Contextual interpretation of digital music notation

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Research Objects and scholarship in the digital age

As scientific research practice has grown to include ever greater quantities of data, larger collaborations, and distributed methods, Research Objects (Bechhofer et al, 2013) have been introduced as a means to gather together the context surrounding an investigation and to support its future validation, understanding, and reuse. In many cases these Research Objects build upon the methods, output, and provenance already captured and encoded by workflow systems -- the digital environments in which the science is conducted.

More recently there have been proposals for the use of Research Objects within the digital humanities and musicology (Dreyfus and Rindfleisch 2014; De Roure et al. 2016). Digital editions and annotations of digitally encoded works can be viewed as manifestations of workflows deployed in musicological scholarship, raising the question of how e.g. editorial annotations in a digital score should reference other digital items within the Research Object and vice versa.

For example, a study of the Mariinsky Opera's rendition of Wagner's *Ring* cycle in November 2014 produced a multimedia dataset including audio, annotations made by a musicologist on a short score before the performance (annotations which could be identified a priori from the score such as dynamics, appearances of a leitmotif, etc.), further annotations captured digitally by the musicologist during the live performance (typically staging and interpretive commentary), and free-form text from a digital pen (Page et al.

2016). If the score in use had been a digital edition encoded in MEI (the XML-based Music Encoding Initiative, as reviewed by Crawford and Lewis 2016) how might we reference the musicologist's annotations? Or the other media objects captured and the metadata describing them; existing Linked Data references to Wagner and leitmotifs; and to earlier surveys and studies made by the musicologist on leitmotif interpretation?

Linked notation in support of musicology

Notation examples are a vital part of analytical essays in musicology, helping to illustrate analytical observations and justify hypotheses, arguments and conclusions. They can be excerpts from a score, or custommade notations which add annotations or comments to the original notation.

Furthermore, the presentation of multiple analogous musical extracts for comparison is often required to support a musicological narrative. Paradigmatic analysis, for example, involves passages of music placed one above another such that analogous elements are directly juxtaposed, with gaps left as necessary to ensure that vertical alignment is preserved. Stacked presentation of different scores or different parts of the same score have been used for well over a century, but they quickly become unwieldy and hard to interpret, especially as the number of extracts increases. What is not available in such paper-based approaches is the interactivity that can make complex comparisons between many extracts practical by turning a static presentation into an iterative exploration of digital materials.

In this paper we consider the example of a digital companion presenting the contents of a Research Object studying the interpretation of leitmotif examples from Wagner's compositions, specifically the *Ring* cycle, as they are presented in numerous historical introductions, opera guides, leitmotivic threads and leitmotif lists included in libretto editions and piano scores. The study of the incidences of these particular leitmotif identifications consists of both the gathering of source material and its digitisation and cataloguing, and a musicological study of the potential relationships, influence and evolution between leitmotif interpretations. To enable the extension and repurposing of the identified leitmotif relationships they are structured using an ontology.

Notation examples in leitmotif guides are usually abstractions drawn from a piano score. When reporting findings from this research it is desirable to present and relate the scholarly arguments back to the musicological context within which they are made:

from the score excerpts in the source material; and to MEI encodings that illustrate and encode both the examples from which they are drawn and to complete (piano) scores of the overall operas.

This enables matching and linking of the examples as they are described in the scholarly text, via semantic hyperlinks, to and from the score, including exact matches and variants, illustrating interpretations, and situating the examples back in context. Encoding interpretations in the form of notation examples as variant readings of a certain passage could thereby chart the 'understanding' of the work as a history of its variants.

(For example comparing: Richard Wagner, Die Walküre, piano score by Felix Mottl, Leipzig,

Peters, 1914, p.165; Hans von Wolzogen, Thematischer Leitfaden durch die Musik zu Richard Wagners Festspiel Der Ring des Nibelungen, 2nd ed., Leipzig, Schloemp, 1876, p.58, 'Schicksalsmotiv'; Gustav Kobbé, Wagner's Music Dramas Analyzed With the Leading Motives, New York: Schirmer, 1923, p. 57, 'Motive of Fate'; George Dunning Gribble, The Master Works of Richard Wagner, London, Everett, 1913, p. 289, 'Fate Motif'.)

Introducing MELD: Music Encoding and Linked Data

To realise the digital notation companion we have developed the MELD framework (Music Encoding and Linked Data). MELD enables the interactive presentation of multimedia contents of the Research Object, such as the images, text, audio, and MEI encoded music notation described in the previous section. These can be explored contextually alongside each other through the use of semantic links, encoded using RDF, which describe the musicological relationships between the resources (and elements within them). In contrast to earlier technologies which have typically aligned resources against a timeline (e.g. in milliseconds, or using MIDI), MELD expresses relationships anchored to musically meaningful items scoped using MEI. Figure 1 shows a screenshot of MELD displaying text and notation, highlighting leitmotifs as identified in different historical guides.

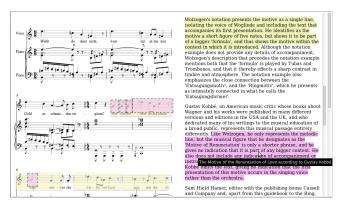


Figure 1. MELD displaying contextualised text and music notation.

To render our music notation (encoded using MEI) we use Verovio (Pugin et al. 2013), an open-source MEI renderer that produces beautiful SVG renditions of the score. In addition, Verovio provides an architecture in which identifiers (in other words, anchors for our relational Linked Data expressions in the MEI XML) are persisted through to the rendering (in SVG) which can be connected to identifiers in our contextual information (in RDF). When rendered (and re-rendered) for the user in our web based application interface, the browser uses these identifiers to generate interface elements and undertake actions that combine information from the MEI and the Linked Data.

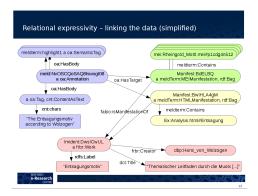


Figure 2. Musicological relationships, encoded using Open Annotations, within the Research Object (simplified).

Within the Research Object, we treat the XML IDs of elements within the MEI resource as fragment identifiers, so URIs can be straightforwardly generated for each notation element of interest. We employ the Web Annotation Data Model (Sanderson et al. 2017), using these URIs as targets of annotations representing each musicological marking. Corresponding annotation bodies are associated with semantic tags defined to encode the different musicological interpretations, which are in turn the annotation bodies of a top-level

annotation targeting the URI of the files currently being viewed, including the music encoding (MEI) and scholarly interpretation (HTML). A simplified example of such relationships is shown in Figure 2.

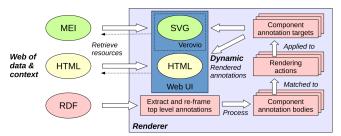


Figure 3. The MELD framework (shading corresponds to that in Figure 2).

The MELD client then uses HTML/CSS and JavaScript, served by a simple web service implemented with Python Flask, and illustrated in Figure 3. The procedure driving the rendering and user interaction is illustrated in Figure 1. The client processes a framed (see the explanation of framing) ISON-LD representation of the RDF graph instantiating the data model. It then performs an HTTP GET call to acquire the MEI resource targeted by the top-level annotation, and renders the corresponding musical score to SVG using Verovio. User interactions are captured using HTML divs drawn as bounding boxes over portions of the SVG corresponding to MEI elements of interest; this is simplified by Verovio's retention of MEI identifiers in the produced SVG output.

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