Open Data Management & Cloud Exam Project

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Contents

Project notes

TODO:

- placeTypeType, artistTypeType, address type;
- check UML cardinality;
- data models for discovery;
- more details on the preservation section;
- sort names;
- possible expansion to deal with images;
- standard for archiving: WAW 96khz, 24bit or FLAC, with MP3 download;

Introduction

Aim: Investigation of (long term) audio file archiving for music + prototyped data model design and implementation.

Data resource: audio files, probably different formats, encodings, metadata content (anche dentro il file id3). **Concepts Contents**

Discovery Access Interoperability

Aim of the project

On the lack of a metadata standard for audio files: EBUcore

- EBUcore (based on Dublin Core).

Data Model: design

What should the data model be able to represent?

A model for audio data resources should be able to represent songs (and their possible different versions) and their groupings (in albums, compilations or other releases). Moreover, it should model authoring for artists (singers and lyricists) and other professional figures such as music producers. The model should handle technical metadata as well. Additionally, relations between different classes (e.g., a work is part of another work, two artists cooperated for a release) should be handeld as well.

A more detailed description of the model entities/classes

The proposed model consists of the following four main classes:

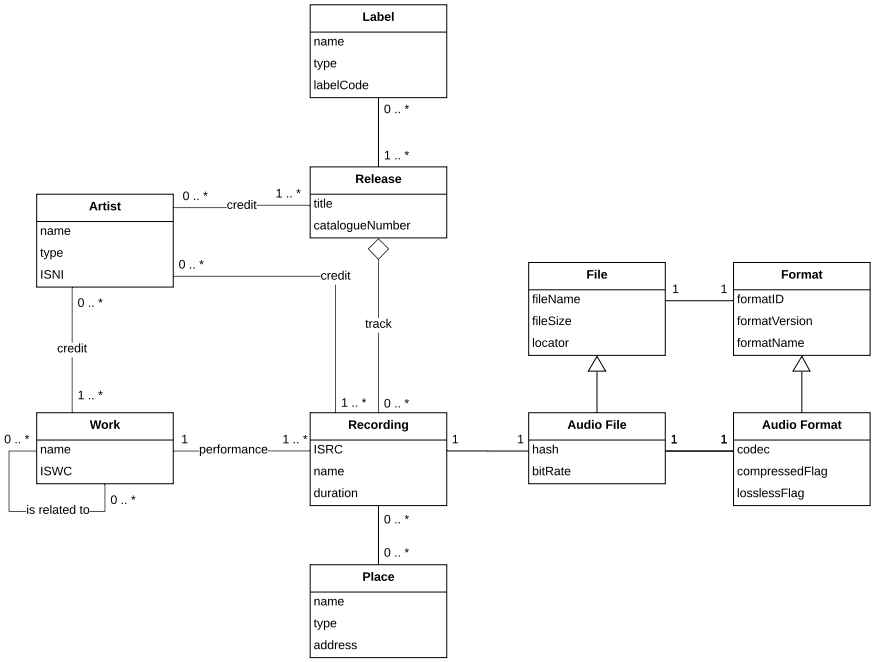
- The smallest object (in terms of granularity) is a **recording**, which represents a uniquely identifiable version of a song, that is the actual audio data. ISRC is a standard identifier for *sound recordings* and can be associated to each recording. A recording has title, ISRC, duration, artist credit and a link to the physical data resource (the audio file). Additional technical metadata for the data resource can be provided.
- Different recordings of the same song refer to the same **work**, which embeds all the different versions of a song. It represents the intellectual creation and can be put in relation to different recordings, different artists or other works. ISWC is a standard identifier for *musical works/compositions* and can be associated to each work. A work has name, ISWC and links to correlated works/artists/records.
- Commercial issues of works are grouped into a **release**. Each release contains a track-list for the recordings it contains and has a title, an artist, information about the label and a form of identification (e.g., a catalogue number provided by the label).
- The paternity of works belongs to **artists**, which represent single musicians, groups of musicians or other professional figures (e.g., producers, lyricists, sound engineers). ISNI is a standard identifier for public entities of contribution to media content and can be associated to each artist. Artists have name, type and ISNI.

Additionally, the following secondary classes are defined:

- **File**. Base class for all the files. A file has name, size and a locator (that is, a link to the actual resource).
  - **Audio File**. Adds file details for audio files, has a hash and a bitrate.
- **Format**. Base class for format metadata. A format has ID, version and name.
  - **Audio Format**. Adds format metadata details for audio files, has codec, compression flag and lossless flag.
- **Label**. Holds information about imprints and record companies that take part in the production and distribution of a release. Label can uniquely identified by their label code.
- **Place**. Specifies the place where music is performed, recorded, mixed, etc.

UML model

In the following model square endpoints denote aggregation and arrow endpoints denote inheritance.



The proposed design assumes each recording, work and release to be associated with a credited artist (i.e., their participation to the *credit* relationship is total). This assumption can be satisfied defining special purpose artists to deal with unknown authors, traditional songs, etc.

Data Model: implementation

Choice of implementation

Concerning available implementation choices for the proposed model, two macro-alternatives have been taken into account: relational databases (RDB) and XML databases.

Relational databases offer a trivial way to enforce constraints between entities using primary keys and foreign keys. For instance, this would allow to properly model the constraints between releases and artists (i.e., a release cannot be credited to an artist whose name is not present in the "artist" relation). Additionally, indexing is easily supported and RDBs have a widespread use. Moreover, RDBs handle many-to-many and many-to-one relationships with ease (consider the artist-release and the work-recording relationships). However, relational databases manifest a reduced flexibility due to their strict integrity constraints

and, once instantiated, are moderately difficult to expand.

On the other hand, XML databases (document-based databases in general) are meant to be a more flexible means to store data, integrity not being their first concern. For a given XML schema, an XML documents can usually contain partial/incomplete information. This is appealing for the task at hand since not all the metadata for a given release may be available. However, many-to-many and many-to-one relationships are harder to handle.

For this particular project, flexibility has been privileged: the model implementation will consists in a XML schema definition (XSD). It should be noted that a PostgreSQL implementation for a similar base model is provided by MusicBrainz, a collaborative music metadata project.

XSD

An implementation of the proposed model can result in XSDs with varying degrees of flexibility. EBUcore XSD provides extreme flexibility and can handle both audio and visual broadcasting resources. Such great flexibility (a necessity, given the wide range of resources EBUcore is able to descrive) is deemed not to provide enough structure for this particular project. At the opposite side of the spectrum a strictly hierarchical XSD, where each document must contain "releases" made of "recordings", might lead to a overly strict model implementation (in this case, a RDB implementation would provably serve the aim of this project better).

Drawing from the considerations of the previous paragraph, the proposed XSD should:

- Provide, where possible, a refinement of the Dublin Core elements, aiming for interoperability;
- Find a balance between a hierarchic structure and the possibility ti accept "partial" entries (e.g., a document that contains only an artist must be handled by the XSD);
- Handle relationships between different elements with reasonable detail.

The resulting XML schema will now be discussed.

On relationships

The UML model presents several many-to-many and many-to-one relationships which have been implemented with different approaches:

- Recording-Place and Release-Label (many-to-many). This relationship has been simplified by defining a Place/Label to be one of the elements of a Recording/Release. This reduces expressiveness: Places and Labels cannot be stand-alone entities. This solution is acceptable since Places and Labels are secondary entities.

- Recording-Audio File (one-to-one). Each Recording is forced to have exactly one Audio File element (using `minOccurs="1"` and `maxOccurs="1"`). The other constraint is enforced by the existence and uniqueness of a `fileID` attribute.
- Audio File-Audio Format (one-to-many). Each Audio File is forced to have exactly one an Audio Format. Audio Format is not a stand-alone entity.
- Work-Recording (one-to-many). Works have the `hasPerformance` relation element, which links a Work to at least one Recording ISRC. On the other hand, Recordings have the `isPerformanceOf` relation element, which links a Recording to exactly one Work ISWC.
- Work-Work (many-to-many). Works have the `hasRelatedWork` relation element.
- Release-Recording (one-to-many, composition). Releases have the `hasTrack` relation element, which links a Release to at least one Recording ISRC.
- Work-Artist, Recording-Artist and Release-Artist (many-to-many). This relationships have been modelled using the `hasArtist` relation element.

All the constraints (cardinality and participation) have been modelled.

On references (and between different documents)

In EBUCore relations are implemented via REFID and ID. While this choice allows for an easy implementation and provides continuity with DTD, XSD offers a much more flexible KEY/KEYREF syntax: identifiers and references are selected using XPath expressions. Keys and keys references (can) act like the primary and foreign keys of a relational database. Additionally, keys can be multi-field (that is, an item can be identified and referenced using more than one field).

Both ID/IDREF and KEY/KEYREF approaches are flexible enough to describe the relations of the UML model; for presented reasons, the KEY/KEYREF paradigm has been adopted in this schema. It is worth nothing how neither of the approaches allows across-document relations and constraints. XSD integrity constraints are indeed intended for use within a single document. There exist XSD extensions such as W3C's Service Modeling Language or other rule-based validation languages such as Schematron that do handle inter-document constraints: these possibilities have not been addressed.

XML example

The following fragment shows a valid instance of a work. It contains both an `id` to identify the work and an `idref` to reference a related recording. Furthermore, it shows how the `label` and `description` attribute can be used to describe related items.

```
<work>
  <ISWC id="ISWC_T-000.000.000-A"></ISWC>
```

```
  <title lang="en">
    <dc:title>Test Work</dc:title>
  </title>
  <hasArtist label="William Wilson" description="Singer"></hasArtist>
  <hasPerformance label="Test Recording" description="Studio Version">
    <relationIdentifier>
      <ISRC idref="ISRC_AAAAA0000000"></ISRC>
    </relationIdentifier>
  </hasPerformance>
</work>
```

A more extensive XML example document has been provided alongside the XSD.

Interfaces and services

A full fledged service that adopts the prototyped XSD is out of the scope of this project. However, some possible services related to the resource discovery and accessibility will now be discussed.

The two main goals an actual implementation of this project should achieve are: music query (i.e., a music search/download service) and database update (i.e., a service devoted to the addition of new documents to the database). Both this services are related to the data storage, which will be briefly discussed as well.

Data discovery

The most fundamental service an archive should provide is a search/filter service.

In order to make data accessible in the first place, a web service should be implemented. Users should have network access the archive, and the archive web page should be identified by a URL. The filtering service should offer the typical search fields for music queries: users should be able to query authors, works, recordings and releases. Luckily, these usual query fields correspond exactly to the main classes of the presented model. Thus, searching for a specific artist would parse the `artist` elements only. Queries would most probably be free-text queries on the various classes.

On the back end, queries would be carried out using XQuery, a query language built on XPath (and a W3C Recommendation for XML queries). Since the data model is known, and has a reasonably strict structure, simple queries could be trivially implemented. For instance, XPath queries are supported by the `xml.etree.ElementTree` Python module.

Traditional information retrieval techniques could be used to substantially improve the results of a query. First of all, spelling correction techniques could be employed. The *Levenshtein distance* offers a simple approach to spelling

correction: if the query returns no record, and thus the query possibly contains a spelling error, the closest results in terms of number of edit operations are retrieved. A query for "Pink Floid" will probably return no results. However, "Pink Floyd" has a unitary edit distance and will be consequently returned as a result. Alternatives approaches would involve using k-gram distance and the Jaccard coefficient for queries. This simple improvement would certainly favour data discovery. Additionally, a popularity value could be used to rank results: the user would be answered with the most popular (in terms of queries or downloads, for instance) items.

- Filtering service (xml indices suffer from index size and construction costs);

Data access

Once the data has been located, it should be easily accessible via download. The user should be able to separately download different versions (i.e., different file formats) of the same resource, if they are available. Ideally, a preview of the resource should be available as well: users should be able to listen to a certain song in their browser without downloading the file itself. It must be pointed out that this is possible only if the file storage allows sequential access to files. As an additional service, a user might want to download all the songs credited to a certain artist: a mechanism exploiting XPath queries to build on-demand compilations should make this service possible.

Data annotation

In all previous sections of the project a strict division between data and metadata has been enforced. The XSD models the metadata structure which has some references to audio files which are separately handled. However, audio files themselves can and should embed metadata. Unfortunately, no standard metadata container for audio files knows widespread use. What follows focuses on commonly used audio file format; they will addressed again in the interoperability and preservation section.

ID3 (and particularly the extended ID3v2) is the *de facto* standard for Mp3 files, the most common and widely used audio file format. ID3 all the common music metadata tags and can store all the metadata of the proposed model. Additionally, it supports image tags to store album covers and similar content. ID3 was designed specifically for Mp3 files few other formats support it (WAW being one).

XMP (Extensible Metadata Platform) is an ISO standard commonly used in JPEG images

Vorbis for flac

Storage and cloud solutions

- Storage (both XML documents and audio files);
- Cloud;

Interoperability and preservation

- Interoperability;
- **OAIS**: sketch model.

Software and tools used