

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

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1 by both researchers, stakeholders, and the public. With
 2 bibliographical data we mean the description of (origi-
 3 nal, transcribed, etc.) musical scores that are typically
 4 found in archives and libraries. In particular, we ad-
 5 dress the representation of musical data about the fif-
 6 teenth and sixteenth centuries in order to provide a
 7 description of early music that reflects musicologists’
 8 views and the modeling needs related to their research.
 9 For example, the fact that a musical composition was
 10 first published in the sixteenth century and since then
 11 multiple editions appeared with some variations from
 12 each other. We therefore need a way to describe a com-
 13 position, its structure, the relations to the various edi-
 14 tions in which it is published, among other data.

15 In the context of this research, the Functional
 16 Requirements for Bibliographic Records (FRBR)¹
 17 [23] and its object-oriented version (FRBRoo)² [4]
 18 are widely used. One of the reasons is likely that
 19 FRBR(oo)³ make a useful distinction between (at
 20 least) three relevant entities for cataloging, i.e., *Work*,
 21 *Expression*, and *Item*. These are meant to capture the
 22 representation of musical compositions (or literary
 23 works) from different abstraction levels. For example,
 24 one may need to model multiple digital files (*Item*) or
 25 musical scores (*Expression*) referring to the same com-
 26 position (*Work*). *Item* can therefore be used to cover
 27 physical books or digital files; *Expression* to model the
 28 text or musical score found in various items; *Work* to
 29 capture musical compositions *per se*. Unfortunately,
 30 apart from these general intuitions, the way in which
 31 these elements are understood and related remains
 32 highly ambiguous. This has created some confusion in
 33 the literature and nowadays the use of FRBR(oo) re-
 34 lies either on common practices for circumventing its
 35 drawbacks or the tacit adoption of its ambiguities (see
 36 Section 3).

37 The paper presents some preliminary considera-
 38 tions on the ontological representation of bibliograph-
 39 ical musical data for scholarly purposes. In contrast
 40 to previous scholarship that focused on specific tasks
 41 or computational techniques (e.g., [21, 31]), our goal
 42 has a foundational flavor. By reviewing the core con-
 43 cepts of FRBR(oo) we propose an alternative approach
 44 which avoids FRBR(oo) ambiguities while keeping the
 45 benefit of distinguishing between works, expressions,
 46

47 ¹<https://www.ifla.org>, last accessed October 2019.

48 ²<https://www.ifla.org/publications/node/11240>, last accessed Oc-
 49 tober 2019

50 ³We use the notation FRBR(oo) to mean both FRBR and FR-
 51 BRoo.

1 and items. Following Guarino [10], this first analytic
 2 step is in our view necessary to support the develop-
 3 ment of well-designed computer applications, which
 4 are able to represent experts’ viewpoints and handle
 5 data in a transparent way. In addition, we exploit the
 6 reasoning capabilities of the Web Ontology Language
 7 (OWL) [14] to support the development and mainte-
 8 nance of a (logically) consistent knowledge base and
 9 to infer new knowledge on the data.

10 The paper is structured as follows. In Section 2 we
 11 review FRBR(oo) by stressing their pros and cons.
 12 Section 3 reports on existing ontologies for musical
 13 data management. Given the broad spectrum of re-
 14 sources nowadays available and the focus of our re-
 15 search, we consider ontologies that explicitly rely on
 16 FRBR(oo). On the basis of this review, Section 4
 17 presents a preliminary ontology for modeling bibli-
 18 ographical musical data that departs from FRBR(oo)
 19 and allows to (automatically) reason over formally en-
 20 coded knowledge. Section 5 shows an example based
 21 on the ontology, while Section 6 concludes the paper
 22 and discusses the need for future work.

23 2. The Functional Requirements for Bibliographic 24 Records (FRBR)

25 Both FRBR and FRBRoo are widely used across re-
 26 sources for musical data modeling (cf. Section 3). We
 27 review in this section some of the core FRBR(oo)’s
 28 modeling elements; by addressing their shortcomings,
 29 we stress the need for an alternative approach.

30 2.1. *Work and Expression*

31 According to FRBR’s documentation [23], a work is
 32 “a distinct intellectual or artistic creation” [23, p.17].
 33 The documentation adds that “[w]e recognize the work
 34 through individual realizations or expressions of the
 35 work, but the work itself exists only in the commonal-
 36 ity of content between and among the various expres-
 37 sions of the work. When we speak of Homer’s *Iliad* as
 38 a work, our point of reference is not a particular recita-
 39 tion or text of the work, but the intellectual creation
 40 that lies behind all the various expressions of the work”
 41 [23, p.17]. The quote suggests that *Work* is introduced
 42 in FRBR for practical cataloging purposes, e.g., to fa-
 43 cilitate the grouping of multiple scores under a com-
 44 mon heading. Quoting again from [23], “the name we
 45 give to [a] work serves as the name of the entire set or
 46 group of expressions that are realizations of the same
 47
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 50
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1 intellectual or artistic creation (e.g., *Lancelot du Lac*).
 2 It is the entity defined as work, therefore, that provides
 3 us with this grouping capability” [23, p.19]. Similar
 4 considerations are expressed in [26]. In this case the
 5 author argues that “the entity work [in FRBR] repre-
 6 sents an abstract concept. [...] The work is recogniz-
 7 able because we have [...] performances and publica-
 8 tions. If anything, [a work] is what all those perfor-
 9 mances and publications have in common” [26, p.16].
 10 This concept seems reasonable at first glance. But once
 11 we start to consider the definition of *Work* in relation
 12 to *Expression*, things become profoundly puzzling.

13 Following [23], an expression is “the intellectual
 14 or artistic realization of a work in the form of alpha-
 15 numeric, musical, or choreographic notation, sound,
 16 image, object, movement, etc., or any combination of
 17 such forms. An expression is the specific intellectual or
 18 artistic form that a work takes *each time it is realized*”
 19 [23, p.19] (emphasis is ours). As this passage suggests,
 20 works are not necessarily realized in expressions. This
 21 overturns the meaning of *Work* previously introduced.
 22 The passages above suggest indeed that works are cre-
 23 ated only *a posteriori* by abstracting from, e.g., expres-
 24 sions for cataloging purposes. Differently, the defini-
 25 tion of *Expression* assumes that works are not neces-
 26 sarily realized suggesting that works are not created
 27 by abstracting from expressions and could even pre-
 28 exist expressions. This view in turn now takes us from
 29 a problem of data modeling to one of the genesis of
 30 artistic work. The idea that works precede their expres-
 31 sions is a Romantic one indeed, aligning as it does with
 32 ideas of genius, inspiration, and the Ideal Work.⁴

33 The ambiguity on the nature of works becomes evi-
 34 dent in FRBRoo’s documentation. Following [4], “an
 35 instance of F1 Work begins to exist from the very mo-
 36 ment an individual has the initial idea that triggers a
 37 creative process in his or her mind. [...] Unless a cre-
 38 ator leaves at least one physical sketch for his or her
 39 work, the very existence of that instance of F1 Work
 40 goes unnoticed, and there is nothing to be catalogued”
 41 [4, p.27]. This view is unfortunate: first, if works are
 42 introduced to classify expressions, it cannot be the case
 43 that their existence precedes the existence of expres-
 44 sions or that works exist without expressions; second,
 45 it is unclear whether FRBR(oo) distinguish between a
 46 work and its originating idea(s). This issue has gener-
 47 ated confusion in the literature. In [34], for instance,
 48

49
 50 ⁴The reader can refer to [2] for further readings on the ideal nature
 51 of works.

1 an example of work – in FRBR sense – is “the ideas in
 2 Lewis Carroll’s head concerning Alice’s Adventures in
 3 Wonderland” (see [3, 7] for similar interpretations).

4 It should be clear that two different interpretations
 5 of *Work* are at play: the first one, according to which a
 6 work is a cataloging entity; the second one, for which
 7 a work is an idea in someone’s mind. These two inter-
 8 pretations cannot be confused and need to be care-
 9 fully distinguished if one aims at modeling data in a
 10 transparent way. Before moving to the next section,
 11 it is worth mentioning that according to Riley [30],
 12 FRBR’s idea of works as entities pre-existing expres-
 13 sions runs the risk of underestimating the musical do-
 14 main. Riley argues indeed that FRBR *Work* is not capa-
 15 ble of making sense of improvisations or musical tra-
 16 ditions for which there is not a clear composition event
 17 leading to a work that is eventually realized in a per-
 18 formance.

2.2. The structure of works in FRBRoo

22 The development of FRBRoo [4] brought various
 23 changes in FRBR, among which the distinction be-
 24 tween the classes *F14 Individual Work*, *F15 Complex*
 25 *Work*, and *F16 Container Work*, all subsumed by the
 26 more general *F1 Work*, see Figure 1.⁵

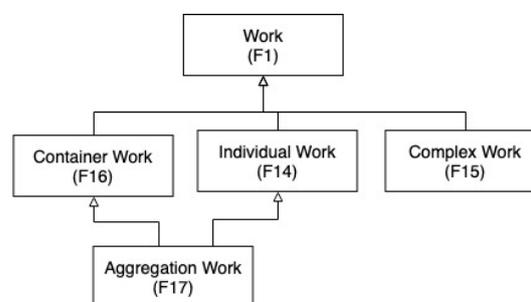


Fig. 1. Partial view on the taxonomy of works in FRBRoo.

40 Following [4], *F14 Individual Work* “comprises
 41 works that are realised by one and only one self-
 42 contained expression, i.e., works representing the con-
 43 cept as expressed by precisely this expression” [4,
 44 p.63]. Differently, *F15 Complex Work* “comprises
 45 works that have other works as members. The mem-
 46 bers of a Complex Work may constitute alternatives to,
 47 derivatives to, or self-contained components of other
 48 members of the same Complex Work” [4, p.63]. The
 49

50 ⁵The taxonomy of FRBRoo includes also *F21 Recording Work*
 51 and other classes, which are not considered here.

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 CRM⁶ [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.⁷ 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

⁶<http://www.cidoc-crm.org/>, last accessed October 2019.

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.

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 FRBRoo 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. FRBRoo-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 FRBRoo, we focus on existing ontologies where the reuse of FRBRoo is explicitly documented. The reader can refer to [8, 17, 21, 28, 39]

1 for further readings on Semantic Web or Linked Open
2 Data approaches for music.

3 The Music Ontology⁸ [27] is a vocabulary to pub-
4 lish and link a broad range of musical data on Web
5 sources. Besides FRBR, it is based on the Timeline
6 ontology, the Event ontology, and Friend of a Friend
7 (FOAF). It covers many different types of entities, in-
8 cluding data about the workflow of music creation,
9 performing events happening in specific places at a
10 certain time, musical instruments, application systems
11 to share music files (e.g., torrent), and e-commerce
12 platforms, among others. The class *Musical Work* ex-
13 tends FRBR's *Work* and it is further specialized in
14 *Movement*, whose instances are self-contained parts
15 of a musical work. With respect to our research, the
16 Music Ontology's scope is wider; e.g., we do not at-
17 tempt at representing marketing or data about pop mu-
18 sic bands. As said, our application focus is on the fif-
19 teenth and sixteenth centuries music and, in particu-
20 lar, on data relevant for scholarly needs. From this per-
21 spective, the Music Ontology does not cover model-
22 ing elements to describe the structure of compositions
23 besides movements which is fundamental for our re-
24 search (cf. Section 4). Also, it relies only on a superfi-
25 cial reuse of FRBR without considering the conceptual
26 and modeling ambiguities that we discussed in Section
27 2. E.g., when using a class like *Musical Work*, it re-
28 mains unclear to which individuals it refers.

29 Doremus⁹ [1, 7] is a project supported by the
30 French National Agency for Research (ANR) involv-
31 ing some of the major French institutions in the cul-
32 tural and musical landscape like the Bibliothèque na-
33 tionale de France (BnF), the Philharmonie de Paris,
34 and Radio France. One of its objectives is to integrate
35 multiple datasets produced and maintained by differ-
36 ent institutions and to make them available through
37 Web resources. For this goal the DOREMUS ontol-
38 ogy¹⁰ has been created by extending both CIDOC-
39 CRM and FRBR(oo). It is not therefore surprising
40 that the ontology heavily relies on the triple Work-
41 Expression-Item. Similarly to the Music Ontology,
42 however, FRBR(oo)'s ambiguities are not analyzed in
43 DOREMUS, a choice leading to confusing claims. For
44 instance, Choffeé and Leresche [7] understand a work
45 as a general entity grouping multiple expressions. Dif-
46 ferently, in a later publication on the same project,
47

1 Achichi et al. [1] define a work as “the abstract in-
2 tention of the author”. It clear that these two inter-
3 pretations reflect the ambiguities in FRBR(oo), although
4 they are neither discussed nor analyzed by [1, 7].

5 Finally, the Music Encoding Initiative (MEI),¹¹
6 which provides an XML encoding of musical data
7 (durations, pitches, etc.), adopts some of the basic
8 elements of FRBR.¹² Similarly to the Music Ontol-
9 ogy and Doremus, the MEI schema does not dig into
10 the conceptual analysis of FRBR and it superficially
11 adopts the interpretation of *Work* as “a distinct in-
12 tellectual or artistic creation” without attempting any
13 clarification of FRBR.

14 To conclude, on the one hand, it is clear that adopt-
15 ing the basic modeling distinctions of FRBR(oo) is
16 valuable for musical data modeling. On the other hand,
17 however, existing resources like the ones considered in
18 this section either do not recognize FRBR(oo)'s ambi-
19 guities, a choice leading to unclear modeling assump-
20 tions, or circumvent such ambiguities with generic
21 claims. As said in the Introduction, we take a dif-
22 ferent approach aimed at grounding the conceptual
23 foundations of ontological modeling for music cata-
24 logging in order to foster the development of transparent
25 knowledge-based models. We present in the next sec-
26 tion a way to deal with FRBR(oo)'s issues while keep-
27 ing the cut-off distinction between works, expressions,
28 and items.

4. Ontological modeling of documentary works

31 The proposal presented in this section departs from
32 FRBR(oo) and builds on library science approaches for
33 the modeling of what we call *documentary work*. We
34 present our proposal throughout this section, while fur-
35 ther commenting in Section 6 on the distinctions (and
36 similarities) with FRBR(oo) and the MEI schema.

37 Following [30, 32, 33], a documentary work is a
38 conventional entity that is intentionally created for cat-
39 aloging purposes, namely, to organize, store, and re-
40 trieve data, among other applications. A documentary
41 work is therefore created *a posteriori* by abstracting
42 from specific and possibly multiple expressions (e.g.,
43 musical scores, editions, sketches) or items (e.g., the
44 individual physical score of Beethoven's *Symphony*
45
46
47

48 ⁸<http://musicontology.com>, last accessed October 2019.

49 ⁹<https://www.doremus.org>, last accessed October 2019.

50 ¹⁰[https://raw.githubusercontent.com/DOREMUS-ANR/
51 doremus-ontology/master/doremus.ttl](https://raw.githubusercontent.com/DOREMUS-ANR/doremus-ontology/master/doremus.ttl), last accessed October 2019.

49 ¹¹<https://music-encoding.org/>, last accessed October 2019.

50 ¹²[https://music-encoding.org/guidelines/v4/content/metadata.
51 html#FRBRentities](https://music-encoding.org/guidelines/v4/content/metadata.html#FRBRentities), last accessed October 2019.

1 *No. 9* which is archived at the library of the University
2 of Tours).

3 In order to provide an ontology for the classification
4 of bibliographical entities, we distinguish between dif-
5 ferent classes of documentary work (see Figure 2).¹³
6 Given the scope of the paper, we focus on the musi-
7 cal domain although in some important respects the
8 notions detailed here could also easily be applied to
9 other domains and especially the performing arts. Be-
10 fore presenting the taxonomy, it is worth stressing that
11 its organization reflects the way in which musical com-
12 positions are formed, e.g., a mass composition as being
13 formed by various movements and sections.

14 Looking at Figure 2, *Documentary Work* is the
15 most general class of the taxonomy subsuming *Sim-*
16 *ple Documentary Work* and *Non-Simple Documen-*
17 *tary Work*, these two classes being disjoint from each
18 other. *Simple Documentary Work* models documentary
19 works that are not further decomposable, i.e., they are
20 the simplest units. Differently, as the label suggests,
21 *Non-Simple Documentary Work* refers to documentary
22 works comprising other works as parts. It should be
23 clear that it is a matter of modeling choice or domain
24 conceptualization to decide which entities are simple
25 and non-decomposable. What is relevant is that these
26 simplest entities, first, play a role for cataloging pur-
27 poses and, second, have some *authorial status*, i.e.,
28 they are not simply fragments designated by a critic
29 or analyst. Considering the example of masses, these
30 consist of various movements, which are sometimes
31 formed by sectional or formal divisions that the com-
32 poser built into the piece. These (authorial) sections,
33 however, are themselves never divided in this way (see
34 below for further comments on sections).

35 Looking back at Figure 2, both *Simple-* and *Non-*
36 *Simple Documentary Work* are specialized into vari-
37 ous subclasses. To better understand the taxonomy, re-
38 call that the components (i.e., movements or sections)
39 of musical compositions in the Western tradition are
40 defined by textual, dramatic, ritual, or purely musical
41 boundaries. In the context of performances, an over-
42 ture, aria, Credo, or minuet are often (but not always)
43 separated by silence (or even applause).¹⁴ In scores or
44

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

49 ¹⁴An example of musical composition including movements that
50 are often played without breaks is Beethoven's *Symphony No.6*. The
51 last three movements of the *Symphony* are clearly marked in the
score but they are often performed without any break.

1 other documentary representations, the boundaries be-
2 tween the various components of a composition are
3 marked by changes in graphical separation devices
4 (e.g., double barline, line break), but also changes in
5 things such as key, meter, performing forces, or even
6 paratextual markers as tempo or genre designation
7 (“allegro ma non troppo,” “gavotte”). In each case, as
8 said, the components of a composition are not frag-
9 ments designated for analytic purposes; rather, they
10 are intentionally created by composers to structure the
11 composition in a certain way.

12 On the basis of these considerations and coming
13 back to the taxonomy, *Simple Documentary Work*
14 subsumes the primitive *Simple Musical Documentary*
15 *Work* to explicitly capture musical data.¹⁵ This class
16 is extended into *Simple Movement*, *Section*, and *Sim-*
17 *ple Musical Composition*. Similarly, *Non-Simple Doc-*
18 *umentary Work* specializes in *Compound Documen-*
19 *tary Work* and *Anthological Documentary Work*, each
20 class being specialized to the musical domain (see Fig-
21 ure 2). We first focus on *Simple Musical Documentary*
22 *Work* and *Compound Musical Documentary Work*, and
23 we then introduce the remaining classes.

24 The first important distinction is between *Sim-*
25 *ple Movement* and *Compound Movement*. Differently
26 from instances of the former, instances of the latter
27 are musical movements that are structurally formed
28 by various sections. Therefore, sections – represented
29 by the *Section* class – are the smallest (bibliographic)
30 units of musical compositions having authorial status;
31 as said, they are not simply fragments.¹⁶

32 The second distinction is between *Simple Musical*
33 *Composition* and *Compound Musical Composition*. In-
34 stances of the latter are formed by (simple or com-
35 pound) movements and can therefore have sections,
36 too. Differently, instances of the former are simple
37 in the sense of comprising neither movements nor
38 sections. An example of *Simple Musical Composi-*
39 *tion* is William Byrd's *Praeludium*; an example of
40 *Compound Musical Composition* is Josquin des Prez's
41 *Missa Pange lingua* (see Section 5).

42 In order to formally represent simple and non-
43 simple documentary works and therefore to character-
44

46 ¹⁵When needed for applications, other classes could be added,
47 e.g., to represent (simple) literary works.

48 ¹⁶If required by modeling needs, one could easily introduce a no-
49 tion for, e.g., compound sections which are formed by further doc-
50 umentary musical works. The distinction between movements and
51 sections suggests that the musical works in our application domain
are sufficiently precisely segmented in two lower subdivisions.

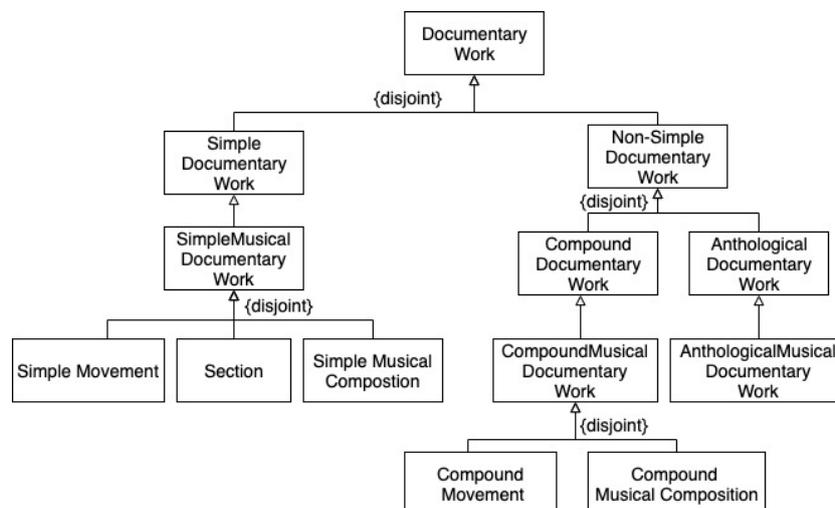


Fig. 2. Taxonomy of documentary works for music.

ize (or define) the structure of musical compositions we rely on the (mereological) relation of *proper-part-of* [6].¹⁷ 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.¹⁸

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.

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

Using the OWL Manchester syntax [15], *Section* and *SimpleMovement* are defined in (Def1) and (Def2), respectively.¹⁹

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

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
 EquivalentTo:
 COMPOUNDMUSICALDOCUMENTARYWORK
 and (HASPROPERPART²⁰ some SECTION)
 and (PROPERPARTOF 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
 EquivalentTo:
 COMPOUNDMUSICALDOCUMENTARYWORK
 and (HASPROPERPART 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
 SubPropertyChain :
 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

²⁰*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 *Missa 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.²¹

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.

```

f1 Individual:
    expression_arte_Hieronym_Graphei
Types :
    EXPRESSION
Facts :
    PUBLISHEDIN "1539" ^^rdfs:Literal,
    PUBLISHEDBY arte_Hieronymi_Graphei,
    PUBLICATIONPLACE Nuremberg

```

²¹We do not represent items in this example; they can be easily added in the knowledge base.

```

f2 Individual:
    expression_Vereniging_voor_Nederlands
        _Muziekgeschiedenis
Types :
    EXPRESSION
Facts :
    EDITEDBY A. Smijers,
    PUBLISHEDIN
        "1922-1965" ^^rdfs:Literal,22
    PUBLISHEDBY Vereniging_voor
        Nederlands_Muziekgeschiedenis,
    PUBLICATIONPLACE Amsterdam

```

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.²³

```

f3 Individual: Missa_Pange_lingua
Types :
    DOCUMENTARYWORK
Facts:
    COMPOSEDBY Josquin des Prez,
    HASMOVEMENT Kyrie,
    HASMOVEMENT Gloria,
    HASMOVEMENT Credo,
    HASMOVEMENT Sanctus,
    HASMOVEMENT Agnus_Dei
    DOCUMENTEDIN expression_arte
        _Hieronymi_Graphei,
    DOCUMENTEDIN expression_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),

²²For simplicity, we sloppily use *published-in* to model both punctual publishing dates and intervals.

²³By 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_spiritus

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

_Hieronymi_Graphei

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*).

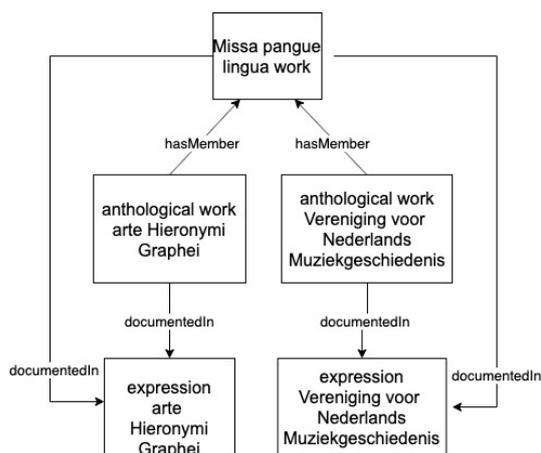


Fig. 3. Partial view on the relations between the *Missa* and the corresponding anthologies and expressions.

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.

²⁴SPARQL 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.

```

1 SELECT * { :Missa_Pange_lingua
2 :HASMOVEMENT ?movement.
3 OPTIONAL { ?movement :HASSECTION
4 ?section. } }

```

Table 1
Result of Query (Q1)

?movement	?section
Kyrie	Kyrie_1
(same value)	Christe
(same value)	Kyrie_2
Sanctus	Benedictus
(same value)	Osanna
(same value)	Pleni_Sunt
(same value)	Sanctus_section
Agnus_Dei	Agnus_Dei_1
(same value)	Agnus_Dei_2
Gloria	Et_in_terra
(same value)	Qui_tollis
Credo	Patrem_omnipotentem
(same value)	Et_incarnatus
(same value)	Crucifixus
(same value)	Et_in_spiritus

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.²⁵ See results in Table 2.

```

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

```

Table 2
Result of Query (Q2)

?expression	?date
expression_arte_Hieronymi_Graphei	1539
expression_Vereniging_voor_Nederlands_Muziekgeschiedenis	1922-1925

²⁵In the same spirit of (Q2) one can easily retrieve all bibliographic data related to the expressions that are present in the knowledge base.

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`),²⁶ 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 inferring 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.

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²⁶<https://music-encoding.org/guidelines/v4/content/metadata.html>, last accessed October 2019.

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