



Collaborative workflows for encoding, validating, and publishing a multimodal digital edition

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Abstract

German lute tablature (GLT), once widespread throughout central Europe in the 15th and 16th centuries, remains underexplored in scholarship and largely abandoned in performance practice, partly due to its significantly greater complexity compared to other tablature types. E-LAUTE is an international, interdisciplinary research project assembling a comprehensive multimodal digital edition of surviving GLT sources, developing a research data infrastructure and corresponding workflows to effectively and sustainably support this collaborative effort. We describe the technologies, tools, environments, and workflows serving to fulfill the varied stakeholder requirements underlying our multimodal digital edition.

CCS Concepts

• **Applied computing** → **Arts and humanities**.

Keywords

German lute tablature, digital edition, research data management

ACM Reference Format:

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1 Introduction

German lute tablature (GLT) was used to notate lute music in the German-speaking world in the 16th century. Unlike French and Italian tablature types or modern guitar tabs, which visually represent the fretboard using numbers or letters (frets) on lines (courses, i.e., string pairs), GLT uses a unique symbol for each course-fret combination. This unintuitive diagrammatic ‘reading from the table’ is a hurdle for today’s users. The simpler Italian and French lute tablature notations remain playable by contemporary lutenists, whereas GLT has been largely abandoned in performance practice. Thus, a large part of the repertoire of secular music (dances, songs, improvisations, etc.) notated in GLT is not accessible to today’s users. This repertoire survives in both manuscripts and prints scattered throughout Central Europe. In the 16th century, these sources were essential cultural media forming an integral part of everyday life in the university and wider bourgeois culture of the German-speaking world. E-LAUTE is creating an Electronic Linked Annotated Unified Tablature Edition of the corpus of music in GLT produced between 1450 and 1550 (c. 2,000 pages), aiming to sustainably unlock this repertoire for the general public and the academic community. We extend the Music Encoding Initiative’s (MEI) schema to support GLT; draft a uniform editorial policy; re-index, re-systematize, and record all relevant bibliographical metadata; provide a historical contextualisation of this music; and develop tools for working with this data. Our team unites scholars in digital humanities, musicology, music performance, German language and literature studies, music informatics, library and information studies, and Web science; addressing correspondingly heterogeneous stakeholder requirements for discoverable, playable, readable, and machine-interpretable music notation.

2 Technologies and resources

Presentation. Public presentation of the E-LAUTE edition is provided through the Austrian National Library (ÖNB) digital editions

Figure 1: The E-LAUTE edition platform’s synoptic view – here, comparing facsimile and rendered GLT edition views of ‘Wo sol ich mich hin keren’ – A-Wn MS47356-8°, fol. 18v (E-LAUTE identifier: Jud_1523-2_n10)

platform.¹ With extensive experience in delivering digital editions from diverse textual sources, ÖNB provides an editorial and technical framework that can combine multiple modalities: original material is transcribed and encoded in TEI-XML; encodings are aligned to their respective facsimiles (provided via IIIF APIs²); and guidelines regarding the reconstruction, genetic analysis and editorial intervention to the source text are developed. A Web-interface offers synoptic views enabling comparison between various source representations, enriched with bibliographic descriptions. Within E-LAUTE this infrastructure is extended to support music-relevant functionalities, including MEI-XML encodings as source, rendering via Verovio [8], and the incorporation of audio recordings, as well as synoptic comparisons across different source documents (such as between concordances, related items, or with vocal models).

The platform is a specialised instance of the GAMS digital humanities asset management system [13]. It includes a Fedora Commons repository, where each data object is ingested and assigned a persistent identifier to ensure its integrity and citability. TEI and MEI encodings are rendered to HTML and SVG using XSLT transformations and Verovio, allowing integrated display of these resources within the platform’s Web-based frontend (Fig. 1). Moreover, a triplestore is provided. In E-LAUTE, this houses metadata and provenance information as RDF triples, queryable via SPARQL, supporting interoperability and exchange with external projects.

Music encoding. MEI gained popularity in cataloging and editing because of its flexibility and its comprehensive model of music semantics, extending beyond CMN to include mensural and neume notations [1]. The MEI community and its Tablature Interest Group have been developing support for tablature notations over a number

of years [6]. An initial model for encoding tablature was introduced in MEI v2.00 (2012), and in 2020, several feature extensions developed in the interim were formally proposed to support various notation types, particularly French and Italian lute tablature [2]. In 2023, E-LAUTE supported further development by implementing these proposals, in the process adding key features specific to GLT; aligning the tablature model’s logic with other MEI models; and advancing the engraving of tablature encoding [3]. The project also applies a custom MEI profile, ‘notehead notation’, which uses stemless black noteheads with superimposed rhythm flags to provide only pitch and onset information, with no interpretation of note duration or voice leading. This faithfully transcribes tablatures into a CMN-like form.

Text encoding. Our sources contain considerable amounts of instructional texts on lute performance. Further, many of the lute pieces are intabulations (instrumental arrangements) of German songs. This raises questions on the relation between texts and poetic form, and on the polyphonic songs and their lute arrangements. We therefore provide transcriptions and editions of corresponding song lyrics from handwritten and printed song books. A main focus lies on the technical solutions combining text and music editions, which will facilitate the study of text-to-music-relations [10].

Audio. Ours is the first digital edition on the ÖNB-platform to introduce audio recordings as a fundamental part of the edition. Pieces are selected for recording by professional lute performance scholars according to their personal preferences and skills, aiming to cover as many sources of the current project phase as possible. The recordings are published under public license (CC BY-SA 4.0).

Metadata. Metadata relating to bibliographic description and to the research process is captured and exposed on the source- and piece-level using Linked Data principles. This includes contextual

¹Available at <https://edition.onb.ac.at/e-laute>

²Available at <https://iiif.io/>

metadata regarding provenance of both the source and our encodings; functional description and codicological characteristics; as well as the provision of identifiers (shelfmarks, RISM ID, and other catalogue IDs). Additional metadata includes titles (original and normalised), content type (music, text, or combination of both), foliation, notation type, language, and research commentaries. Concordances and other items related to individual pieces are identified and provisioned with authority data for persons and locations. Further, rich metadata is captured as part of the audio recordings, detailing aspects of the recording process as well as the precise encoding being performed. This information provides important context for processing from the perspective of music informatics research.

3 Encoding tools

E-LAUTE assembles, develops, and interconnects a number of research tools to support collaborative edition workflows (Fig. 2).

Bibliographic metadata. To re-systematise and re-index materials within an environment specifically designed to the requirements of describing pre-1600s European sources, we have developed the E-LAUTEdb database and bespoke data entry interface in close collaboration with the project’s humanities scholars. The database models both musicological and philological concerns, including teaching texts and lyrics for the intabulations, questions of vocal and textual concordances, paratexts, and readability. Though conceived and developed within E-LAUTE, we are already engaged in planning the reuse of this database within external, synergistic projects investigating compatible contexts. This relational data is exposed as Linked Open Data via a set of mapping scripts using the Python `RDFLib` module, and ingested into a Blazegraph triplestore instance hosted within the ÖNB’s edition platform. This will enable complex search methods combining all metadata of the project using SPARQL query templates.

Typesetting tools. Fronimo is lute tablature software that allows users to typeset, edit, transpose and organise music in various historical tablature styles.³ It is one of the few tools to support German lute tablature (alongside Italian and French).

MuseScore is an open-source software package that allows score creation, editing, and playback.⁴ It supports some types of lute tablature, but not GLT. Here, it is used for typesetting tablature editions in CMN before conversion to MEI.

Conversion and analytical tools. Tablature files typeset in Fronimo (.ft3) are converted using `luteconv`,⁵ using a simple Web-frontend and REST-API wrapper⁶ integrated into our MEI editor `mei-friend` (below). Fronimo-to-MEI conversion happens automatically and transparently when an .ft3 file is opened. Equivalently, MusicXML from MuseScore is converted automatically using `mei-friend`’s integrated Verovio instance.

`AbsoLutely Tabulous`⁷ (`abtab`) is a modular, extensible toolbox for computational processing and analysis of music in lute tablature, designed as a portable command-line tool that runs on Windows and Unix-based operating systems. An integration with

`mei-friend` using an approach akin to the `luteconv` wrapper is under development. `abtab` combines symbolic music notation-general and lute tablature-specific tools within a single environment, supporting integrative workflows to suit specific user needs. Within E-LAUTE, `abtab` produces CMN-like notehead notation transcriptions from tablature encodings; generates polyphonic transcriptions to bootstrap the CMN edition process; and ‘fits’ intabulations to corresponding vocal models, supporting musicological analyses.

Edition tooling. E-LAUTE uses `mei-friend`⁸ [5] for collaborative editing and proof-reading of all notation documents. This open-source browser-based editor facilitates the music encoding process through its provision of an interactive graphical notation panel alongside the MEI-XML. The rendered notation is produced by an integrated Verovio instance, using recent extensions for rendering GLT. `mei-friend` also features integration with git cloud services, including project-specific CI/CD automation, simplifying collaborative encoding and proof-reading workflows. Finally, the editor has recently been extended with a graphical interface for editorial markup [7], which has proved highly useful to our project.

4 Environments

Our project’s encoding tools are interconnected over the Web providing for simple and efficient data exchange throughout our workflows. Typeset documents are stored in git cloud services. MEI conversion is handled automatically using REST APIs, transparently to the user, and music encodings are edited in `mei-friend`, with the editor’s in-browser git instance and integration with git cloud services providing a versioned, collaborative working environment.

DBRepo [12] is an open-source database repository that provides versioned access to data from E-LAUTEdb as well as to other structured (i.e. relational/tabular) data produced in the project. Specifically, it stores metadata on our research data objects, allowing for efficient filtering and the creation of subsets of the entire corpus based on arbitrary selection criteria. It will also hold a range of features (chroma, MFCCs, onsets, etc.) characterizing the audio content of the recordings produced in the project, or features extracted from scores, to foster analytics. All data and metadata changes are versioned, and all versions are citable (implementing the recommendations of the RDA Working Group on Data Citation [9]), ensuring reproducibility of research based on identified states of the data, with each data or metadata subset selected by researchers receiving an individual DOI. The TU-RDM institutional data repository (based on Invenio RDM) is used to provide access to published versions of content files (MEI and TEI-XML, audio recordings) and their metadata. Older versions are accessible through version-specific DOIs; a DOI identifying the latest version is also provided.

5 Workflows

Workflows to create, interconnect, validate, and publish the multimodal resources making up the edition are illustrated in Fig. 2.

Metadata capture. Bibliographic and research data is mirrored from E-LAUTEdb into DBRepo for versioning purposes using temporal tables, and mapped to a graph schema as Linked Data. The graph is extended with audio metadata and other project-specific

³Available at <https://sites.google.com/view/fronimo/home>

⁴Available at <https://musescore.org>

⁵Available at <https://bitbucket.org/bayleaf/luteconv>

⁶Available at <https://luteconv.mdw.ac.at>

⁷Available from <https://github.com/reinierdevalk/abtab>

⁸Available at <https://mei-friend.mdw.ac.at>

information, ingested into the edition triplestore, and published within TU-RDM (each new version receiving its own DOI).

Music typesetting and encoding. Both transcriptions and editions of lute tablature are typeset in Fronimo, edited in mei-friend (following MEI conversion via the luteconv integration) and stored in a shared git repository. This is done using the tablature notation type of the source, typically GLT in our collection; other notation types (typically French and Italian lute tablature) are automatically generated as derivative encodings upon release (see below). To generate notehead notation from existing tablature encodings, an abtab module produces MEI which is then edited in mei-friend (mainly to inject header information) before storage in the repository. CMN editions are typeset in MuseScore, converted from MusicXML to MEI in mei-friend (using Verovio) and enhanced with editorial markup and header information, before storage in the repository. An abtab module for automatic (polyphonic) transcription has been developed, and its integration into the workflow is currently being tested. All MEI encodings receive a standardised MEI header, automatically generated by a CI/CD action triggered via mei-friend's git integration, containing the per-piece information retrieved from the Linked Data graph.

Text encoding. For the encoding of text (song texts, treatise material, marginalia) in TEI, the Oxygen XML editor is used. The text encoders describe the related content following TEI guidelines adjusted to the project-specific requirements and using a TEI header template with metadata from E-LAUTEdb. After testing the transcription and edition versions with XSLT stylesheets and linking to the respective facsimiles, the encodings are stored using git, following the same release process as for the music encodings.

Release process. When editing work is completed on a source, proof-reading is conducted by another E-LAUTE domain expert (using Oxygen for textual and mei-friend for music encodings), in an iterative process that ends when the source is deemed ready for release. At this stage, a formal release is created for the source in the git cloud storage platform, which triggers a further, automated validation through a CI/CD pipeline. This ensures XML validity

and cross-checks encoded metadata (header information) with the bibliographic information obtained from E-LAUTEdb. On successful validation, derivative encodings are generated for tablature transcriptions and editions. All resources are published via TU RDM and the edition platform under public license (CC BY-SA 4.0).

Reproducible research The edition's various score and audio representations can be cross-linked from TU RDM with metadata in DBRepo and accessed via a provided JupyterHub environment. These systems combine to form a flexible virtual research environment across institutional boundaries, in which researchers in music informatics and digital musicology may programmatically interact with the data to conduct symbolic score analyses, audio signal processing, and MIR tasks such as audio-to-score alignment. Integration of this infrastructure within our edition architecture facilitates novel interactions with the various forms of data available, supporting ease-of-use and reproducibility, ultimately aiming to increase the FAIRness of our research data and processes.

6 Limitations, conclusions, future work

E-LAUTE is entering the final year of the first of an anticipated three 3-year modules. We are tracking limitations of our current solutions, which we plan to tackle in future work. Our data models are robust but require extension: the bibliographic RDF extracted from E-LAUTEdb is largely project-specific, currently prioritising expedience over interoperability. Mapping to generalised, established ontologies is intended in future work, as we continue to seek and develop synergies with external projects. While our project's contributions to modelling GLT in MEI, released as part of MEI v5.1, provide good coverage of our sources, specific aspects – such as fingering and *suspir* (pause) indicators – remain unaddressed, but are in development for a future MEI release. Further, though Verovio now renders GLT, certain glyphs are missing from the standard SMuFL font set. We have formally proposed these for release in a future version of SMuFL.⁹ While our project team is representative of our identified stakeholders, user studies will be required to evaluate and improve the usability of our platform. Design concepts supporting user-contributed enrichment (see, e.g., [4, 11]) have been developed and will be implemented in future work. Most importantly, we plan to expand the set of sources represented within the edition, intended to comprise seven volumes at completion of the current module, to eventually encompass all surviving sources of GLT.

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⁹Provisionally, we address these limitations through the use of MEI directives (<dir> elements) and analogous glyphs – see, e.g., the 'dots' in the rendered GLT in Fig. 1, which stand in for the flag-uptick fingering indicators in the facsimile.

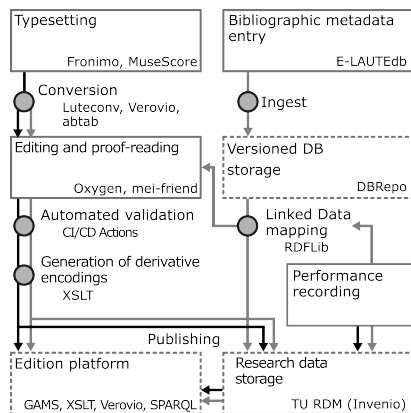


Figure 2: Project workflows. Solid rectangles: tool-assisted manual activities. Circles: automated processes. Dashed rectangles: published data. Black arrows: content flows. Gray arrows: metadata flows.

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