of conversion). The properties and features of each technique are provided textually, which does not facilitate a quick comparison. In the next section, we propose the first classification dedicated to FRBRization techniques.

4 A Novel Classification of FRBRization Techniques

This survey aims at exploring the various issues faced by existing FRBRization techniques, bringing a more precise view of this migration process and facilitating the comparison of existing solutions through a multi-criteria classification. Because many projects gravitate around FRBR, we do not consider the Integrated Library Systems (ILS) which do not include a transformation tool. This choice is justified with regards to current and future challenges on FRBRization such as scalability and semantic enrichment. Besides, our classification focuses on semi-automated techniques, i.e., any FRBRization solution in which most of the algorithm proceeds without human intervention. This excludes manual projects which have not detailed any automated process to transform their catalog, for instance the Austlit project [4] or Data.BNF [19].

Our classification makes use of three criteria of comparison:

[1] http://www.theeuropeanlibrary.org/confluence/display/wiki/TELplus+project

– **Type of FRBRization** which relates to the methods for identifying FRBR entities from the legacy model. Two strategies are found in the literature. The former consists of grouping physical form of records by comparing descriptive keys (e.g., a concatenation of author names and title) to deduce more abstract levels (see Section 4.1). The latter aims at interpreting the original fields of the records (e.g., with mapping rules) to build the FRBR entities and relationships (see Section 4.2).

– **Model Expressiveness** that deals with the models designed to receive FRBRized data. Three variations are presented: a *limited model* means that the main entities from the first group of FRBR are not completely implemented, a *standard model* indicates that the FRBRization technique takes into account the entities and relations from the three groups of the basic FRBR model and an *enhanced model* corresponds to specific implementations where significant changes have been made to the initial FRBR model.

– **Specific Enhancements** used to improve the quality or the performance of the FRBRization process. It may include additional steps, improvements of algorithms or interoperability enhancements (see Section 4.3).

Figure 2 depicts the FRBRization techniques classified according to our criteria. For instance, the FRBRization project TelPlus is classified under *rule-based interpretation of fields*, *standard model* and it includes *clustered deduplication* and *evaluation metrics* as specific enhancements. The rest of this section provides details for each technique according to these criteria.

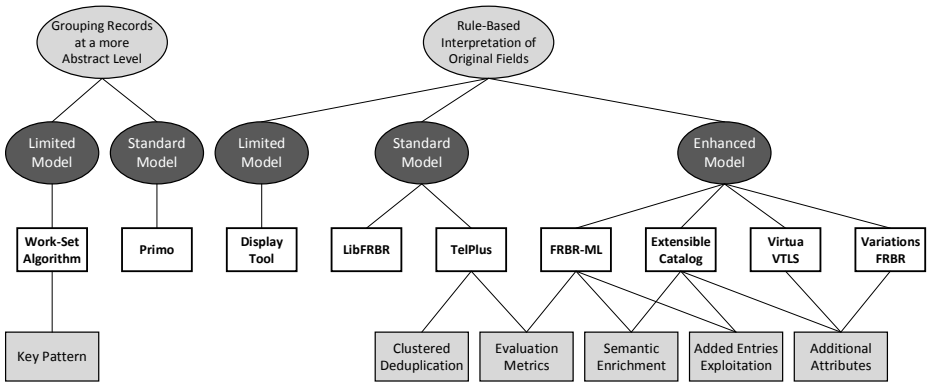

Fig. 2. Classification of the FRBRization Techniques, with the Type of FRBRization in light-grey circled boxes, the Model Expressiveness in dark-grey circled boxes, the Solutions in white squared boxes and the Specific Enhancements in light-grey squared boxes

4.1 Grouping Records at a more abstract level

When FRBRizing, it appears that a large part of the MARC records corresponds to the FRBR Manifestation entity. In such a case, the most complex task is to produce Work and Expression entities from the MARC records. Thus, the initial intuition is to group the derived Manifestations into relevant clusters which represent a more abstract level. A common solution deals with the detection of the Work entities based on generated description keys from Manifestation attributes, and to deduce the primal Expression that links the Works to the Manifestations.

Among the first projects about FRBRization, the studies from OCLC describe how to automatically group records at a more abstract level [5]. The well-known **Work-Set algorithm**, applied in FictionFinder and WorldCat's catalog [16], was designed to produce "sets of Works" for MARC records based on the generation and the comparison of normalized keys [17]. This process is based on three main steps to build these keys: constructing an author portion, constructing a title portion and grouping these portions according to four specific patterns. Each portion is built according to mappings with MARC fields and matching with authority files. These studies reveal two major issues from this technique: the precision about the semantic level of the deduced Works (e.g., a too large clustering may lead to groups at more higher level than the original FRBR Work) and the difficulty to identify the variations of a same Work at Expression level.

Another experience in the grouping records category is **PRIMO** from *Ex Libris* [25]. This commercial discovery tool provides FRBRization features by proposing transformation options like automatic grouping of records under a single Work. In addition, the FRBRization includes a pre-processing step which consists in harvesting catalog data into an intermediate model so that records can be cleaned. We cannot provide more details about PRIMO since technical information are not available, for example about deduplication and model expressiveness.

As a summary, the techniques based on grouping Manifestations under Works can be seen as a reorganization of the catalog rather than a real transformation. Furthermore, even if the patterns (based mainly on title and authors fields) are useful for clustering records, they are not sufficient to detect all the complex relationships that can exist between entities and must be completed by additional processes using the original fields to fully exploit the capabilities of FRBR.

4.2 Interpreting each fields of the original records

The second type of FRBRization aims at building a FRBR catalog by mainly applying mapping rules between the initial catalog metadata and the FRBR attributes. In the context of MARC catalogs, such a process is basically performed

by reading each record's field and identifying whether it matches any rule. Depending on the quality and completeness of the input catalog data, the rules have to be more or less complex to create not only the FRBR entities but also the different relationships that link them. It is worth noting that a single MARC record usually generates more than one FRBR entity. Indeed, a MARC record contains information for different FRBR entities. Conversely, information about the same FRBR entity may appear in several MARC records, in particular when the second and the third FRBR groups are considered. In the rest of this section, we describe the major projects based on this kind of extraction technique.

The **LC Display Tool** is one of the first prototype for FRBRization provided by the researchers from the Library of Congress in 2003 [28]. This solution takes as input MARC21 records and it can produce FRBR XML and HTML. The process uses MARCXML as an intermediate format to benefit from the XML format and from the MARC leader fields. Rules stored in XSL files are applied to the MARCXML catalog to clean the data and to generate FRBR entities. The process returns a list of Works, each of them hierarchically linked to one Expression and one Manifestation and containing title and author attributes. This representation focuses on the main entities from the first group of the FRBR model which is a very limited expression of the capabilities of FRBR. Such choices for displaying results have also raised early issues in terms of visualization of FRBR entities. Indeed the hierarchical organization of XML (e.g., if using HTML) combined with the large amount of relationships available in FRBR may produce very large files which makes it more difficult to read.

The **TelPlus** project [21] allowed the realization of a semi-automatic transformation process for MARC records. The FRBRization is based on a preprocessing stage for correcting and enriching records, a rule-based extraction step and a deduplication phase. Several issues are raised by this study such as the minimum information needed in each record to guarantee a good quality of the process, the large amount of duplicate FRBR entities generated and the high complexity of some mapping rules. They face the first issue by providing a list of requirements to filter the records in input. The second one (i.e., duplicates entities) is managed with a clustered deduplication process (see Section 4.3). They deal with the last issue (i.e., complex rules) by using an extension of the extraction tool from Aalberg [1] to enable the implementation of more complex rules. The experiments have been performed on a large number of heterogeneous records (from TelPlus project) and the output model used is a quite standard version of initial FRBR model designed in RDF[2]

LibFRBR is another rule-based implementation built in the context of FRBRizing the Chinese Koha system [9]. This project includes a FRBRization tool written in Perl which can harvest data in MARC21 or CMARC, extract FRBR entities from the three groups and store them in FRBRXML or in the Koha

[2] FRBR in RDF, http://vocab.org/frbr/core.html

database. There are only few information about the model used by the tool which seems to be close of the standard initial FRBR model. A cataloguing interface for performing corrections on the transformed data and for clustering equivalent FRBR entities has been implemented and evaluated. Compared to previous tools, the advantages of LibFRFR reside both in the edition of the mapping rules (which are not hard-coded) and in the cataloguing interface which involves librarians in the process.

Virtua VTLS is also a solution which provide a rule-based interpretation of input fields to extract FRBR concepts [14]. A specificity of this commercial tool is that MARC records can coexist with FRBR entities, i.e., FRBR is implemented as an optional layer. Although only few technical informations are given about the FRBRization, many options and user interfaces have been presented to analyse MARC records and FRBRize the catalog. Furthermore, the FRBR model has been extended to allow complex relationships between different works of a same bibliographic family (e.g., *Super Works*).

The **Variations** or **V/FRBR** project, dedicated to musical content, brings a new FRBRization tool with an extended FRBR implementation [26]. A major proposal of this project deals with the model because three XML-based schemas have been released: a strict version of FRBR and FRAD entities, an extended model which globally allows to add more meta-information to the previous strict model and the V/FRBR model which is based on the extended model in which attributes have been adapted to the musical context. The other contribution is a Java-based tool that has been designed to FRBRize musical data to build a FRBRized OPAC called Scherzo [22]. The results of the project show that FRBRization may also succeed in real-world contexts by using sophisticated extraction rules. However, the mapping rules were apparently hardcoded even if a complete documentation have been freely provided with the project.

In **eXtensible Catalog** (XC) [6], FRBRization is handled by the Metadata Service Toolkit with the goal of improving the quality of the migration. This open-source tool is composed of a pre-processing phase with mechanisms to harvest and normalize records (from OAI-PMH repositories[3]), a transformation phase to migrate the normalized data (FRBRization) and an aggregation phase to detect and merge duplicate entities [7]. In this project, the Metadata Service Toolkit is a component inside a full ILS solution, and the implemented model (the XC schema) has been extended, mainly with the *Holding* entity, i.e., a specific implementation of the FRBR Item entity to handle MARC21 Holding records. Several interesting challenges of FRBRization are faced by XC in terms of input model management and normalization of extracted data (see Section 4.3).

[3] OAI-PMH, https://www.openarchives.org/pmh/

FRBR-ML [29] is an extended version of Aalberg's FRBRization tool [1]. In addition to the transformation aspects, it aims at promoting interoperability between different models such as MARC and FRBR. Thus, this new system is built on an XML based intermediate model which was designed to ease exporting data in various semantic formats. The FRBRized records are represented with an hybrid semantic format which may use external attributes from the Linked Open Data.

To summarize, all these rule-based solutions cover various model needs. FRBRization techniques based on enhanced model may be more complex to design but offer a better completeness in terms of transformed data. Furthermore, a major part of the solutions has managed to improve the quality of their transformation at different steps. At the beginning of the process, some have chosen to involve the user feedback with an intuitive interface to create or refine the rules and to ease building the output model. At the end of the process, several solutions have provided an aggregation phase to find and merge duplicate records. It is a critical step especially when rules are applied on fields that may contain duplicate values.

4.3 Specific Enhancements

The last criterion of our classification is about specific enhancements, mainly designed for tackling quality or performance issues. These enhancements have been isolated from the standard features presented previously because they don't represent a fundamental step of the initial FRBRization process but are needed to face the metadata migration challenges (see Section 2).
The FRBR model and its extensions are suitable for the representation of many information in the cultural heritage domain. However, the original model only provides a limited set of attributes and relationships labels which are mainly concepts. Thus, to cover the practical requirements of librarians and to enhance related information, it may be useful to include **additional attributes** while modelling with FRBR. Several tools are able to integrate vocabularies from other models. For instance, Virtua VTLS uses RDA vocabulary and rules[4] to provide a more structured and interoperable catalog. Similarly, eXtensible Catalog extends its models with elements from RDA and Dublin Core [6].
The **exploitation of added entries** from the initial data has been widely studied to find solutions for extracting data stored in the MARC21 7xx fields[5]. Such fields may contain additional authors, geographic names, information about Agents at the Expression level (e.g., cover drawer, translator) and the challenge is to store this information in the correct FRBR entity. Variations [26] and eXtensible Catalog [6] roughly use the same method for exploiting these added entries: creation of new FRBR entities from specific fields (e.g., in MARC21 *700, 710* or *740* with a second indicator equal to *2*). Variations may create several levels of

[4] Virtua does not provide any public specification about its use of RDA.
[5] MARC21 7xx fields, http://www.loc.gov/marc/bibliographic/bd70x75x.html

Works[6] while eXtensible Catalog can directly create a new Expression and its parent Work[7]. In FRBR-ML, the idea for disambiguating information contained in the MARC21 7xx fields is to analyse similar records that may not contain the ambiguity [29]. This search is performed either in the same collection, in external collections (z39.50 or SRU/SRW) or in knowledge bases such as the Linked Open Data cloud[8] (LOD).

An interesting enhancement for FRBR catalogs is the **semantic enrichment**, i.e., the addition of extra information such as new attributes or relationships. Using the potential of external data can both enhance the completeness of the process and also improve the validation of the results. However, this task involves many new issues because of the heterogeneity of the databases that can be used. For instance, using both information from structured sources (e.g., LOD) and non-structured sources (e.g., websites) involve effective and efficient matching tools at schema and instance levels. FRBR-ML performs matching to external knowledge bases (LOD cloud) for discovering the semantic type of an ambiguous field (e.g., person, location) and detecting missing relationships between FRBR entities [29]. As for eXtensible Catalog, it can perform a specific data fusion process to merge the attributes from equivalent entities [7].

Descriptive keys are used for comparing records and for detecting duplicates, thus improving quality [7, 21, 9, 29]. The issue is to find the most relevant **patterns for descriptive keys**. In the Work-Set project, the OCLC has proposed four patterns to fulfil this goal [16]. For instance, one of the patterns is the combination of author name and title. These four OCLC patterns are still a reference for the generation of descriptive keys for bibliographic content, and they have been applied in the most recent FRBRization techniques.

The deduplication, which aims at detecting duplicate records, is one of the most time consuming step because of the Cartesian product applied between all records. The **clustered deduplication enhancement** impacts efficiency by reducing the execution time of the deduplication. In the TelPlus project, each FRBR entity produces a set of keys (according to the patterns for descriptive keys from OCLC [16]). The intuition is to group in the same cluster all entities that share at least one identical value for one of their keys. The last step identifies duplicates inside clusters by comparing their keys and computing similarity values with thresholds.

Evaluation of the FRBRization process is crucial, but it requires the **definition of evaluation metrics**. TelPlus proposes a metric for the evaluation of the aggregation level (i.e., the percentage of duplicate entities extracted). The FRBR-ML project [29] defines three metrics to measure the degree of completeness (i.e., the amount of information lost during FRBRization), the minimality rate (i.e., the amount of redundant information, at the property, record and collection levels) and the extension rate (i.e., the amount of enriched information). Finally, our classification enables the identification of relevant techniques accord-

[6] Converting MARC to FRBR, http://www.dlib.indiana.edu/projects/vfrbr/projectDoc
[7] XC, https://code.google.com/p/xcmetadataservicestoolkit/wiki/TranserviceIntro
[8] Linked Open Data cloud, http://linkeddata.org/

ing to the type of FRBRization and the model expressiveness. Compared to the initial FRBRization process, most tools have proposed specific enhancements either for effectiveness (quality aspects) or efficiency (performance aspects).

5 Conclusion

This paper introduces a survey about FRBRization tools and projects to provide a more comprehensive view of this process. To the best of our knowledge, this is the first classification according to criteria such as the type of FRBRization and the model expressiveness. Our contribution is useful both for librarians who need to choose a FRBRization technique and for IT company working on cultural heritage data who plan to design mature FRBRization tools. According to the results of our study, we advocate that the FRBRization process must be refined to cover the most recent challenges of metadata migration. For instance, involving user feedback at the initialization phase (e.g., rule selection) can reduce human mistakes. Furthermore, the quality of the process can be enhanced by providing additional steps at the post-processing phase such as an automatic evaluation step or a semantic enrichment step based on external sources.

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