Semantics for music researchers: How country is my country?

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Abstract The Linking Open Data cloud contains several music related datasets that hold great potential for enhancing the process of research in the field of Music Information Retrieval (MIR) and which, in turn, can be enriched by MIR results.

We demonstrate a system with several related aims: to enable MIR researchers to utilise these datasets through incorporation in their research systems and workflows; to publish MIR research output on the Semantic Web linked to existing datasets (thereby also increasing the size and applicability of the datasets for use in MIR); and to present MIR research output, with cross-referencing to other linked data sources, for manipulation and evaluation by researchers and re-use within the wider Semantic Web.

By way of example we gather and publish RDF describing signal collections derived from the country of an artist. Genre analysis over these collections and integration of collection and result metadata enables us to ask: "how country is my country?".

1 Background and motivation

Much of the work of researchers in the field of Music Information Retrieval (MIR) focusses on the algorithmic extraction of information from music. However, there are many problems associated with the design and implementation of distributed systems within which such algorithms might be deployed.

We can broadly describe the process an MIR researcher typically follows in three steps; we also highlight some of the issues and, at an abstract level, how linked data and semantic web technologies might assist in building a complete system.

1. **Assemble a collection of audio input.** To evaluate an algorithm, the researcher must acquire a wide selection of "signal" – typically digital audio files – for the algorithm to process. Music recordings are often restricted from free exchange amongst researchers, either explicitly through copyrights or implicitly through the high overheads of managing detailed and intricate licensing. Even when audio data is freely available and distributable

a difficult balance must be found to avoid "over-fitting" of algorithms to a particular set of signals: whilst a widely shared, understood, and re-usable collection is critical for comparative evaluation, tuning an algorithm to such a collection during development (knowing it will be the benchmark) is likely to detrimentally affect performance against more randomly selected input (i.e. real-world tests). It is therefore useful to create and modify large collections of audio data quickly and flexibly which can be shared between researchers for comparative evaluation. Restrictions on the distribution of actual audio files can be accommodated through the separate description of collections and correctly modelling the relationship between artefacts (e.g. distinguishing between a work, a performances of the work, recordings of the performance, and published media of the recording); metadata exchange can then occur independently and be cross-referenced against any institutional or other private archive of audio. Linking existing metadata for audio files and basing collection generation on this information is desirable for quickly trialling an algorithm against particular musical facets (e.g. a particular period and style derived from the composers).

2. **Apply the algorithm to the audio input.** There are many MIR systems which enable an algorithm to be applied to signal. More recently some systems have begun to adopt practices and tools from the scientific workflow community, for example the Meandre workflow enactment system [1]. Any such system must be able to recognise an input collection and apply the algorithm across it. Where institutionally restricted collections of signal are in use a system must match local audio files to any abstract, metadata based, collection descriptions.

3. **Publish and evaluate algorithm output.** The MIR community has a 7 year history of comparative evaluation in the MIREX competition; the most recent (2010) MIREX adopted a Meandre derived framework for executing the algorithms under test [2]. More generally, evaluation of results requires a common structure into which analytic output can be published for comparison, rather than data structures inherited from the development tool or environment a researcher was using. As faster computational resources become more readily available and can be applied to MIR tasks, the opportunity to undertake analysis on an ever greater scale brings with it the associated problems of managing ever greater quantities of result data. Links from results back to recorded signal (and audio file artefacts) and capturing provenance are equally important: an single algorithm is not normally sufficient to make a definitive assertion, e.g. to classify a recording as jazz. For this reason it is important that the representation of results can be used as input for creating derivative collections of input for further MIR analysis such that information extracted from multiple algorithms can be combined and refined.

2 System overview and "Country/country" example

Employing new RDF encodings for collections and results that utilise existing ontologies (including the Music Ontology, GeoNames, Provenance Vocabulary, and OAI-ORE), and by deploying a linked data audio file repository and services for publishing collections and results, we present a proof-of-concept system that addresses the problems outlined in the previous section. While the principles and design described here can be applied to all MIR systems, for demonstration purposes we have developed a specific use case known as "Country/country". In this section we outline the components of the system, which approximately align to the steps in the previous section (with the addition of a pre-step), detailing the generic purpose of each service, followed by the specific implementation in Country/country (*in italics*).

0. An Audio File Repository which serves audio files and linked data about the audio files using HTTP. *For our public demonstrator a subset copy of the free-licensed Jamendo collection*[1] *has been used.* Using the Music Ontology[3], the relationship to the track it is a recording of, and the "definitive" URI for that track (*as minted by the Jamendo linked data service at dbtune*[2]) is asserted in the linked data.

1. A Collection Builder web application that enables a user to publish sets of tracks described using RDF. The backend uses SPARQL to build collections and takes advantage of links between datasets: *e.g. the Jamendo service incorporates links to geographic locations as defined by GeoNames*[3]*, so the Collection Builder can identify all the tracks offered by Jamendo recorded by artists from a specific country.* An optional second stage of collection builder takes a collection and "grounds" the constituent tracks against available recordings of those tracks by posing SPARQL queries to Audio File Repositories. *In the case of Country/country we "ground" a country derived collection against our Audio File Repository of locally available signal.*

2. The Analysis is performed by a NEMA[2] *genre classification* workflow:

- We have extended the myExperiment[4] scientific collaborative environment to support the Meandre[1] workflows used by NEMA.
- myExperiment has also been modified to accept the collections RDF published in step 1) and marshal the target tracks contained within to the analysis workflow.
- Within the (Meandre-based) *genre classification* workflow a head-end component has been written to dereference each track URI passed to the workflow and, using the linked data published by the signal repository, retrieve both the local copy of the audio file and the reference to the *original Jamendo identifier.* This URI persists through the genre analysis workflow until it reaches a new tail-end component where the analysis is published using RDF – including links back to the *Jamendo* URI.

[1] *http://www.jamendo.com/*
[2] *http://dbtune.org/jamendo/*
[3] *http://www.geonames.org/ontology/*

3. **A Results Viewer** web application retrieves the collections RDF from 1) and results RDF from 2), cross-referencing them via the URIs used throughout the system. The user can identify trends in genre classification within and between collections. Results can be pooled and compared using existing and new collections and inform the creation of new sets. To demonstrate how further links can easily be made to existing datasets and inform derivative collection generation, relevant associations from other linked data sets are shown (*e.g. artists of the same genre and country from DBpedia and the BBC for a particular analysed track*).

3 Online demonstrator

The Country/country demonstrator system is available at:
`http://www.nema.ecs.soton.ac.uk/countrycountry/`

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