

PROBADO MUSIC: A MULTIMODAL ONLINE MUSIC LIBRARY

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ABSTRACT

After several years of research and development, PROBADO *Music*—a multimodal digital music library system—is now made available for the public. To allow access to anyone from anywhere, we have prepared a collection of public domain music material that is accessible through our system. Besides streaming and presenting digital music documents (scanned sheet music, audio recordings, and lyrics), PROBADO *Music* employs current techniques from the field of *music information retrieval* to offer enhanced browsing, navigation, and search functionalities. We strongly believe that such novel library systems will appeal to music-lovers and can support musicians, musicologists, and music teachers in their work.

1. INTRODUCTION

More and more music archives and libraries pursue the digitization of their collections. One reason for these activities is long term preservation. In addition, the digitization of music collections enables their computer-based remote access. Several institutions already offer online-access to their collections (see, e.g., *Petrucci Music Library*,¹ *Chopin Early Editions*,² or the *Neue Mozart Ausgabe*³). But the document presentation often lacks in user convenience. If for a piece of music several documents are available, the user has no possibility of easily and intuitively accessing them simultaneously. However, being able to listen to a recording while reading the score or quickly comparing two different interpretations of a piece would constitute great benefits. Another shortcoming of many online music libraries are the provided search functionalities. Frequently, only metadata search is available and therefore the user has to know the name of the sought-after piece of music. For digital music documents content-based query techniques can significantly simplify the search process. Some online-collections already support content-based search to some extent, e.g., the melody search of the *Petrucci Music Library* [9]. However, they

lack the capability of directly accessing the match positions within the documents.

The project PROBADO⁴ aims at developing prototypes for enhanced digital library systems for non-textual documents that eliminate the mentioned shortcomings. As two examples of non-textual document types, (architectural) 3D models and music documents are considered. In PROBADO *Music* sophisticated user interfaces and content-based retrieval techniques enable online access to large digital music libraries. As a result of our research and development efforts, the PROBADO *Music* prototype is now made available to the public at:

<http://www-mmdb.iai.uni-bonn.de/probado>

Furthermore, we collected a large corpus of public domain music documents from various sources and prepared it for presentation with our library system.

The remainder of this paper is organized as follows. In Section 2 we present details on the user interface and in Section 3 we describe the preprocessing workflow for music collections as well as the administration system MACAO. In Section 4 the public domain music collection created and managed by our research group is introduced. We conclude the paper with an outlook on future work.

2. PROBADO MUSIC FRONTEND

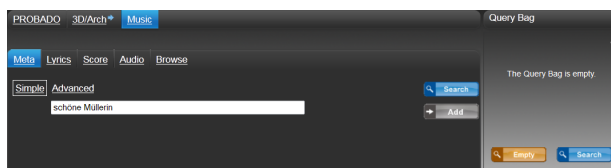


Figure 1: Web interface of PROBADO *Music* with various search masks.

When first accessing PROBADO *Music*, several masks for the formulation of queries are offered to the user (see Figure 1). Besides metadata based search, PROBADO *Music* includes content-based search mechanisms. For each modality (lyrics, score, and audio), the system implements according MIR-techniques to search through all documents of that modality. Therefore, the user can also use lyrics to search for a piece of music. Furthermore, a score

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¹<http://imslp.org>

²<http://chopin.lib.uchicago.edu>

³<http://www.nma.at>

⁴<http://www.probado.de>

editor (Figure 2) allows for the formulation of symbolic queries. Audio matching techniques are available as well. But rather than free query formulation, the user can use extracts from the document collection for search. We will explain this type of query formulation later in this section. As last option, the user is offered a tree-based presentation of all pieces of music contained in the music collection.

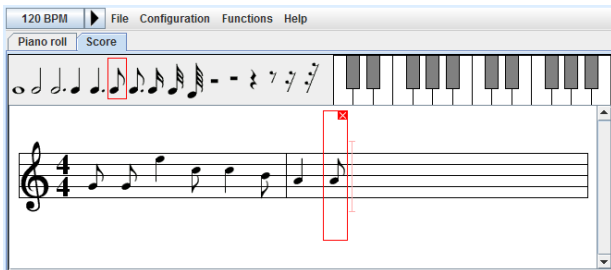
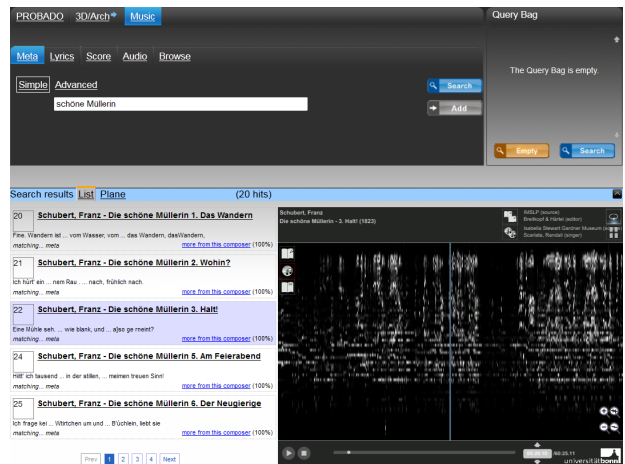


Figure 2: Editor for symbolic score queries. The user can choose between a classic score view and a more technical piano roll visualization.

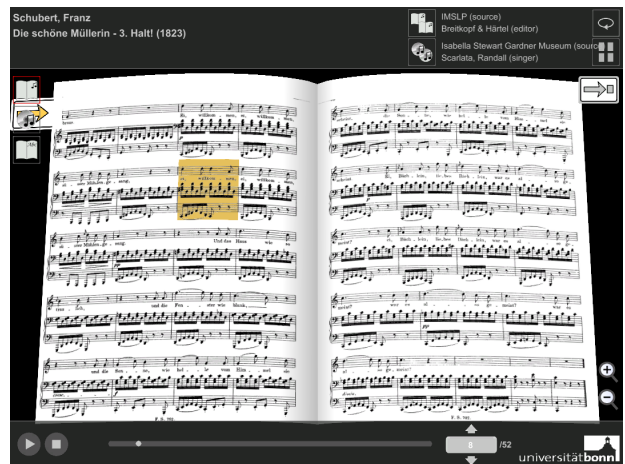
After starting a search (e.g., searching for the string “schöne Müllerin” in the metadata), the hit list is presented to the user (see Figure 3a). In *PROBADO Music*, a piece of music-centered document access is pursued. Therefore, rather than listing all documents matching the current query, pieces of music are returned as hits. After selecting a result, all documents containing the according piece of music are made available for presentation. The current *PROBADO Music* prototype supports three document types—sheet music, audio, and lyrics—and offers visualizations for each of them (see Figure 3). After selecting a piece for visualization, a document of the according document type is opened in every view. However, the user can easily exchange the document selected for presentation through lists containing all sheet music versions and all recordings of the current piece of music respectively.

A further innovation of *PROBADO Music* are multi-modal navigation functionalities through the inclusion of sheet music-audio synchronization techniques, see Figure 4. As one benefit, these techniques enable score following. While playing the audio, the currently audible measure is highlighted in the score. Another convenience introduced by sheet music-audio synchronization is score-based navigation. The user can freely browse through the currently loaded score book. Upon selecting a measure in the score, the audio recording will automatically jump to the according time position and playback will continue from there. In addition, the employed synchronization allows for keeping the musical position while exchanging the score or audio document selected for visualization. Thus, the user can quickly compare different recordings of a piece of music without repeatedly searching for the specific position he/she is interested in. Similarly, lyrics following and lyrics-based navigation are available.

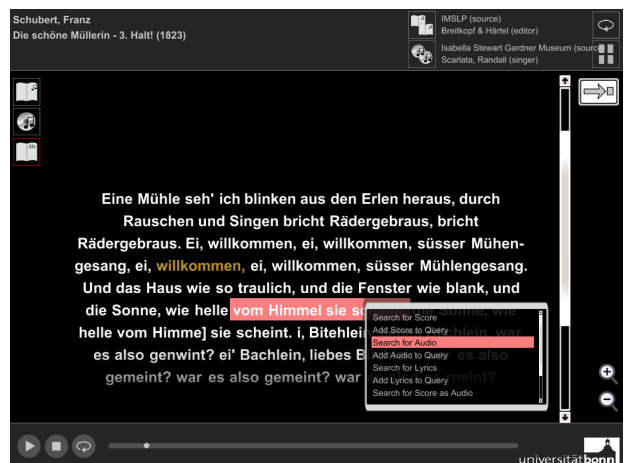
In addition to the previously described search masks, the user can create content-based queries from within the



(a) Web interface for query formulation (top) and result list (bottom left). On the bottom right, the music documents are presented. Here, the audio player view offering common audio player capabilities together with a spectrogram visualization of the recording is shown.



(b) Visualization of a scanned score book in *PROBADO Music*. The current measure is highlighted and updated during audio playback.



(c) In the Lyrics visualization, the current musical position is highlighted (on the word level). Text can be selected and queried. Equally, score or audio segments can be used as query.

Figure 3: The *PROBADO Music* user interface.

visualized documents (see Figure 3c). In each view, the user can mark an arbitrary region. Due to the previously described synchronization, the user can then de-

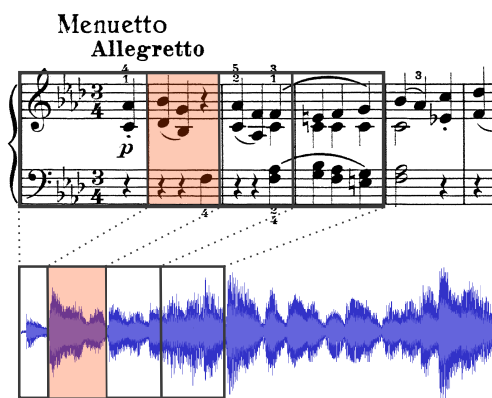


Figure 4: Sheet music-audio synchronization for the first measures from the third movement of Beethoven’s *Piano Sonata No. 1*. Regions in the score image are mapped to corresponding time intervals in an audio interpretation.

cide whether to use the matching score-, audio-, or lyrics-extract as query. Upon accessing the result of a content-based query, the exact match positions are visualized in the documents, Figure 5. The user can thereby quickly navigate through all matches and compare them.

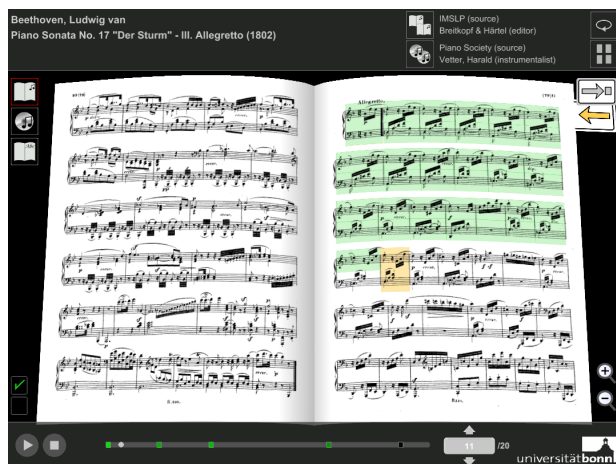


Figure 5: Hit visualization for an audio query consisting of the first 15 measures from the third movement of Beethoven’s *Piano Sonata No. 17*. The matching regions are highlighted both in the music documents and on the timeline below.

3. MACAO

To avoid digital graveyards, digital music collections need to be organized properly. Therefore, an entire process chain for digitizing, processing, organizing, annotating, and linking the data is required. In *PROBADO Music* such a workflow was defined and implemented through the administration system MACAO (“Music Administration for Content Analysis and Organization”). Given a collection of scanned sheet music pages and digitized CDs, the data is organized and prepared by abiding the following steps.

- **Metadata:** In cooperation with the Bavarian State Library (BSB), an entity-relationship model based on the FRBR model [5] was developed. Using this model the metadata information of the music collection is created. To help with this manual step, MACAO provides convenient input masks.
- **Dissemination preparation:** To enable streaming and presentation of music documents, derived file types need to be created (e.g., textures for the score visualization). In addition, several file types, only required for the subsequent preprocessing steps, are derived from the input data. Upon adding a CD or a score book to the collection these derived file formats are created completely automatically.
- **Content extraction:** Given scanned sheet music pages, their musical content has to be reconstructed using Optical Music Recognition techniques (OMR). The resulting symbolic score formats contain all music related information available on the scanned images. The lyrics of pieces containing voice parts are usually recognized by the OMR system as well. In *PROBADO Music* this information is used as the lyrics data presented to the user. Thus, the additional effort of finding and digitizing libretti can be avoided. For the upcoming music synchronization and indexing, score documents and audio files need to become comparable. Therefore, they are converted into a common midlevel feature representation. For the given data types and the intended MIR-tasks, chroma-features are a well suited representation [1, 4]. Their calculation can again be performed fully automatic and no user interaction is required.
- **Segmentation and work identification:** The content of a new music document has to be split into individual segments, each associated to a single piece of music. Afterwards, the according metadata entries of the pieces of music have to be mapped to the segments. Automatic segmentation techniques, filters, and input masks support the user in accomplishing this task.
- **Synchronization:** Music synchronization techniques are employed to enable score-following and score-based navigation. Once the input data was correctly associated to the pieces of music the linking data is calculated without requiring further user interaction. For details on the employed synchronization methods, we refer to the literature [7]. Using the sheet music-audio synchronization results in combination with the lyrics extracted from the score scans, lyrics-audio synchronization and lyrics-based navigation are quickly realized as well.
- **Content-based indexing:** The indexes for content-based search are calculated fully automated. Again, we refer to the literature for information on content-based search techniques [2, 6].
- **Revision:** The employed synchronization method can produce erroneous linking structures which

will result in a poor music presentation by the PROBADO *Music* frontend. The main error source is introduced by the OMR process. Although the recognition rates of current OMR systems are already remarkable, they will probably never be perfect. For error classes that have a strong influence on the synchronization result MACAO provides according editing masks. Additionally, performance related deviations in the repeat structure can occur and might require manual rework.

For more details on the PROBADO *Music* system architecture and the employed MIR-techniques we refer to [3].

4. MUSIC COLLECTION

In the context of the PROBADO project, the Bavarian State Library digitized an extract of their music collection. In total approximately 72,000 score pages and 800 commercial CDs were digitized. However, open access to this digitized copyrighted material cannot be granted by the BSB. Instead, a collection of public domain material was setup as proof of concept.⁵

The Multimedia Signal Processing Group in Bonn is now making an effort of providing a larger, free music collection that is accessible with the PROBADO *Music* system and incorporates several data sources. We used exclusively public domain documents or material that is published under a Creative Commons Attribution License⁶ or a comparable license. The documents were collected from the following sources:

- *Isabella Stewart Gardner Museum*, Boston⁷
- *Mutopia Project*⁸
- *Petrucci Music Library*
- *Piano Society*⁹
- *Saarland Music Data (SMD)*¹⁰
- *Wikimedia Commons*¹¹

Currently, our music collection contains 249 pieces of music from 15 different composers. More details are given in Table 1. The collection can be accessed via the PROBADO *Music* prototype.

5. OUTLOOK

The goal of PROBADO *Music* is a holistic music experience where all documents related to a piece of music are made available simultaneously. Therefore, the extension of the system to provide access to other document types is architecturally considered and could be realized in the future. In a feasibility study we already showed the potential

⁵The collection will be freely accessible at www.probado.de.

⁶<http://creativecommons.org>

⁷http://www.gardnermuseum.org/music/listen/music_library

⁸<http://www.mutopiaproject.org>

⁹<http://pianosociety.com>

¹⁰http://www.mpi-inf.mpg.de/resources/SMD/SMD_Western-Music.html

¹¹http://commons.wikimedia.org/wiki/Main_Page

Composer	Pieces	Score pages	Tracks
Bach, J. S.	14	61	4
Beethoven, L. van	55	511	76
Brahms, J.	12	97	16
Busoni, F.	1	14	1
Buxtehude, D.	1	5	1
Chopin, F.	15	141	22
Elgar, E.	6	50	2
Fauré, G.	4	83	4
Franck, C.	4	43	8
Grieg, E.	3	54	1
Liszt, F.	1	78	1
Mozart, W. A.	30	215	29
Respighi, O.	3	33	3
Schubert, F.	44	120	6
Schumann, R.	49	141	89
Total	249	1,864	275

Table 1: Content of the free music collection accessible with PROBADO *Music*. The collection contains approx. 1,900 score pages and a total of approx. 31 hours of audio material.

for adding music videos [8]. Other imaginable documents include programs, concept drawings for costumes, stage designs, and musicological texts.

Although our music collection already contains a quite representative number of pieces, we will aim at enlarging the collection by adding further public domain material.

6. REFERENCES

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