

# *Lohengrin TimeMachine*: Musicological Multimedia Made with MELD

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## Abstract

Music and the scholarship around it can be challenging to present in the forms associated with books and articles – primarily linear and with an emphasis on the static and visual over the sonic and interactive. We introduce the *Lohengrin TimeMachine*, a multiple-path multimedia app, optimised for a touch-screen tablet. The app offers two essays about motifs in the opera – one in textual form, and one a 30-minute video. These linear narratives are supported by audio examples, along with dynamic links that take the reader into a fully-interactive exploration of the occurrence of motifs across the opera. The reader's journey is supported with recorded music and scores, as well as novel visualisations of the orchestration and the timeline of the opera. The app is designed to operate over standards-based web documents published online, with extension and reuse in mind. In this paper, we describe the app, its underlying technology, and the journeys it supports.

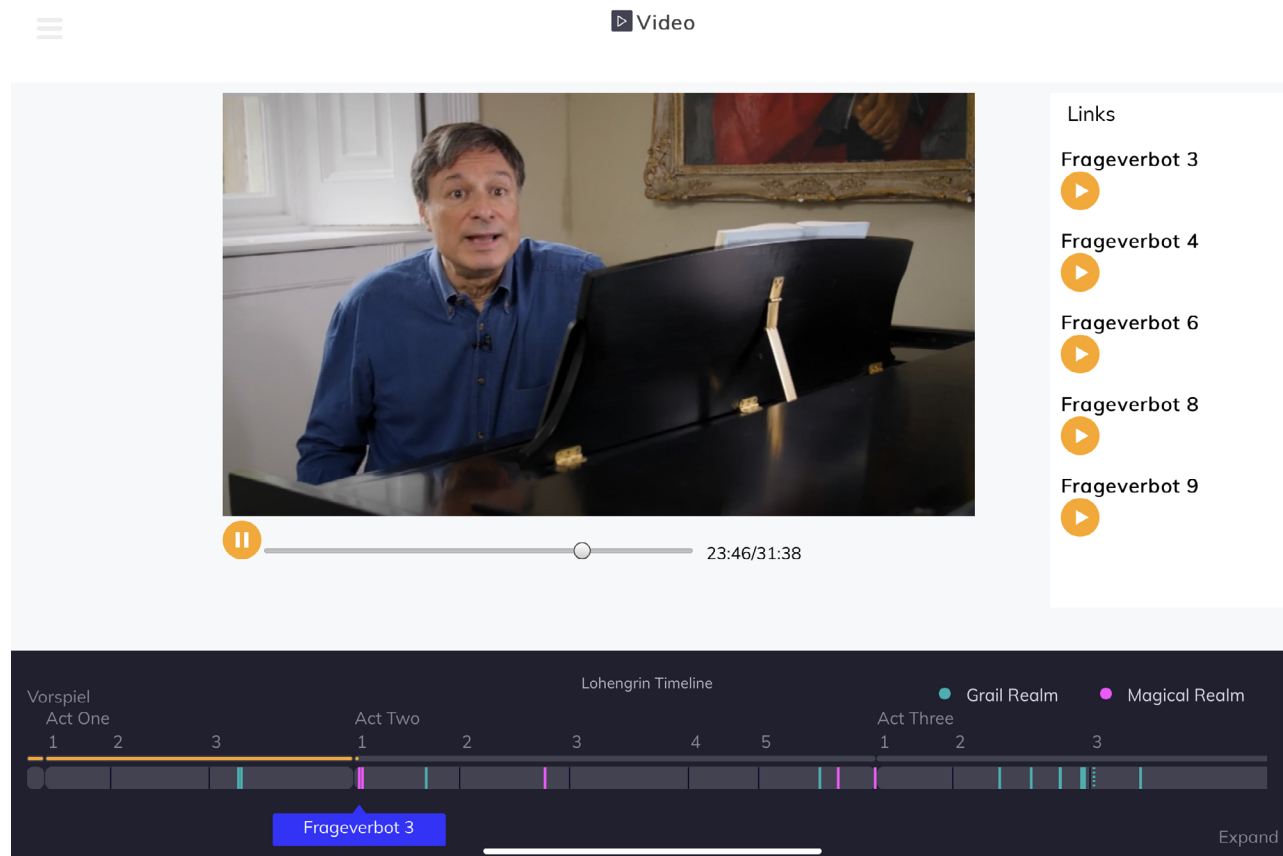
## Introduction

Musicology is often presented in linear, textual form, even though its materials are complex and multimodal. Scholarship must necessarily simplify and dramatically reduce complexity in order to make an ordered prose argument that others can follow. More detailed interaction with the scholar's observations occurs almost entirely through other resources.

We present the *Lohengrin TimeMachine*, a web application in which linear musicological scholarship (in the form of an essay and a 30-minute video) is augmented by user-driven interactive, multiple-path exploration of related material that can be explored with or independently from the narrative. The material, which includes musical notation, audio, analytical content, and textual quotation is accessed through a touchscreen-optimised web application for guided and self-directed exploration. Underlying resources are published on the web using standard file formats (including MEI and TEI) and associated with machine-readable Linked Data, supporting the creation of additional interfaces or analyses.

The application is intended to be accessible to enthusiastic amateurs as well as scholars, and concerns Wagner's use of motifs in his early opera, *Lohengrin*, advocating a more sophisticated understanding than 'Leitmotif' guides often communicate. It is optimised for use with a tablet, without excluding other means of browsing. The musicological content was conceived, written and, for the video, presented by co-author Laurence Dreyfus, a Wagner specialist, with the companion realised through a multi-disciplinary collaboration.

The *Lohengrin TimeMachine* allows users to explore the compositional devices Wagner uses to vary his motifs, browsing the whole opera for motif occurrences and their musical and textual contexts. Visualisations and recordings support the analysis, making it accessible to an audience that might otherwise struggle with a Wagnerian orchestral score. Exploration of this material can follow or be triggered by the musicological article and video, but can also be entirely reader-driven, with free browsing of the curated musical landscape.



**Figure 1:** The *Video* view of the *Lohengrin TimeMachine*. Relevant links appear in the sidebar on the right as the video progresses. The opera timeline at the bottom is present in all views.

## The Application and Its Data

The application dynamically constructs views using data published openly using standard file formats and Linked Data frameworks [3]. Materials are retrieved live from a public web server. Music notation is published as MEI, and text, including the main article, as TEI. Relationships and more abstract information are made available using the Resource Description Framework (RDF),<sup>1</sup> serialised as JSON-LD<sup>2</sup> and N-Quads<sup>3</sup>: annotations use the Web Annotation model<sup>4</sup> [1], while much of the musical information is represented using the Music Ontology.<sup>5</sup>

The sum of all these forms an independent, repurposable, and open Research Object [5]. Interactive user views are generated directly and dynamically in the browser from this knowledge graph using novel visualisations, which enable the user to navigate all possible paths through the evidential multimodal materials.

### Technical Implementation

The TimeMachine is constructed as a MELD application – that is, it uses the MELD 2.0 (Music Encoding and Linked Data) framework<sup>6</sup> [7]. MELD traverses Linked Data graphs, ‘following its nose’ by successively requesting web-accessible Linked Data – with each set of statements read potentially giving links to new URIs to explore. From this data, MELD builds up a local knowledge graph within the browser, allowing apps to discover, select and filter relevant information. The MELD framework provides reusable components for creating and retriev-

1 <https://www.w3.org/TR/rdf11-concepts/> (accessed January 12, 2022).

2 <https://www.w3.org/TR/json-ld/> (accessed January 12, 2022).

3 <https://www.w3.org/TR/n-quads/> (accessed January 12, 2022).

4 <https://www.w3.org/TR/annotation-vocab/> (accessed January 12, 2022).

5 <http://musicontology.com/specification/> (accessed January 12, 2022).

6 <https://meld.web.ox.ac.uk/> (accessed January 12, 2022).

Yet this iteration of **FRAGEVERBOT 9** doesn't repeat Lohengrin's prohibition so much as *issue a threat* about the ban. To notice this shift is to pay attention to a subtle change in the x-segment. Instead of the **FRAGEVERBOT** leading off with a heavy downbeat, Wagner has added a little anticipatory upbeat before the first note, which immediately evokes the opening signal of a brass fanfare (da-dá). This additional upbeat even prevents the *recall* of Lohengrin's opening words – *Nie sollst du mich befragen* –, which began with a strong accent on the word *Nie* [Never]. The text of the **FRAGEVERBOT** therefore recede into the background, and the theme transforms itself instead as an orchestral fanfare of doom. It is as if a mighty instrumental choir taunts Elsa with a spiteful recollection of the promise she made. Note also the **FRAGEVERBOT** is no longer heard in Lohengrin's region of A flat and A minor, summoning forth the holy Grail, but is transposed downwards into Ortrud's realm located a third lower of F (and F sharp) minor. As one can see from the TimeMachine, Wagner maintains this threatening upbeat into the next two iterations found in Act III/ii – **FRAGEVERBOT 10** and **11** – even when the tonal realm shifts back to

Vorspiel  
Act One  
1 2 3  
Act Two  
1 2 3 4 5  
Act Three  
1 2 3

Lohengrin Timeline

Grail Realm  
Magical Realm

Frageverbot 3

Expand

Links Motifs

Frageverbot 9  
Inspect

Frageverbot 10  
Inspect

Frageverbot 11  
Inspect

**Figure 2:** The *Essay* view, with the text in the centre, the opera timeline (below) and links to other views (right). The Motifs tab on the right, when selected, allows navigation within the essay text by motif iteration number, in a similar manner to a conventional index.

ing annotations, as well as for displaying and interacting with musical, textual, graphical and audio-visual materials. Other uses of the framework include an interactive composition [2], a masterclass annotation app [4], and a visualiser for comparing piano performances [6].

MELD is written in Javascript (as are its apps, including the *Lohengrin TimeMachine*). It uses the React framework<sup>7</sup> and operates over resources and data structured using Web standards. Linked Data consumed by the app uses and extends that which can be processed by core MELD libraries, drawing on ontologies including the Music Ontology, Dublin Core,<sup>8</sup> FRBR,<sup>9</sup> and, crucially, Web Annotations. FRBR is used here not only at the level of the complete work, but also to relate the abstract concept of, for example, the *Frageverbot* motif to the iterations of that motif that occur in the original score and, from those, to the editions and recordings that we include.

Music notation is encoded as MEI, rendered using a MELD component that calls the Verovio toolkit.<sup>10</sup> TEI is used for textual content, including the essay, commentary and historical texts, and is rendered to screen using CETELcean.<sup>11</sup> Both these are Javascript libraries that preserve structures and IDs in their output where possible. Where Verovio outputs SVG images, CETELcean creates HTML with custom tags. Both of these are placed within the Document Object Model (DOM) of their web page and can be easily manipulated with JavaScript and styled using CSS.

MELD applications such as the *Lohengrin TimeMachine* start the MELD graph traversal based on one or more initial URLs that point to RDF that declares the area of interest – in this case the *Frageverbot* motif and the

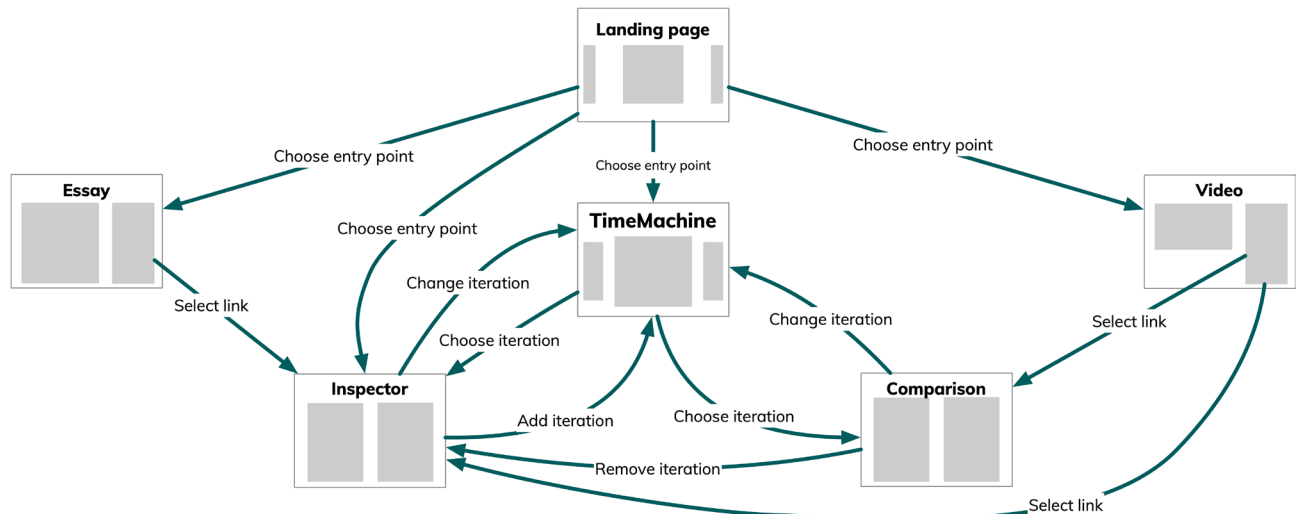
7 <https://reactjs.org/> (accessed January 12, 2022).

8 <https://www.dublincore.org/specifications/dublin-core/> (accessed January 12, 2022).

9 <https://vocab.org/frbr/> (accessed January 12, 2022).

10 <https://www.verovio.org/> (accessed January 12, 2022).

11 <https://teic.github.io/CETELcean/> (accessed January 12, 2022).



**Figure 3:** Diagram showing the main pages of the application and the flows between them. The *TimeMachine* view is a central navigation point, both for selecting single iterations of the motif and for choosing a second with which to compare.

essays. A local knowledge graph is built within a certain number of traversal steps from that. The application then dynamically selects the components of the interface based on the information and relationships to media that have been discovered. Much of the interface is constructed of generic MELD components, which are then styled for the specific look of the app using CSS.

### Using the Application

A user visiting the app website will initially encounter a landing page with links to several entry points for exploring the app (a diagram of paths the app offers between views is given as Figure 3). The *essay* and *video* themselves are integrated in the app, providing important narrative grounding and intuitive starting points. Readers or viewers are presented with relevant links into various other application views as they progress through the narrative (Figures 1 and 2).

Most links point to a form of the *Inspector* view (Figure 4). This gives the user a variety of information and visualisations about one iteration of the motif being discussed. In the terms of this app, an iteration of a musical idea is one instantiation of it at a particular point in the music (thus, the *Frageverbot* motif has 17 iterations in the opera itself, and one that occurs in a cut scene). Two iterations can be selected for side-by-side juxtaposition, using a separate *Comparison* view (Figure 5).

Selecting motif iterations from an overview of a complete opera can be daunting, and in this case is achieved through the *TimeMachine* view (Figure 6). Users can also flick left or right through motif occurrences, visualised in a carousel-like rapid overview.

Many types of information and visualisation recur within different page-level views. Audio and textual information, including libretto (or ‘poem’) content, are made available – this is both a crucial reflection of the integrated nature of Wagner’s artistic conception and a practical help to those for whom the score is not an easy way of engaging with the material.

Throughout the app, we provide two different visualisations for music notational content. Vocal scores are rendered from MEI using Verovio, with structural analysis (musical sections) dynamically overlaid (Figure 4, left pane). Activating these annotations triggers audio playback from the beginning of that section.

For full orchestral scores, a new, more abstract, notational visualisation of MEI is used, simplifying the complexity of a Wagnerian orchestral score. In our Orchestration pane, each instrument playing at a particular time is shown as a coloured ribbon, with the instrument’s section of the orchestra providing the colour (Figure 4, right pane). This makes clear differences in orchestration that may be made invisible by the reduction to vocal score. The visualisation is generated live in the browser based on a full score in MEI, and is rendered as an SVG image. It is implemented as a reusable React component within the `meld-clients-core` module, and so can be

The screenshot displays the 'Inspector' view of a music analysis application. The top navigation bar includes 'Iteration' and 'Inspect Compare'. The main content area is titled 'Frageverbot 9 - F Minor (x+as)' and features a 'Change motif iteration' button. The interface is divided into two main panes: 'Vocal Score' on the left, showing musical notation for measures 2097-2101, and 'Orchestration' on the right, which lists various instruments and their active periods. The orchestration list includes 3 Flutes, 2 Oboes, Cor anglais, 2 B♭ Clarinets, Bass Clarinet, 3 Bassoons, Horn in F, 2 Horns, 3 F Trumpets, 3 Trombones, E♭ Bass tuba, Timpani, Organ, Violin, Viola, Cello, and Contrabass. A text box below the list provides performance instructions: 'Accented 3 trumpets and 3 trombones with full orchestra ff, timpani roll and tutti strings tremolo ff, organ tacet'. At the bottom, a 'Lohengrin Timeline' shows the opera's structure with a blue bar for 'Frageverbot 9'.

**Figure 4:** Inspector view, showing the Vocal Score pane (Verovio) and the Orchestration summary pane.

easily incorporated into other applications. The list of instruments or singers, and the divisions of the orchestra or choir can be customised for any specific application.

For an opera thousands of bars long, overviews are crucial. In addition to the *TimeMachine* view itself, every view has a timeline at the bottom, which shows all occurrences of a motif, providing a visual summary and a base for navigation. The view summarises the sequence within the opera, supporting quick comparisons, and also acting as an index to detail views.

## Discussion

The application is possible because of a combination of factors. With a musicological study that was conceived by its author for interactive exploration, and collaborating on design with that author, we can ensure that the visualisations we provide are relevant and add to the scholarly argument and to a user's understanding of the material.

On a technological level, the combination of web standards and formats – especially MEI – that are easily addressed using URLs supports building rich, specialised applications without the need for bespoke or closed data formats. Furthermore, open-source rendering libraries such as Verovio and CETEIcean, which preserve to a large extent the structure of their originating documents and propagate IDs through from the XML to the rendered result, provide essential support for semantics on the data level to be transformed into interactive exploration on the application level in a principled and re-usable way.

The app itself is quick and responsive once loaded, and, although it takes 10–20 seconds on initial load to process and reframe the graph for use, we believe this to be within reasonable expectations for a modern

**Figure 5:** Comparison view, showing the Vocal Score panes for two iterations of the *Frageverbot* motif. A structural analysis (x and y segments) is indicated on the score. Both iterations are labelled clearly in the timeline, so their place in the opera is clear. Colour coding in the timeline of motifs in the ‘Magical’ and the ‘Grail’ realm (as magenta and turquoise lines, respectively) draws attention to and gives context for some of the differences in timbre and setting.

web application. This processing time itself depends substantially on the Javascript JSON-LD library,<sup>12</sup> and has improved by a factor of 10 as the library has matured.

By relying on walking Linked Data graphs to discover information and resources, MELD has no requirement for its materials to be collocated on the same server or published by the same institution. Although individual MELD components, such as the score component, have certain expectations for supplied parameters, the framework is not strongly opinionated or exclusive about the ontologies of its knowledge graph, and applications frequently transform graph data before it goes into these components. This makes the framework highly flexible for external data. There is no reason in principle why information and media could not be drawn from multiple external sources, such as Wikidata, Europeana, or YouTube, nor anything to prevent others building MELD apps using the *Lohengrin TimeMachine’s* resources.

The MELD framework has already been used for a variety of musically-rich interfaces. We believe that the *Lohengrin TimeMachine* can serve as a model for many more.

## Acknowledgements

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<sup>12</sup> <https://github.com/digitalbazaar/jsonld.js> (accessed January 12, 2022).

The screenshot displays the 'Time Machine' interface for the opera *Lohengrin*. The main view shows musical notation for 'Frageverbot 2 – A Minor (x-x-y)'. The notation includes vocal lines for Lohengrin and piano accompaniment. A commentary box is overlaid on the left, containing the following text:

**Commentary**

Lohengrin sings complete FRAGEVERBOT a semitone higher: orchestration on repeat altered with woodwind anticipations which correspond to stage direction *noch bestimmter*, (more decisively).

Below the commentary is a play button and a progress indicator showing 0:00/0:38. At the bottom, a 'Lohengrin Timeline' is visible, showing the structure of the opera: Vorspiel, Act One (1, 2, 3), Act Two (1, 2, 3, 4, 5), and Act Three (1, 2, 3). The 'Frageverbot 2' motif is highlighted in a blue box on the timeline, corresponding to Act Two, measure 3. The timeline also indicates the 'Grail Realm' (green) and 'Magical Realm' (purple).

**Figure 6:** The *TimeMachine* view, set to browse by vocal score. Flicking sideways scrolls through all the iterations of the motif in the opera in order of occurrence. Browsing is also possible using visualisations of the Orchestration or Libretto ('Poem', as Wagner called it).

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