Prelude for an ontology of documentary musical data. A conceptual analysis of FRBR(oo)

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Abstract. Ontologies for the representation and management of both knowledge and data about music are widely used for disparate purposes. In this context, the Functional Requirements for Bibliographic Records (FRBR) and its object-oriented version (FRBRoo) are used to distinguish a musical composition (Work) from its scores (Expression), among other things. Unfortunately, both FRBR and FRBRoo rely on unclear modeling assumptions leading to ambiguous and opaque data models. The purpose of the paper is to dig into some foundational (conceptual) aspects related to the representation of bibliographical musical data. In particular, we first propose a critical evaluation of FRBR/FRBRoo. Second, on the basis of such an evaluation, we depart from these models and propose an alternative approach which keeps some of the useful distinctions in FRBR/FRBRoo while getting rid of their ambiguities. We formally represent our ontology in the Web Ontology Language (OWL) to (ultimately) take advantage of both reasoning and data management methods and technologies.

Keywords: Music ontology, FRBR, data modeling, music cataloging, reasoning

1. Introduction

Modeling approaches based on the Semantic Web offer great opportunities to scholars in the humanities to organize, publish, and share their data [8, 20]. In this context, ontologies are used as machine-processable vocabularies to semantically characterize (meta-)data, automatically reason over data through formally encoded knowledge, and to guarantee the interoperability of datasets produced by different parties, just to mention some common application scenarios [35].

For musical knowledge representation and data management, which are at the focus of this paper, multiple ontologies and Semantic Web technologies (e.g., SPARQL endpoints) are nowadays available (cf., e.g., [9, 27, 28, 39]). Given the heterogeneity of music, the spectrum of data that ontologies capture is very broad, from the encoding of MIDI files in Semantic Web languages [21] to ontologies aimed at describing different genres or forms of music, including also data about bands or composers [7, 27], just to mention a few examples (see also Section 3).

The research presented in the paper contextualizes within the effort of publishing bibliographical data about music in the Linked Open Data (LOD) cloud; the goal is to make the data accessible and reusable.
by both researchers, stakeholders, and the public. With bibliographical data we mean the description of (original, transcribed, etc.) musical scores that are typically found in archives and libraries. In particular, we address the representation of musical data about the fifteenth and sixteenth centuries in order to provide a description of early music that reflects musicologists’ views and the modeling needs related to their research.

For example, the fact that a musical composition was first published in the sixteenth century and since then multiple editions appeared with some variations from each other. We therefore need a way to describe a composition, its structure, the relations to the various editions in which it is published, among other data.

In the context of this research, the Functional Requirements for Bibliographic Records (FRBR)\(^1\) [23] and its object-oriented version (FRBR\(\text{oo}\))\(^2\) [4] are widely used. One of the reasons is likely that FRBR\(\text{oo}\)\(^3\) make a useful distinction between (at least) three relevant entities for cataloging, i.e., Work, Expression, and Item. These are meant to capture the representation of musical compositions (or literary works) from different abstraction levels. For example, one may need to model multiple digital files (Item) or musical scores (Expression) referring to the same composition (Work). Item can therefore be used to cover physical books or digital files; Expression to model the text or musical score found in various items; Work to capture musical compositions per se. Unfortunately, apart from these general intuitions, the way in which these elements are understood and related remains highly ambiguous. This has created some confusion in the literature and nowadays the use of FRBR\(\text{oo}\) relies either on common practices for circumventing its drawbacks or the tacit adoption of its ambiguities (see Section 3).

The paper presents some preliminary considerations on the ontological representation of bibliographical musical data for scholarly purposes. In contrast to previous scholarship that focused on specific tasks or computational techniques (e.g., [21, 31]), our goal has a foundational flavor. By reviewing the core concepts of FRBR\(\text{oo}\) we propose an alternative approach which avoids FRBR\(\text{oo}\) ambiguities while keeping the benefit of distinguishing between works, expressions, and items. Following Guarino [10], this first analytic step is in our view necessary to support the development of well-designed computer applications, which are able to represent experts’ viewpoints and handle data in a transparent way. In addition, we exploit the reasoning capabilities of the Web Ontology Language (OWL) [14] to support the development and maintenance of a (logically) consistent knowledge base and to infer new knowledge on the data.

The paper is structured as follows. In Section 2 we review FRBR\(\text{oo}\) by stressing their pros and cons. Section 3 reports on existing ontologies for musical data management. Given the broad spectrum of resources nowadays available and the focus of our research, we consider ontologies that explicitly rely on FRBR\(\text{oo}\). On the basis of this review, Section 4 presents a preliminary ontology for modeling bibliographical musical data that departs from FRBR\(\text{oo}\) and allows to (automatically) reason over formally encoded knowledge. Section 5 shows an example based on the ontology, while Section 6 concludes the paper and discusses the need for future work.

2. The Functional Requirements for Bibliographic Records (FRBR)

Both FRBR and FRBR\(\text{oo}\) are widely used across resources for musical data modeling (cf. Section 3). We review in this section some of the core FRBR\(\text{oo}\)’s modeling elements; by addressing their shortcomings, we stress the need for an alternative approach.

2.1. Work and Expression

According to FRBR’s documentation [23], a work is “a distinct intellectual or artistic creation” [23, p.17]. The documentation adds that “[w]e recognize the work through individual realizations or expressions of the work, but the work itself exists only in the commonality of content between and among the various expressions of the work. When we speak of Homer’s Iliad as a work, our point of reference is not a particular recitation or text of the work, but the intellectual creation that lies behind all the various expressions of the work” [23, p.17]. The quote suggests that Work is introduced in FRBR for practical cataloging purposes, e.g., to facilitate the grouping of multiple scores under a common heading. Quoting again from [23], “the name we give to [a] work serves as the name of the entire set or group of expressions that are realizations of the same

\(^1\)https://www.ifla.org, last accessed October 2019.
\(^3\)We use the notation FRBR\(\text{oo}\) to mean both FRBR and FRBR\(\text{oo}\).
intellectual or artistic creation (e.g., Lancelot du Lac). It is the entity defined as work, therefore, that provides us with this grouping capability” [23, p.19]. Similar considerations are expressed in [26]. In this case the author argues that “the entity work [in FRBR] represents an abstract concept. [...] The work is recognizable because we have [...] performances and publications. If anything, [a work] is what all those performances and publications have in common” [26, p.16]. This concept seems reasonable at first glance. But once we start to consider the definition of Work in relation to Expression, things become profoundly puzzling.

Following [23], an expression is “the intellectual or artistic realization of a work in the form of alphanumeric, musical, or choreographic notation, sound, image, object, movement, etc., or any combination of such forms. An expression is the specific intellectual or artistic form that a work takes each time it is realized” [23, p.19] (emphasis is ours). As this passage suggests, works are not necessarily realized in expressions. This overturns the meaning of Work previously introduced. The passages above suggest indeed that works are created only a posteriori by abstracting from, e.g., expressions for cataloging purposes. Differently, the definition of Expression assumes that works are not necessarily realized suggesting that works are not created by abstracting from expressions and could even pre-exist expressions. This view in turn now takes us from a problem of data modeling to one of the genesis of artistic work. The idea that works precede their expressions is a Romantic one indeed, aligning as it does with ideas of genius, inspiration, and the Ideal Work.4

The ambiguity on the nature of works becomes evident in FRBRoo’s documentation. Following [4], “an instance of F1 Work begins to exist from the very moment an individual has the initial idea that triggers a creative process in his or her mind. [...] Unless a creator leaves at least one physical sketch for his or her work, the very existence of that instance of F1 Work goes unnoticed, and there is nothing to be catalogued” [4, p.27]. This view is unfortunate: first, if works are introduced to classify expressions, it cannot be the case that their existence precedes the existence of expressions or that works exist without expressions; second, it is unclear whether FRBR(oo) distinguish between the classes F14 Individual Work, F15 Complex Work, and F16 Container Work, all subsumed by the more general F1 Work, see Figure 1.5

2.2. The structure of works in FRBRoo

The development of FRBRoo [4] brought various changes in FRBR, among which the distinction between the classes F14 Individual Work, F15 Complex Work, and F16 Container Work, all subsumed by the more general F1 Work, see Figure 1.

Following [4], F14 Individual Work “comprises works that are realised by one and only one self-contained expression, i.e., works representing the concept as expressed by precisely this expression” [4, p.63]. Differently, F15 Complex Work “comprises works that have other works as members. The members of a Complex Work may constitute alternatives to, derivatives to, or self-contained components of other members of the same Complex Work” [4, p.63]. The taxonomy of FRBRoo includes also F21 Recording Work and other classes, which are not considered here.

4The reader can refer to [2] for further readings on the ideal nature of works.

5The reader can refer to [2] for further readings on the ideal nature of works.
documentation adds that complex works are useful to grasp “[t]he conceptual unity observed across a number of complete signs, which makes it possible to organise publications into bibliographic families” [4, p.26]. An example of complex work given in [4] is Whitman’s *Leaves of grass*, which comprises both the English deathbed edition and its French translation done by Bazalgette, among other editions and translations (cf. [4, p.19]). It should be clear that *F15 Complex Work* has at least two different meanings. First, it can be used as a cataloging entity collecting multiple expressions (e.g., multiple translations of the same literary work). From this perspective a work is complex because it has members (cf. the relation *R10 has member* in [4]) the various individual works it collects.

Second, it can also be used to model structured works such as symphonies (or novels) comprising multiple movements (chapters). Quoting from [4], “a work can be recognized as being composed of several structural parts. This is [...] modelled as: *F15 Complex Work* is a *F1 Work*, and *F15 Complex Work R10 has member F1 Work*” [4, p.26]. An example provided in the documentation is “Dante’s textual work entitled ‘Divina Commedia’ (F15) [which] has member Dante’s textual work entitled ‘Inferno’ (F15)” [4, p.90]. In this second sense a work is complex because it is structured into various parts. FRBRoo itself recognises the ambiguity of the class *F15* and the documentation adds that the relation *P148 has component*, taken from CIDOC CRM [5], can be used instead of *R10 has member* to model “an instance of *F15 Complex Work* and its structural parts” [4, p.26].

Finally, *F16 Container Work* is an umbrella for various classes and it is meant to model works resulting from the selection and reorganization of other works such as anthologies. The latter are explicitly represented by means of the class *F17 Aggregation Work*. According to [4], an aggregation work does not comprise the aggregated works as parts and FRBRoo does not cover a relationship to model the link between, e.g., an anthology and its composing units. This is unfortunate because, from a modeling stance, it is useful to represent the structure of anthologies; for example, one may want to retrieve the musical pieces that are included in a musical anthology like *The fourth book of Gesualdo’s Five Voice Madrigals*. In addition, the choice of modeling anthologies (and containers works) as works that do not comprise their units is debatable. Vellucci [37], for instance, distinguishes between unified work and aggregated work. The former covers symphonies or operas having “components parts [that] derive their meaning within the context of the complete work” [37, p.139]. Differently, “[a]n aggregated work brings works [...] together to form a collective form, but each component work in the aggregate retains its independent unit” [37, p.140]. What this suggests is not that aggregated works lack parts but rather that the distinction between, e.g., symphonies and anthologies depends on the way in which their parts are linked via unity or dependency conditions.

In summary, looking at FRBR(oo) from a conceptual modeling perspective, the attribution of multiple meanings to the same modeling elements make them ambiguous and confusing. In particular, whenever one considers the notion of *(F1) Work*, it is not clear whether reference is done to an idea in someone’s mind or to a conventional entity created for documentary needs. Along the same lines, in the case of *F15 Complex Work* it is not clear whether it is used to model structured entities like symphonies or cataloging entities which abstract from multiple expressions. In the terminology of Weber [38], *(F1) Work* and *F15 Complex Work* are cases of construct overload, a phenomenon occurring “when a single grammatical construct can stand for two or more ontological constructs. The grammatical construct is overloaded because it is being used to do more than one job” (quoted in [11, p.30]). This overload has to be avoided in order to allow both humans and machines to transparently access and process data’s semantics.

3. FRBR(oo)-based ontologies for music

Semantic Web and Linked Open Data resources are widely used for musical data management. Given the scope of our paper on the conceptual foundations of documentary musical data management, we report on the state of the art relevant for our goals. In particular, since we propose a (preliminary) ontology based on the triple Work-Expression-Item that revises the basic assumptions of FRBR(oo), we focus on existing ontologies where the reuse of FRBR(oo) is explicitly documented. The reader can refer to [8, 17, 21, 28, 39]

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7The relation *R10 has member* holds between *F15 Complex Work* and *F1 Work*; since (i) *F17 Aggregation Work* is not subsumed by *F15 Complex Work* and (ii) FRBRoo’s documentation stresses the difference between *F15* and *F17*, *R10 has member* cannot be used to model the structure of aggregation works.
for further readings on Semantic Web or Linked Open Data approaches for music.

The Music Ontology[8] [27] is a vocabulary to publish and link a broad range of musical data on Web sources. Besides FRBR, it is based on the Timeline ontology, the Event ontology, and Friend of a Friend (FOAF). It covers many different types of entities, including data about the workflow of music creation, performing events happening in specific places at a certain time, musical instruments, application systems to share music files (e.g., torrent), and e-commerce platforms, among others. The class Musical Work extends FRBR’s Work and it is further specialized in Movement, whose instances are self-contained parts of a musical work. With respect to our research, the Music Ontology’s scope is wider; e.g., we do not attempt at representing marketing or data about pop music bands. As said, our application focus is on the fifteenth and sixteenth centuries music and, in particular, on data relevant for scholarly needs. From this perspective, the Music Ontology does not cover modeling elements to describe the structure of compositions besides movements which is fundamental for our research (cf. Section 4). Also, it relies only on a superficial reuse of FRBR without considering the conceptual and modeling ambiguities that we discussed in Section 2. E.g., when using a class like Musical Work, it remains unclear to which individuals it refers.

Doremus[9] [1, 7] is a project supported by the French National Agency for Research (ANR) involving some of the major French institutions in the cultural and musical landscape like the Bibliothèque nationale de France (BnF), the Philharmonie de Paris, and Radio France. One of its objectives is to integrate multiple datasets produced and maintained by different institutions and to make them available through Web resources. For this goal the DOREMUS ontology[10] has been created by extending both CIDOC-CRM and FRBR(oo). It is not therefore surprising that the ontology heavily relies on the triple Work-Expression-Item. Similarly to the Music Ontology, however, FRBR(oo)’s ambiguities are not analyzed in DOREMUS, a choice leading to confusing claims. For instance, Choffé and Leresche [7] understand a work as a general entity grouping multiple expressions. Differently, in a later publication on the same project, Achichi et al. [1] define a work as “the abstract intention of the author”. It clear that these two interpretations reflect the ambiguities in FRBR(oo), although they are neither discussed nor analyzed by [1, 7].

Finally, the Music Encoding Initiative (MEI),[11] which provides an XML encoding of musical data (durations, pitches, etc.), adopts some of the basic elements of FRBR.[12] Similarly to the Music Ontology and Doremus, the MEI schema does not dig into the conceptual analysis of FRBR and it superficially adopts the interpretation of Work as “a distinct intellectual or artistic creation” without attempting any clarification of FRBR.

To conclude, on the one hand, it is clear that adopting the basic modeling distinctions of FRBR(oo) is valuable for musical data modeling. On the other hand, however, existing resources like the ones considered in this section either do not recognize FRBR(oo)’s ambiguities, a choice leading to unclear modeling assumptions, or circumvent such ambiguities with generic claims. As said in the Introduction, we take a different approach aimed at grounding the conceptual foundations of ontological modeling for music cataloging in order to foster the development of transparent knowledge-based models. We present in the next section a way to deal with FRBR(oo)’s issues while keeping the cut-off distinction between works, expressions, and items.

4. Ontological modeling of documentary works

The proposal presented in this section departs from FRBR(oo) and builds on library science approaches for the modeling of what we call documentary work. We present our proposal throughout this section, while further commenting in Section 6 on the distinctions (and similarities) with FRBR(oo) and the MEI schema.

Following [30, 32, 33], a documentary work is a conventional entity that is intentionally created for cataloging purposes, namely, to organize, store, and retrieve data, among other applications. A documentary work is therefore created a posteriori by abstracting from specific and possibly multiple expressions (e.g., musical scores, editions, sketches) or items (e.g., the individual physical score of Beethoven’s Symphony

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12https://music-encoding.org/guidelines/v4/content/metadata.html#FRBRentities, last accessed October 2019.
No. 9 which is archived at the library of the University of Tours).

In order to provide an ontology for the classification of bibliographical entities, we distinguish between different classes of documentary work (see Figure 2).\textsuperscript{13}

Given the scope of the paper, we focus on the musical domain although in some important respects the notions detailed here could also easily be applied to other domains and especially the performing arts. Before presenting the taxonomy, it is worth stressing that its organization reflects the way in which musical compositions are formed, e.g., a mass composition as being formed by various movements and sections.

Looking at Figure 2, Documentary Work is the most general class of the taxonomy subsuming Simple Documentary Work and Non-Simple Documentary Work, these two classes being disjoint from each other. Simple Documentary Work models documentary works that are not further decomposable, i.e., they are the simplest units. Differently, as the label suggests, Non-Simple Documentary Work refers to documentary works comprising other works as parts. It should be clear that it is a matter of modeling choice or domain conceptualization to decide which entities are simple and non-decomposable. What is relevant is that these simplest entities, first, play a role for cataloging purposes and, second, have some authorial status, i.e., they are not simply fragments designated by a critic or analyst. Considering the example of masses, these consist of various movements, which are sometimes formed by sectional or formal divisions that the composer built into the piece. These (authorial) sections, however, are themselves never divided in this way (see below for further comments on sections).

Looking back at Figure 2, both Simple- and Non-Simple Documentary Work are specialized into various subclasses. To better understand the taxonomy, recall that the components (i.e., movements or sections) of musical compositions in the Western tradition are defined by textual, dramatic, ritual, or purely musical boundaries. In the context of performances, an overture, aria, Credo, or minuet are often (but not always) separated by silence (or even applause).\textsuperscript{14} In scores or other documentary representations, the boundaries between the various components of a composition are marked by changes in graphical separation devices (e.g., double barline, line break), but also changes in things such as key, meter, performing forces, or even paratextual markers as tempo or genre designation (“allegro ma non troppo,” “gavotte”). In each case, as said, the components of a composition are not fragments designated for analytic purposes; rather, they are intentionally created by composers to structure the composition in a certain way.

On the basis of these considerations and coming back to the taxonomy, Simple Documentary Work subsumes the primitive Simple Musical Documentary Work to explicitly capture musical data.\textsuperscript{15} This class is extended into Simple Movement, Section, and Simple Musical Composition. Similarly, Non-Simple Documentary Work specializes in Compound Documentary Work and Anthological Documentary Work, each class being specialized to the musical domain (see Figure 2). We first focus on Simple Musical Documentary Work and Compound Musical Documentary Work, and we then introduce the remaining classes.

The first important distinction is between Simple Movement and Compound Movement. Differently from instances of the former, instances of the latter are musical movements that are structurally formed by various sections. Therefore, sections – represented by the Section class – are the smallest (bibliographic) units of musical compositions having authorial status; as said, they are not simply fragments.\textsuperscript{16}

The second distinction is between Simple Musical Composition and Compound Musical Composition. Instances of the latter are formed by (simple or compound) movements and can therefore have sections, too. Differently, instances of the former are simple in the sense of comprising neither movements nor sections. An example of Simple Musical Composition is William Byrd’s Praeludium; an example of Compound Musical Composition is Josquin des Prez’s Missa Pange lingua (see Section 5).

In order to formally represent simple and non-simple documentary works and therefore to character-

\textsuperscript{13}Figure 2 shows only the taxonomy of documentary works. It does not show horizontal relations between the classes. The use of these relations is discussed throughout this and the next section.

\textsuperscript{14}An example of musical composition including movements that are often played without breaks is Beethoven’s Symphony No.6. The last three movements of the Symphony are clearly marked in the score but they are often performed without any break.

\textsuperscript{15}When needed for applications, other classes could be added, e.g., to represent (simple) literary works.

\textsuperscript{16}If required by modeling needs, one could easily introduce a notion for, e.g., compound sections which are formed by further documentary musical works. The distinction between movements and sections suggests that the musical works in our application domain are sufficiently precisely segmented in two lower subdivisions.
ize (or define) the structure of musical compositions we rely on the (mereological) relation of proper-part-of [6]. In classical mereology one commonly takes the relation of part-of between two entities x and y as primitive and define proper-part-of between x and y as: x part-of y but not y part-of x. In addition, proper-part-of is a strict order (i.e., an irreflexive, transitive, and anti-symmetric relation) further characterized by principles such as weak or strong supplementation [6]. Given the use of Semantic Web languages for our application context and their limited expressivity (in comparison to plain first-order languages) in favour of computational tractability, we use proper-part-of as a primitive, transitive OWL object property. By adopting this relation, Simple Documentary Work is formally characterized as a documentary work that does not comprise any documentary work as part, whereas Non-Simple Documentary Work has other works as part. For the sake of shortness, we show here only some (simplified) formulas (e.g., we omit axioms universally quantified); the reader can refer to the OWL file for a complete overview of the ontology.  

Using the OWL Manchester syntax [15], Section and SimpleMovement are defined in (Def1) and (Def2), respectively.

**Def1** Class: SECTION

EquivalentTo:

SIMPLEMUSICALDOCUMENTARYWORK

and (PROPERPARTOF some

COMPOUNDMOVEMENT)

(a section is a simple musical documentary work that is proper part of some compound movement)

**Def2** Class: SIMPLEMOVEMENT

EquivalentTo:

SIMPLEMUSICALDOCUMENTARYWORK

and (PROPERPARTOF some

COMPOUNDMUSICALCOMPOSITION)

(a simple movement is a simple musical documentary work that is proper part of some compound musical composition)

Simple Composition is a primitive class. Intuitively, its instances are whole musical compositions which are not part of any larger composition. Hence, differently from sections and movements, which are always related to some larger compositions, simple compositions are stand-alone. Since these three classes are subsumed by Simple Documentary Work, their instances

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17The use of part-of relations for musical data management is documented in the literature; see, e.g., [13, 29] although the authors do not provide technical insights on formal aspects or reasoning mechanisms.

18https://ontohub.org/documentary-work-for-music/DMWOnto. owl

19As a comment on the notation, we use Def. for definitions, Ax. for axioms, f. for formulas in examples, and Q. for queries. Prefixes for namespaces are omitted.
do not have proper parts. In this way the ontology formally excludes, e.g., simple movements from having sections or simple compositions from having movements. These restrictions are relevant to rule out undesired interpretations of the ontology, therefore to allow computer systems to reason in a coherent way with respect to domain knowledge.

Subclasses of Compound Documentary Work are defined in the same spirit, see (Def3) and (Def4).

**Def3** Class: CompoundMovement

\[ \text{CompoundMusicalDocumentaryWork} \]

\[ \text{(hasProperPart}^\text{30} \text{some Section)} \]

\[ \text{and (ProperPartOf} \text{some CompoundMusicalComposition)} \]

(a compound movement is a compound musical documentary work that has proper part some sections and is proper part of some compound musical composition)

**Def4** Class: CompoundMusicalComposition

\[ \text{EquivalentTo:} \]

\[ \text{(CompoundMusicalDocumentaryWork} \]

\[ \text{and (hasProperPart} \text{some CompoundMovement or SimpleMovement))} \]

(a compound musical composition is a compound musical documentary work that has compound movements or simple movements as proper parts)

In order to facilitate domain experts in populating and querying the ontology, we include the (object properties) relations movement-of and section-of (and their inverses) under proper-part-of. The former has domain either Simple Movement or Compound Movement, and range Compound Musical Composition; the latter has domain Section and range Compound Musical Documentary Work. In addition, the object property chain in (Ax1) guarantees the propagation of sections from (compound) movements to (compound) musical compositions.

**Ax1** ObjectProperty: sectionOf

\[ \text{SubPropertyChain:} \]

\[ \text{sectionOf o movementOf} \]

For example, the Kyrie movement of des Prez’s Missa Pange lingua has three sections, i.e., Kyrie_1, Christe, and Kyrie_2 (see next section). By means of the property chain, the sections of the Kyrie are sections of the Missa, too. As we will see in Section 5, this kind of reasoning can be useful for querying purposes.

We now introduce the remaining classes shown in Figure 2, i.e., Anthological Documentary Work and Anthological Musical Documentary Work, which is subsumed by the former and is explicitly introduced for the musical domain. As the labels suggest, these classes model anthologies, i.e., documentary works that are formed by the aggregation of multiple works which are put together according to some unity criteria. An example is Gesualdo’s Madrigali a cinque voci, Libro Quarto. Anthologies can be created according to different modalities. For instance, the Libro Quarto was compiled by the composer (in collaboration with his editor and printer). But even in the years around 1600, pieces by Gesualdo’s contemporaries were often anthologized by printers into anthologies that contained the works of dozens of composers. Following Vellucci [37], it is important to stress that the unity criteria satisfied by an anthological (musical) work is weaker in comparison with the unity criteria satisfied by a compound work. The latter is an integral whole whose components stand in a specific structure which cannot be broken to preserve the identity of the whole work. Differently, the parts forming anthologies are independent and are connected only because, e.g., they were composed by the same artist or were produced in a certain chronological order, among other criteria. The reader can refer to the OWL file for formal characterization of anthologies. For the sake of clarity, it is worth mentioning that the relation has-member further extends proper-part-of and is used to relate anthologies to their members (cf. Section 5).

Before moving to the next section, it is worth spending some words on expressions and items for their relevance in modeling bibliographic information. As said at the beginning of the section, documentary works are created by abstracting from expressions and/or items in order to organize them for cataloging purposes. Recall the ambiguity of FRBR(oo)’s notion of Work with respect to Expression: as ideas, works are entities possibly realized in expressions; as bibliographic entities, they result from organizing multiple expressions under the same heading (cf. Section 3). To avoid FRBR(oo)’s ambiguity and to clearly modeling the relation between expressions and documentary works, on the one hand, we use the relation documented-in (documents for its inverse) holding between Documentary Work and Expression. On the other hand, we borrow from

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30 has-proper-part is the inverse of proper-part-of.
FRBR(oo) the relation named carries between expressions and items.

We present in the next section an example based on the distinctions discussed throughout this section. We will also see the use of some other relations to model data about composers, publishers, or the publication date of expressions.

5. Representing Josquin des Prez’s Missa Pange lingua

We consider in this section the representation of Josquin des Prez’s Missa Pange lingua according to the modeling elements of the ontology. Recall that the Missa was published for the first time in 1539 in the Missae tredecim quatuor vocum (Nuremberg: arte Hieronymi Graphei, 1539), and since then it has appeared in several publications. An example is the Werken van Josquin des Prez, edited by A. Smijers, H. Vinders, B. Appenzeller, and N. Gombert (Amsterdam: Vereniging voor Nederlands Muziekgeschiedenis, 1922-1965), among others. These publications are both examples of anthologies comprising multiple compositions among which the Missa Pange lingua. From a data modeling perspective, musicologists wish to represent the same (documentary) work as being found in multiple anthologies. The notions of documentary work and expression are useful for this goal.

From the previous section, recall that documentary works are abstracted from expressions with the purpose of organizing them. Accordingly, each publication mentioned above is represented as an instance of Expression with specific bibliographical data, see (f1) and (f2). Looking at the formulas, we use the data property published-in, and the object properties published-by, publication-place, and edited-by to represent these data.

\[ \text{Individual: } \text{expression}_\text{arte_Hieronymi_Graphei} \]

\[ \text{Types: } \text{EXPRESSION} \]

\[ \text{Facts: } \text{PUBLISHEDIN} \text{“1539”} \quad \text{rdfs:Literal}, \text{PUBLISHEDBY} \text{arte_Hieronymi_Graphei}, \text{PUBLICATIONPLACE} \text{Nuremberg} \]

By abstracting from the expression we now represent the documentary works, first the Missa and then the anthological works where it is documented. The Missa is formed by five movements, i.e., the Kyrie, Gloria, Credo, Sanctus, and Agnus Dei, see formula (f3). Because of its compound structure, by automatically reasoning over the data through the axioms of the ontology, the Missa is classified as a Compound Musical Documentary Work. Looking at formula (f3), the object property documented-in relates the Missa to its corresponding expressions making sense of the fact the same (documentary) work is found in multiple expressions.

\[ \text{Individual: } \text{Missa}_\text{Pange_lingua} \]

\[ \text{Types: } \text{DOCUMENTARYWORK} \]

\[ \text{Facts: } \text{COMPOSEDBY} \text{Josquin des Prez}, \text{HASMOVEMENT} \text{Kyrie}, \text{HASMOVEMENT} \text{Gloria}, \text{HASMOVEMENT} \text{Credo}, \text{HASMOVEMENT} \text{Sanctus}, \text{HASMOVEMENT} \text{Agnus Dei}, \text{DOCUMENTEDIN} \text{expression}_\text{arte_Hieronymi_Graphei}, \text{DOCUMENTEDIN} \text{expression}_\text{Vereniging_voor_Nederlands_Muziekgeschiedenis} \]

The Kyrie has three sections, namely, Kyrie_1, Christe, and Kyrie_2 (f4). It is therefore an instance of Compound Movement. Similarly for the Sanctus (f5), the Agnus Dei (f6), the Credo (f7), and the Gloria (f8),

\[ ^{22}\text{For simplicity, we sloppily use published-in to model both punctual publishing dates and intervals.} \]

\[ ^{23}\text{By reasoning over the ontology these relations can be derived. They are included here only for the sake of clarity.} \]
which comprise various sections, too. The Missa does not therefore comprise any simple movement.

\[ f4 \] Individual: Kyrie
Types: DOCUMENTARYWORK
Facts:
HASSECTION Kyrie_1,
HASSECTION Christe,
HASSECTION Kyrie_2

\[ f5 \] Individual: Sanctus
Types: DOCUMENTARYWORK
Facts:
HASSECTION Sanctus_section,
HASSECTION Pleni_Sunt,
HASSECTION Osanna,
HASSECTION Benedictus

\[ f6 \] Individual: Agnus_Dei
Types: DOCUMENTARYWORK
Facts:
HASSECTION Agnus_Dei_1,
HASSECTION Agnus_Dei_2

\[ f7 \] Individual: Credo
Types: DOCUMENTARYWORK
Facts:
HASSECTION Patrem_omnipotentem,
HASSECTION Et_incarnatus,
HASSECTION Crucifixus,
HASSECTION Et_in_spiritum

\[ f8 \] Individual: Gloria
Types: DOCUMENTARYWORK
Facts:
HASSECTION Et_in_terra,
HASSECTION Qui_tollis

Finally, formulas (f9) and (f10) represent the anthologies at the work level. In particular, they are two different anthologies, each one documented in a specific expression and each one having the same Missa as member.

\[ f9 \] Individual: anthology_arte
Types: ANHOLOGICALMUSICAL
DOCUMENTARYWORK
Facts:
DOCUMENTEDIN expression_arte
_Hieronymi_Graphei,
HASMEMBER Missa_Pange_lingua

\[ f10 \] Individual: anthology_Vereniging_voor
_Nederlands_Muziekgeschiedenis
Types: ANHOLOGICALMUSICAL
DOCUMENTARYWORK
Facts:
DOCUMENTEDIN expression_Vereniging_voor_Nederlands_Muziekgeschiedenis,
HASMEMBER Missa_Pange_lingua

Figure 3 shows a (partial) graphical representation of the model for the Missa Pange lingua presented in this section (the figure does not show the structure of the Missa).

Fig. 3. Partial view on the relations between the Missa and the corresponding anthologies and expressions.

The following SPARQL queries show some examples about retrieving data from the knowledge base.\[ ^{24} \]

Q1 Retrieve the movements of Missa_Pange_lingua and for each movement its sections, if the latter are present. See results in Table 1.

\[ ^{24} \text{SPARQL queries are performed over an instantiation of the free release of GraphDB (http://graphdb.ontotext.com/, last accessed October 2019). For the sake of shortness, we omit PREFIX statements from the queries.} \]
SELECT * { :Missa_Pange_lingua :HASMOVEMENT ?movement. OPTIONAL {?movement :HASSECTION ?section.}}

Table 1

<table>
<thead>
<tr>
<th>?movement</th>
<th>?section</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kyrie</td>
<td>Kyrie_1</td>
</tr>
<tr>
<td>(same value)</td>
<td>Christe</td>
</tr>
<tr>
<td>(same value)</td>
<td>Kyrie_2</td>
</tr>
<tr>
<td>Sanctus</td>
<td>Benedictus</td>
</tr>
<tr>
<td>(same value)</td>
<td>Osanna</td>
</tr>
<tr>
<td>(same value)</td>
<td>Pleni_Sunt</td>
</tr>
<tr>
<td>(same value)</td>
<td>Sanctus_section</td>
</tr>
<tr>
<td>Agnus_Dei</td>
<td>Agnus_Dei_1</td>
</tr>
<tr>
<td>(same value)</td>
<td>Agnus_Dei_2</td>
</tr>
<tr>
<td>Gloria</td>
<td>Et_in_terra</td>
</tr>
<tr>
<td>(same value)</td>
<td>Qui_tolis</td>
</tr>
<tr>
<td>Credo</td>
<td>Patrem_omnipotentem</td>
</tr>
<tr>
<td>(same value)</td>
<td>Et_incarnatus</td>
</tr>
<tr>
<td>(same value)</td>
<td>Crucifixus</td>
</tr>
<tr>
<td>(same value)</td>
<td>Et_in_spiritum</td>
</tr>
</tbody>
</table>

Table 2

<table>
<thead>
<tr>
<th>?expression</th>
<th>?date</th>
</tr>
</thead>
<tbody>
<tr>
<td>expression_arte_Hieronymi_Graphei</td>
<td>1539</td>
</tr>
<tr>
<td>expression_Vereniging_voor_Nederland_Muziekgeschiedenis</td>
<td>1922-1925</td>
</tr>
</tbody>
</table>

Query (Q1) reflects the way in which data are structured in the knowledge base. By relying on reasoning mechanisms, we could directly retrieve the Missa’s sections without retrieving the corresponding movements.

Q2 Retrieve the expression where the :Missa_Pange_lingua is documented and its publication date. See results in Table 2.

SELECT * { :Missa_Pange_lingua :DOCUMENTEDIN ?expression. ?expression :PUBLISHEDIN ?date}

The results of query (Q2) reflect the axiomatisation of the ontology and the entailment regime of the query engine. The Missa is not indeed directly related to its expressions although this information can be derived from the data via automated reasoning (see the OWL file). In addition, one can easily access all movements and sections of the Missa documented in these expressions. In the same lines, assuming to have multiple publications for the same documentary work, they can be easily retrieved. As said throughout the paper, this shows the usefulness of the unambiguous, formally represented distinction between work and expression, distinction which leads to the capability of navigating through multiple expressions (or even items) about the same documentary work.

Some remarks are due. First, differently from both FRBR(oo) and the ontologies documented in Section 3, our approach ascribes a clear intended semantics to the modeling elements at stake. E.g., it is clear that we represent documentary works for bibliographical modeling, or that a compound composition is a work comprising some movements. Second, our approach has an explicit manner to deal with both the structure of compositions and the structure of anthologies. As shown, this is useful for data organization and information retrieval. Finally, considering the example presented in this section, note that each anthology corresponds to a separate expression. Since the anthologies have been edited by different editors and published in different years, the two expressions cannot be indeed identified. Despite this, the same Missa-work is documented in the two expressions. Alternatively, one could distinguish between two different Missa-works, one for each expression. This second approach is adopted in FRBRoo through the notion of F14 Individual Work. In our understanding, it is challenging to convey to a unique, definitive solution for representing multiple editions. The identity of works with respect to expressions is hotly debated [24] and different domains (e.g., music vs. literary studies) likely require different solutions. In comparison to FRBRoo, our approach allows to avoid associating a work to each expression and it avoids in this way the inevitable duplication of data required by FRBRoo. However, it has to be clear that our ontology does not prescribe a rigid approach to model alternative editions and each user can rely on the solution that better suits with his/her assumptions and modeling requirements.
6. Discussion and conclusions

We presented throughout the paper some important conceptual flaws of FRBR(oo) that unfortunately affect the foundations of existing ontologies for musical data management and knowledge representation. Since FRBR(oo) are recurrently used across the Semantic Web and Linked Open Data communities, we think it is important to take a critical stance and promoting their revision. From this perspective, we discussed an alternative approach based on the notion of documentary work. Some final remarks are needed.

First, as stressed by Smiraglia [33], Vellucci [37], Riley [30], Pietras and Robinson [25] among others, the definition of Work has been recurrently debated. Treitler [36], for instance, addresses the problem from both a historical and cultural perspective, noting that it is hard to convey to a unique definition of Work fitting the complexity of all musical forms, genres or historical periods. In Smiraglia’s words [33], “[...] works are artifacts of the cultures from which they arise”. These considerations have motivated our departure from a pure theoretical stance on the intended meaning of Work, adopting instead a notion relative to the cataloging domain. This is a relevant move in our understanding because, for data organization purposes, it takes an instrumental view required for computer science applications to music.

Second, our approach departs from FRBR(oo) while sharing at the same time some (high-level) commonalities, above all, the triple Work-Expression-Item. More specifically, we stressed in Section 3 the ambiguities of the modeling elements (F1) Work, F15 Complex Work, and F16 Container Work. In our proposal, we rule out the interpretation of documentary works as ideas. Second, we distinguish and formally characterise the structure of different types of works. In particular, we distinguish between (i) compound works whose movements (and sections) form integral wholes, e.g., symphonies or masses; and (ii)anthological works whose members are intentionally aggregated to satisfy some unity criteria related to, e.g., genre resemblance or authorship. The distinctions between these notions, which are useful to model documentary musical data, are either blurred in F15 Complex Work or only scarcely modelled via F16 Container Work.

Third, differently from existing research efforts, our contribution takes the benefits of the formal semantics of OWL to automatically reason over knowledge and data. The MEI XML schema, for instance, covers elements and relations to represent the structure of musical works (see, e.g., componentList, relationList), among which part-of relations. By relying on a pure XML encoding, however, the formal semantics of these elements can not be automatically verified, nor automated reasoners can be used for inferencing purposes. In addition, differently from our ontology, the MEI schema does not include explicit relations to structure a musical work into movements or sections. Despite the differences, the two representations are however orthogonal; e.g., data extracted from MEI files could be organized via the ontology; then, reasoning mechanisms could be employed to infer new knowledge on the data or check their intended meaning. For this purpose to be achieved future work is required to strengthen our proposal and matching specific application requirements.

Concluding, it is important to stress that our contribution is preliminary and given the complexity of music there is no surprise that further work is needed. From a foundational perspective it is necessary to cover modeling elements to explicitly represent (meta) data on derivations or performances of musical works (cf., e.g., [29]), as well as to further characterize the elements that are already present in the ontology. Also, it is necessary to investigate the representation of alternative musical editions in order to get a mature approach. From an application stance it is desirable to align our ontology to existing resources (e.g., CIDOC, CRM, FOAF, etc.) and vocabularies, or possibly even reuse (portions of) existing ontologies. In this sense, the establishment of a research community working on common (or at least integrable) Semantic Web and Linked Open Data resources for music is a desiderata to better support scholars research efforts and data sharing on the LOD cloud.

References


26https://music-encoding.org/guidelines/v4/content/metadata.html, last accessed October 2019.
E.M. Sanfilippo et al. / Prelude for an ontology of documentary musical data


