Knowledge–based Music Recommendations: Models, Algorithms and Exploratory Search

Pasquale Lisena

EURECOM, Sophia Antipolis, France
pasquale.lisena@eurecom.fr

1 Introduction

Classical music is a niche in the world of streaming music services. This niche actually constitutes a super-genre that groups together a multiplicity of different genres – from Gregorian chant to symphony, from ballet to chamber music – and involves artists who play a greater variety of functions than their colleagues in modern music: composers, conductors, instrumentalists, voices, soloists, members of orchestras, etc. Fans of classical music are underrepresented on social media and music streaming platforms [11]. Recommender systems requires special strategies for dealing with this category of music, considering also the huge material of centuries among which selecting relevant items [5]. The research in recommender system and music information retrieval (MIR) for classical music is currently at an early stage, while recently gaining new attention.

My dissertation focuses on classical music, researching how to represent and exploit its information, making use of Semantic Web technologies, Knowledge Graphs Embeddings and Knowledge-based recommender systems.

The remainder of this paper will report the main contribution of this dissertation: the realisation of the DOREMUS Knowledge Graph (KG) and the access of the information of this graph by the final user through exploration and recommendation. Finally, we will report some conclusion and point out future research challenges.

2 DOREMUS: a Classical Music Knowledge Graph

An important part of this dissertation has been dedicated on the realisation of the DOREMUS Knowledge Graph, a specialised dataset in classical music metadata [1]. The ambition of the DOREMUS KG consists in collecting the music information coming from different archives – libraries, concert halls, radio, etc. – and provide access to it through an unified ontology able to represent the full complexity of music information.

In order to overcome the limitation of the popular Music Ontology [10], the DOREMUS model[1] has been developed as extension of FRBRoo, for describing cultural objects [2], exploiting its structure made of Work-Expression-Event

[1] http://data.doremus.org/ontology/

triplets which can in sequence represent the composition, a performance, a publication, the realisation of a derivative work, etc. Such event-based model particularly suits music as time-based art, produced by the interaction of different actors. Together with the ontology, a set of controlled vocabularies in SKOS helps in dealing with multiple languages or alternative labelling – i.e. "sax" and "saxophone", or the French keys "Do majeur" and "Ut majeur". The vocabularies includes also hierarchical and sibling relationships between them – so that the "violin" is a narrower concept with respect to "string", while "gospel" is related to "spiritual". We collected, implemented, and published 23 controlled vocabularies belonging to 18 different categories, among which genres, instruments, and musical keys.

The DOREMUS KG has been populated using `marc2rdf`, an open source prototype we developed for the automatic conversion of MARC bibliographic records to RDF using the DOREMUS ontology [6]. The conversion process relies on explicit expert-defined transfer rules (or mappings) that indicate where in the MARC file to look for what kind of information, providing the corresponding property path in the model as well as useful examples that illustrate each transfer rule. The role of these rules goes beyond being a simple documentation for the MARC records, embedding also information on some librarian practices in the formalisation of the content (format of dates, agreements on the syntax of textual fields, default values if the information is absent). A *string2vocabulary* component performs an automatic mapping of string literals to URIs coming from controlled vocabularies, disambiguating against alternate labels. As additional feature, this component is able to recognise and correct some noise that is present in the source MARC file: this is the case of musical keys declared as genre, or fields for the opus number that contain actually a catalogue number and vice-versa. These cases, together with other typos and mistakes, have been identified thanks to the conversion process and the visualisation of the converted data, supporting the institution which provide the data in they work of updating and correcting constantly their data.

Before the realisation of the KG, a list of questions has been collected from domain experts, which have then been used for evaluating both the model and the KG content. These questions reflect real needs of the institutions and reveal problems that they face daily in the task of selecting information from the database (e.g. concert organisation or broadcast programming) or for supporting librarian and musicologist studies. They can be related to practical use cases (the search of all the scores that suit a particular formation), to musicologist topics (the music of a certain region in a particular historical period), to interesting stats (the works usually performed or published together), or to curious connections between works, performances or artists. Most of the questions are very specific and complex, so that it is very hard to find their answer by simply querying the search engines currently available on the web. Nevertheless, the model and the KG revealed to be flexible enough for providing answers to most of the questions.

3 Exploration and Recommendation

Exploration and recommendation are two sides of the same medal. With the first one, we let the user browse the datasets, discover connections on his own, understand how we build the knowledge. Through recommendation, we remove this responsibility to the user with the purpose of presenting what he needs in a particular moment.

We enable the user to explore the DOREMUS data through Overture, a web exploratory search engine for DOREMUS data[2]. The complexity of music information – and consequently of the DOREMUS ontology – has led us to realise a generic solution for transforming the SPARQL output in a format that is more suitable for its consumption in web applications and not only, published under the name of *SPARQL Transformer* [9, 7]. This library uses the JSON format for describing both the query and the desired output format. Furthermore, the SPARQL bindings are merged on the base of URIs, aggregating the information speaking about the same real-word object. Thanks to merging and parsing capabilities, the result is a more compact data structure respect to the SPARQL standard JSON output. SPARQL Transformer is used in Overture to collect the information from the KG.

The application allows to search for works, performances and publications through a facet-based interface. Once the first element detail is visualised, the user has two options:

- he can explore the links contained in the page – referring to genres, artists, instruments, etc. – and visualise the part of the graph sharing those links, in a *follow-your-nose* approach;
- he can take advantage of the *similar items* tab, which lists some recommendation.

These recommendation are realised on the base of the similarity between graph embeddings, which are generated at different levels:

1. For simple features (e.g. genre, key, instrument), we compute embeddings applying *node2vec* [3] on two sub-graphs: the one of the controlled vocabularies and the one corresponding to the usage of their values in the DOREMUS dataset;
2. For complex features (e.g. artist), we generate the embeddings by the combination of its corresponding feature embedding. In the case of artists, we generate a vector composed of birth and death date, birth and death place, genre, key, and casting (instrument) of his composition, together with the played instrument;
3. Finally, for the work, we combine again simple and complex feature embedding, following the same rules. We take in account composition date, genre, casting, soloist instrument, key, composer.

[2] http://overture.doremus.org/

The biggest advantage of this method is that the embeddings computation is required only for the simple features: each embedding is re-used in different combinations [8]. This system reduces the similarity problem as the reverse of an Euclidean distance, which we can further optimise by adding weights to each dimension.

For this reason, we perform a study of different kinds of editorial playlists – web radio, concert programs, streaming playlists. Our intuition is that there are some hidden rules which are followed in playlist creation and decide which artist or which work should follow another. The weights have been extracted from the variance in the embedding values of works within and between playlists. The results revealed strong differences in the impact of specific features: for example, playlists proposed for streaming generally include works from the same composition period, while web radios diversify more. Domain experts evaluated the system, confirming that such generated weights improve the quality of the recommendation.

4 Conclusion and future directions

With over 420,733 works and 89,872 artists, the DOREMUS Knowledge Graph[3] is the largest dataset of classical music metadata, which is constantly catching the interest of research institutes and other music related projects, among which MusicBrainz. The DOREMUS ontology and the controlled vocabularies are available for being reused, while IFLA endorsed these resource as a de-facto standard for this community. Current adoption limits are related to its structure: it allows to represent fine-grained information, but at cost of an high model complexity. In a future *divide et impera* approach, the information can be stored into different layers, for instance in the new RDF* and SPARQL* syntax [4], in order to obtain a trade-off between keeping queries simple and making the full information available where required.

SPARQL Transformer[4] is already deployed in two communities driven by H2020 projects, and is progressively being adopted by small simple projects, which are clearly the main target of this work. Next effort in producing documentation and tutorial will foster this adoption even towards people with less knowledge in Semantic Web technologies.

Our work about classical music recommendation has shown a way to decompose a graph and re-assemble it as partial embeddings, in a way that can scale up to the huge material coming from centuries of music. This is just a first study in a field that is calling for further research. This can not avoid the collection of a ground truth dataset for classical music recommendation, possibly realised in collaboration with music streaming services. Given the absence of personalisation, an application of the recommender system can be used for assisting editors in the generation of playlists for a broad public. Finally, future research can ad-

[3] http://data.doremus.org
[4] https://github.com/D2KLab/sparql-transformer

dress the cold-start problem of recommenders, taking benefit of the information coming from the graph.

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