Fostering Openness and Accessibility of Music Archives through Multilayer Formats

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Abstract

This paper explores the critical intersection of openness and accessibility in the context of digital music archives, emphasizing the challenges posed by rare, fragile, and often handwritten materials. Building upon previous research, the study introduces multilayer representation formats, particularly the IEEE 1599 standard, as a viable solution to bridge gaps in usability, inclusivity, and interpretability for diverse user groups, including those with sensory, motor, and cognitive impairments. Through two case studies drawn from the Ricordi Historical Archive, the paper demonstrates how multilayer formats enable synchronized access to musical content across various modalities, including symbolic notation, audio, visual media, and metadata. The adaptability of these formats not only facilitates richer and more equitable access for scholars and the general public but also supports the design of assistive technologies and personalized interfaces. Ultimately, the work highlights the potential of multilayer approaches to transform music archives into inclusive, interactive spaces that preserve cultural heritage while democratizing engagement with music.

Keywords: Music, Archives, Collections, Accessibility, Usability, Inclusion, Multilayer formats, IEEE 1599

Questo articolo esplora l'importante intersezione tra apertura e accessibilità nel contesto degli archivi musicali digitali, sottolineando le sfide poste dai materiali rari, fragili e spesso manoscritti. Basandosi su ricerche precedenti, lo studio introduce formati di rappresentazione multistrato, in particolare lo standard IEEE 1599, come soluzione praticabile per colmare le lacune in termini di usabilità, inclusività e interpretabilità per diversi gruppi di utenti, compresi quelli con disabilità sensoriali, motorie e cognitive. Attraverso due casi di studio tratti dall'Archivio Storico Ricordi, il documento dimostra come i formati multistrato consentano l'accesso sincronizzato ai contenuti musicali attraverso varie modalità, tra cui la notazione simbolica, l'audio, i media visivi e i metadati. L'adattabilità di questi formati non solo facilita un accesso più ricco ed equo per gli studiosi e il pubblico in generale, ma supporta anche la progettazione di tecnologie assistive e interfacce personalizzate. In definitiva, il lavoro evidenzia il potenziale degli approcci multistrato per trasformare gli archivi musicali in spazi inclusivi e interattivi che preservano il patrimonio culturale e allo stesso tempo democratizzano il coinvolgimento con la musica.

Parole chiave: Musica, Archivi, Collezioni, Accessibilità, Usabilità, Inclusione, Formati Multistrato, IEEE 1599

1. Introduction

While the earlier work primarily identified the challenges related to openness and accessibility in digital music archives, the present paper extends that discussion by proposing multilayer formats for music information, such as IEEE 1599, as a concrete solution to address those issues.

Music archives constitute critical repositories of cultural, educational, and scholarly significance, safeguarding the legacy of musical traditions while offering invaluable insights into the historical development of artistic practices, institutions, and societal frameworks. By encompassing a wide array of materials, such as audio recordings, musical scores, visual artifacts, personal correspondence, instruments, audiovisual media, publications, and digital resources, these archives play a pivotal role in preserving the musical heritage of past generations for the benefit of future ones.

Frequently housed within institutions such as opera houses, conservatories, and historical collections, music archives are essential not only to researchers and practitioners but also to the general public. Nevertheless, despite their recognized importance, these repositories continue to face substantial challenges with respect to accessibility. Ensuring that diverse audiences, regardless of background, ability, or expertise, can engage with and derive benefit from archival holdings is essential for cultivating a more inclusive understanding and appreciation of cultural heritage.

In this context, the advent of digital technologies represents a transformative force capable of addressing the limitations traditionally associated with archival access. Digitization initiatives, the establishment of online repositories, and the development of user-centered digital tools have the potential to fundamentally alter the ways in which archival content is disseminated and engaged with. These technological advancements offer solutions to longstanding issues related to geographic constraints, limited physical availability, and the fragility of original materials, while simultaneously enabling new modes of interaction with archival content.

The principles of open access, in particular, are instrumental in democratizing the availability of these resources, thereby extending their use beyond the academic community to encompass musicians, educators, students, and the wider public. At the same time, digital technologies offer critical opportunities for improving accessibility for individuals with physical or cognitive

impairments. Assistive technologies such as screen readers, braille displays, and content simplification tools enhance the usability of archival materials for all users, thereby contributing to a more equitable cultural landscape.

This paper builds upon a previous contribution titled "Unlocking Music Archives: Openness and Accessibility," presented at the 21st Conference on Information and Research Science Connecting to Digital and Library Science (IRCDL 2025), held on February 20–21, 2025, in Udine, Italy [1]. While the earlier work primarily identified the challenges related to openness and accessibility in digital music archives, the present paper extends that discussion by proposing multilayer formats for music information, such as IEEE 1599, as a concrete solution to address those issues.

It adopts a dual approach—aimed at promoting both openness (broadening general access) and accessibility (addressing the specific needs of individuals with disabilities)—to underscore the multifaceted role of technology in the preservation and dissemination of musical heritage.

To illustrate these themes, the present study examines two use cases derived from materials held in the Ricordi Historical Archive, specifically a handwritten letter and an autograph musical score by Giacomo Puccini. These case studies serve to demonstrate the practical implications of digitization and digital engagement strategies for making archival materials more broadly accessible and inclusive. Through this exploration, the paper seeks to highlight ongoing initiatives and identify future directions for the development of music archives as open and accessible cultural repositories.

The remainder of the paper is structured as follows: Section 2 introduces the foundational concepts of openness, accessibility, usability, and inclusivity, and examines their specific application within the context of music archives. Section 3 provides an overview of the current state of research on openness and accessibility in digital music archives, highlighting key technological and methodological developments. Section 4 presents two case studies from the Ricordi Historical Archive that illustrate real-world challenges and opportunities for improving access to archival materials. Section 5 explores the concept of multilayer formats, with a focus on the IEEE 1599 standard, outlining its structure, functionalities, and use in digital archival initiatives. Section 6 discusses how multilayer formats can be leveraged to support inclusive access, addressing the needs of users with various sensory, motor, and cognitive impairments. Section 7 concludes the paper by summarizing the main findings and proposing directions for future development in the field of accessible and open digital music archives.

2.   Open and Accessible Music Archives

Openness [2], in the digital world, has various domains to which it can relate: open source (for software), open access (for scientific output), open content, open educational resources (for learning materials). A central issue with all these forms of digital openness is that it is free available and has an open license[1]. Openness is based on a set of principles and practices that ensure outputs are made publicly available without cost or access restrictions. This core idea supports the democratization of knowledge and resources, making them accessible to everyone regardless of their location, financial situation, or social background. At its heart, openness is

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[1] OpenupEd (a service of EADTU, a European institutional association for online, open & distance higher education) definition of Digital Openness (last accessed: October 16, 2025),

https://www.openuped.eu/mooc-features/43-digital-openness

driven by the belief that knowledge should be treated as a public good—freely shared to encourage innovation, learning, and cultural development. The ideals of openness emphasize transparency and the free flow of information. By removing financial and structural barriers, openness promotes fairer access to knowledge, allowing people and communities around the world to both benefit from and contribute to our shared understanding.

The W3C[2] Web Accessibility Initiative (WAI[3]) outlines that digital resources must be accessible, usable, and inclusive, ensuring that they can be effectively used by all individuals, regardless of their abilities or circumstances. Accessibility [3] means providing equal access to people with or without physical, sensory, or cognitive impairments, allowing everyone to perceive, navigate, and interact with web content in a meaningful way. Usability [4] focuses on the overall user experience (UX) and the design of user interfaces (UI), emphasizing that interfaces should be intuitive and efficient for everyone, including those with disabilities. Inclusivity [5], on the other hand, extends beyond impairments to embrace the full spectrum of human diversity. This includes considering factors such as economic background, education level, geographic location, age, culture, language, religion, and personal identity or preferences. In essence, inclusivity is about creating digital environments where no one is excluded, and every form of diversity is respected and supported.

This work highlights the importance of applying the principles of openness, accessibility, usability, and inclusivity to musical archives, using two case studies drawn from the Ricordi Historical Archive as key examples. Musical archives present a particularly compelling area for exploration, given the rarity and fragility of their contents, often one-of-a-kind items that risk deterioration before they can be digitized. Traditionally, these archives have remained closed to the general public, accessible only to specialists using dedicated tools. This makes accessibility an especially pressing concern. Even when materials are successfully digitized and preserved, there remains a critical need to ensure they are not only available but also understandable and usable by a wider audience beyond academic or professional circles.

3. Related works about openness and accessibility in Music Archive

A growing body of research underscores the limited openness and accessibility of music archives, particularly for individuals with various types of disabilities. At the same time, the literature offers a range of strategies aimed at addressing these limitations.

One critical aspect of digitized archival content is metadata—typically presented as plain text used to describe and organize information. While metadata is widely employed for data classification, it is rarely designed with accessibility in mind [6]. However, when thoughtfully implemented, metadata can significantly enhance access for users with disabilities by improving searchability and supporting assistive technologies such as screen readers. Semantic HTML [7] and specialized attributes like title, alt, and lang are examples of how metadata can contribute to a more inclusive user experience [7].

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[2] World Wide Web Consortium (last accessed: October 16, 2025), https://www.w3.org/

[3] Web Accessibility Initiative (last accessed: October 16, 2025), https://www.w3.org/WAI/

Music archives frequently house autograph materials, original handwritten documents that are often difficult to interpret, yet hold historical value precisely because of their unique penmanship. Transcribing these texts is complex and traditionally relies on experts such as graphologists. Technological advancements, however, have enabled new approaches using Optical Character Recognition (OCR) [[9] and Handwritten Text Recognition (HTR) [10]. These methods allow handwritten content to be converted into machine-readable text, making it accessible to screen readers and text-to-speech systems. Such innovations are particularly valuable for visually impaired users or those who rely on auditory information. Recent progress in recognizing cursive writing has further expanded the potential for accessibility in this area [11]. One of the case studies featured later in this paper illustrates how archives often contain such documents, e.g. contracts, letters, and records, that benefit from these technologies.

Musical scores represent another essential category within music archives. Making these materials accessible involves both digitizing the visual content and converting it into structured digital formats. However, interpreting musical notation introduces unique challenges. The process known as Optical Music Recognition (OMR), the musical counterpart to OCR, faces difficulties due to the intricate and variable nature of music symbols [12]. Advances in this field, such as Music Object Recognition (MOR) [13] and end-to-end OMR models [14], are helping to overcome these challenges, including the transcription of complex, non-monophonic compositions.

Access to archival audio recordings presents additional concerns [15][16][[17], especially when balancing open access with copyright and ownership restrictions. Institutions like the Italian National Audio Record Library[4] are dedicated to preserving and providing public access to these sound documents. In contrast, other institutions, such as Teatro alla Scala, treat audio archives as just one facet of a broader archival collection. Audio recordings, serving as alternative interpretations of written scores, are valuable not only for blind and visually impaired (BVI) individuals but also for those who are unable to read music notation.

The diversity of materials housed in music archives is vast. Beyond scores and audio/video recordings, archives often include photographs, performance posters, librettos, metadata documenting timelines and casts, and more. When the archive is associated with an active music institution, such as an opera house, the collection may also feature stage props, set maps, costumes, accessories, and wigs. Achieving true openness and accessibility requires addressing the needs and formats of each of these elements individually.

To guide this process, five key steps toward comprehensive archival accessibility have been proposed [18]:

1. Acquiring and preserving significant collections,
2. Processing these collections internally with accessibility in mind,
3. Publishing detailed online descriptions,
4. Developing robust online finding aids, and
5. Making the collections themselves publicly accessible via the web.

While many music archives are making progress, the path forward requires the collaboration of numerous stakeholders with varying goals and priorities—factors that often complicate or delay the realization of fully accessible and open archival systems.

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[4] Istituto Centrale per i Beni Sonori ed Audiovisivi (last accessed: October 16, 2025), http://www.icbsa.it/.

4.   Two Scenarios

To explore the challenges and opportunities surrounding the openness and accessibility of music archives, we present two illustrative scenarios, both drawn from the Ricordi Historical Archive[5]. This prestigious Italian archive safeguards a remarkable collection of original manuscripts, including the handwritten scores of 23 out of 28 operas by Giuseppe Verdi, nearly the entire operatic oeuvre of Giacomo Puccini (excluding *La Rondine*), and a wide range of works by composers such as Vincenzo Bellini, Gioachino Rossini, Gaetano Donizetti, Luigi Nono, Franco Donatoni, Salvatore Sciarrino, and Sylvano Bussotti.

What makes the Ricordi Archive particularly noteworthy is the breadth and richness of its holdings, which offer a multifaceted lens on Italian cultural, artistic, and industrial history. Beyond musical manuscripts, the archive houses a vast array of materials connected to major operatic premieres, both in Italy and around the world, including costume and set designs, personal correspondence, production records, and other documents tied to the music publishing industry.

The archive's holdings span multiple artistic disciplines, from visual arts and stage design to decorative arts, offering valuable insight into costume history, jewelry design, scenic construction, and publishing practices. To give a sense of its scale, the collection includes:

- Around 8,000 scores
- Over 16,000 letters exchanged between composers, librettists, performers, and other cultural figures
- Approximately 10,000 set and costume designs
- More than 9,000 librettos
- Over 6,000 historical photographs
- An exceptional collection of Art Nouveau and Art Deco posters created by renowned artists of the time

This rich and varied landscape of materials highlights the complex nature of music archives and underscores the importance of considering openness and accessibility across multiple media types, including not just scores and letters, but also iconographic materials, monographs, props, and more.

To enhance public access, many of these visual materials have been digitized and made available through Internet Culturale[6], the official digital portal of the Italian National Library Service. Launched in 2005, this platform serves as a centralized gateway to the digital catalogs and collections of Italy's libraries, archives, and cultural institutions. Most of the digital content accessible via Internet Culturale is in the public domain and originates from digitization initiatives led by the partner libraries, which retain ownership of both the original items and their digital versions.

First Scenario

The first scenario explores the collection of letters and letter copies preserved in the Ricordi Historical Archive. While these materials may initially seem similar to general handwritten texts,

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[5] Archivio Storico Ricordi (last accessed: October 16, 2025), https://www.archivioricordi.com/

[6] Internet Culturale (last accessed: October 16, 2025), https://www.internetculturale.it/

they often contain embedded musical content, such as sketches of musical themes or editorial changes to compositions, adding layers of complexity and value.

Spanning from the early 19th to the late 20th century, the archive houses exchanged approximately 15,000 autograph letters between the Ricordi publishing house and prominent figures from the music and cultural world. Notable correspondents include composers like Giuseppe Verdi, Giacomo Puccini, Franz Liszt, and Luigi Nono; librettists such as Luigi Illica and Arrigo Boito; and famous performers including Teresa Stolz and Victor Maurel. The 20th-century portion of the archive features extensive correspondence with influential Italian cultural figures like Gian Francesco Malipiero and Ildebrando Pizzetti.

These letters are of great interest to specialists such as musicologists, historians, sociologists, and others, because they offer unique insights into artistic practices, professional relationships, and socio-economic contexts. Yet, expanding access to these materials for the broader public, including people with disabilities and those from underrepresented or disadvantaged backgrounds, is crucial for fostering more inclusive engagement with cultural heritage.

However, several significant challenges remain. Due to their historical value and fragile condition, the letters must be carefully preserved and are currently stored in a secure vault at the Ricordi Archive headquarters in Milan, accessible only by appointment. The paper and ink were never intended for long-term durability, so physical handling must be minimized.

Even when access is granted, legibility becomes the next hurdle. The handwritten nature of the documents can make interpretation difficult. For example, Giacomo Puccini's handwriting is notoriously hard to decipher, even for native Italian readers. One letter, (see Figure 1), dated July 17, 1913, and sent from Viareggio to publisher Tito Ricordi, illustrates these issues clearly (available online at Internet Culturale)[7].

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[7] The above-mentioned letter is consultable here (last accessed: October 16, 2025):
https://www.internetculturale.it/jmms/iccuviewer/iccu.jsp?id=oai%3Awww.internetculturale.sbn.it%2FTeca%3A20%3ANT0000%3AMI0285_PUCCINII-056
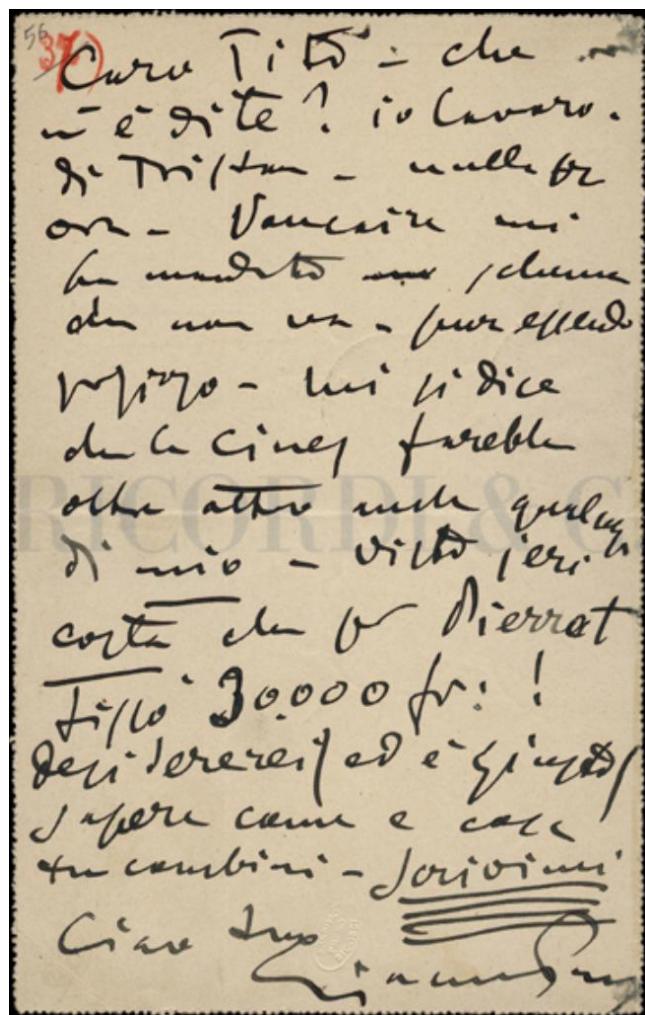
Figure 1 Handwritten letter sent by Puccini to the publisher Tito (II) Ricordi on July 17, 1913. Courtesy of the Ricordi Historical Archive.

The transcription, courtesy of the Ricordi Historical Archive, is:

> Caro Tito - che
> n'è di te? io lavoro.
> di Tristan - nulla per
> ora - Vaucaire mi
> ha mandato uno schema
> che non va - pur essendo
> prolisso - mi si dice
> che la Cines farebbe
> oltre altro anche qualcosa
> di mio - visto ieri
> Costa che per Pierrot
> fissò 30.000 fr.!
> desidererei (ed è giusto)
>
> sapere come e cosa
> tu combini - Scrivimi
>
> Ciao tuo
> Giacomo Pucci[ni]

A possible translation into English is:

> Dear Tito, what's up with you? I am working. From Tristan, nothing for
> now. Vaucaire sent
>
> me a draft that is not good, despite being verbose. I am told that Cines
> would do something
>
> of mine in addition to other things. Yesterday I saw Costa who settled
> on 30,000 francs for
>
> Pierrot! I would like to know (and it's right) how and what you are
> doing. Write to me.
>
> Ciao, your Giacomo Pucci[ni]

In this letter, Puccini discusses his opera project *Il trittico*, referencing figures like Tristan Bernard, who initially suggested a fairy tale for one part of the trilogy. Though Puccini ultimately chose works by Giovacchino Forzano (*Suor Angelica* and *Gianni Schicchi*), the letter also mentions Maurice Vaucaire, who translated some of Puccini's works into French, and the film *Histoire d'un Pierrot*, scored by Mario Pasquale Costa and released in 1914.

This single letter illustrates several broader accessibility issues:

- Historical language and stylistic nuances, even for a native speaker, can be difficult to understand.
- Contextual knowledge is often necessary to interpret references to people, places, cultural works, and even abbreviations like "fr." for francs.

Despite these obstacles, such documents offer invaluable perspectives on Puccini's network, creative process, and the socio-cultural dynamics of his time. They also provide a more personal glimpse into the composer's character and relationships.

A final challenge lies in the searchability and indexing of these handwritten materials. Without detailed metadata, finding specific content—like every instance where Puccini discusses payments or collaborations—requires expert familiarity with the entire archive. As discussed earlier, the use of descriptive and accessibility-focused metadata could greatly enhance navigation and usability for a wider range of users.

Second Scenario

The second scenario focuses on the openness and accessibility of musical scores, particularly autograph manuscripts. As noted earlier, physical access to these invaluable cultural artifacts is severely restricted. Originals, such as the scores of Verdi or Puccini, are made from fragile, time-sensitive materials and are typically not accessible to the general public. These documents are preserved with great care and displayed only on special occasions, such as curated exhibitions, where viewers can see a limited selection of open pages through protective glass.

Beyond physical access, scores pose unique challenges in terms of symbolic accessibility, especially for blind or partially sighted musicians. Traditional music notation is highly visual, and alternative formats are essential for accessibility. Two major options are:

- Large print scores (Modified Stave Notation, MSN [19]), which offer adaptable layouts for musicians with limited vision. These can be customized by enlarging symbols, adjusting spacing, or modifying line thickness to enhance readability.
- Braille music [20], which adapts the literary braille system to musical notation, enabling blind musicians to read music through touch.

However, these formats are not easily integrated into traditional music archives, which prioritize preserving original materials in their authentic form. The challenge becomes even greater with autograph scores, which are typically handwritten and contain unique annotations, revisions, and visual cues absent from published editions. For both scholars and enthusiasts, elements like the composer's handwriting, working notes, and corrections provide critical insight into the creative process—details that are difficult to convey in accessible formats.

Rendering these manuscripts accessible for blind or visually impaired (BVI) individuals presents significant hurdles. While it's technically possible to offer tactile or digital alternatives, such as embossed pages or high-contrast images, capturing the expressive nuances of a composer's handwriting remains an open problem. Unlike symbolic notation, which can be translated into braille, visual and stylistic details resist straightforward conversion.

To illustrate these complexities, we turn once again to the Ricordi Historical Archive, focusing on a handwritten page from Puccini's *Madama Butterfly* (see Figure 2)[8]. This page not only features the core musical notation but also shows additions, deletions, and editorial marks made in colored pencil, traces of the composer's evolving thought process. Such rich, multi-layered content underscores the challenge of ensuring accessibility without compromising the authenticity and integrity of the original materials.

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[8] The page is publicly available at
https://www.internetculturale.it/jmms/iccuviewer/iccu.jsp?id=oai%3Awww.internetculturale.
sbn.it%2FTeca%3A20%3ANT0000%3AMI0285_MS_RARI_G5_01-03 (last accessed: October 16, 2025).
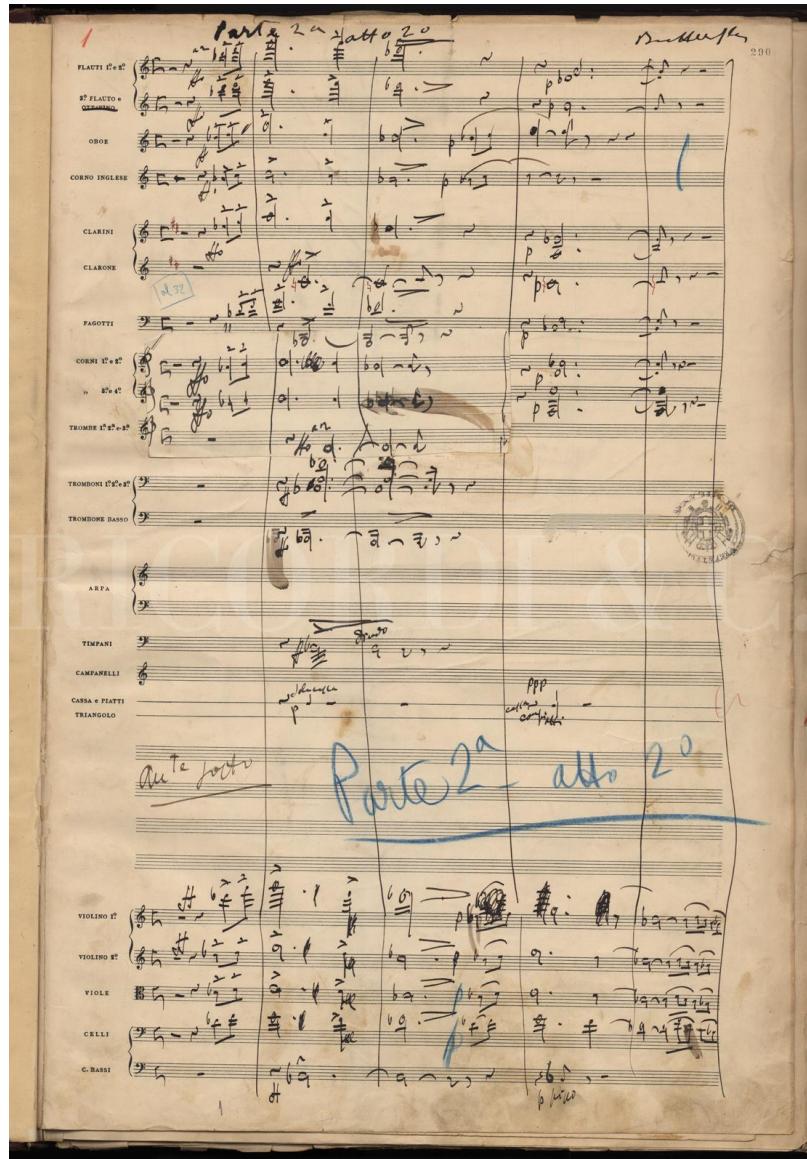
Figure 2 Giacomo Puccini, Madama Butterfly, Act 2, Part 2, page "03-Carta : 290r". Courtesy of the Ricordi Historical Archive.

5.   Multilayer Formats

Among the technological solutions capable of enhancing accessibility and inclusivity in digital music archives, multilayer representation formats stand out for their ability to encode the

richness and complexity of musical content across diverse modalities. One prominent example is the IEEE 1599 standard, an XML-based format designed to support a comprehensive and synchronized description of music information through multiple parallel layers. These include metadata, logical and structural descriptions, notation, performance data, and audio/video recordings.

IEEE 1599, in accordance with other similar formats [21], defines a six-layer model that aims to capture the multifaceted nature of musical works. Each layer focuses on a specific domain of information. Specifically, the general layer contains metadata about the composition, such as title, composer, and date. The logic layer encodes the abstract musical content as conceived by the composer, typically in the form of organized musical events (e.g., notes, rests, articulations), independent of any specific notation. The structural layer describes the internal architecture of the piece, including thematic sections, formal divisions, and hierarchical relationships such as motifs or movements. The notational layer represents one or more graphical scores (manuscripts, printed editions, or digitally engraved versions), each potentially with its own layout and notation style. The performance layer records data related to human or computer performances, such as MIDI sequences or control parameters. Finally, the audio layer provides links to recorded performances, either as audio files or synchronized audiovisual content. These layers are not isolated; rather, they are interconnected through a shared structure that enables precise alignment and navigation across representations of musical events.

The core idea behind multilayer formats is that a single musical event can be represented in several ways, each suited to different user needs or interpretive goals. IEEE 1599, for instance, employs a central data structure, called the *spine*, that acts as a common reference point for linking heterogeneous event descriptions across layers. This star-model approach enables inter-layer and intra-layer synchronization, thus fostering seamless navigation and cross-referencing among representations.

The IEEE 1599 format has also demonstrated its value in public exhibitions, where it serves as a powerful tool for engaging audiences that are not necessarily musically trained, thus providing access to archive content. A notable example is its application at La Scala Theater in Milan in collaboration with Archivio Storico Ricordi (see Figure 3). In several exhibitions, IEEE 1599 was used to synchronize digital scores, audio recordings, and visual content within a unified framework.[9] This approach enabled visitors to explore operatic works not only by listening to music, but also by following the corresponding notated score and accessing related archival materials in real time. The format's capacity to encode both symbolic and performance data, along with metadata and graphic representations, allowed for a rich, multimodal presentation that enhanced audience engagement and deepened understanding of the repertoire. Such implementations demonstrate the potential of IEEE 1599 in promoting cultural heritage through immersive, accessible digital experiences.

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[9] A list of cultural initiatives using IEEE 1599 is available at https://ieee1599.lim.di.unimi.it/practice_exhibitions.php (last accessed: October 16, 2025).
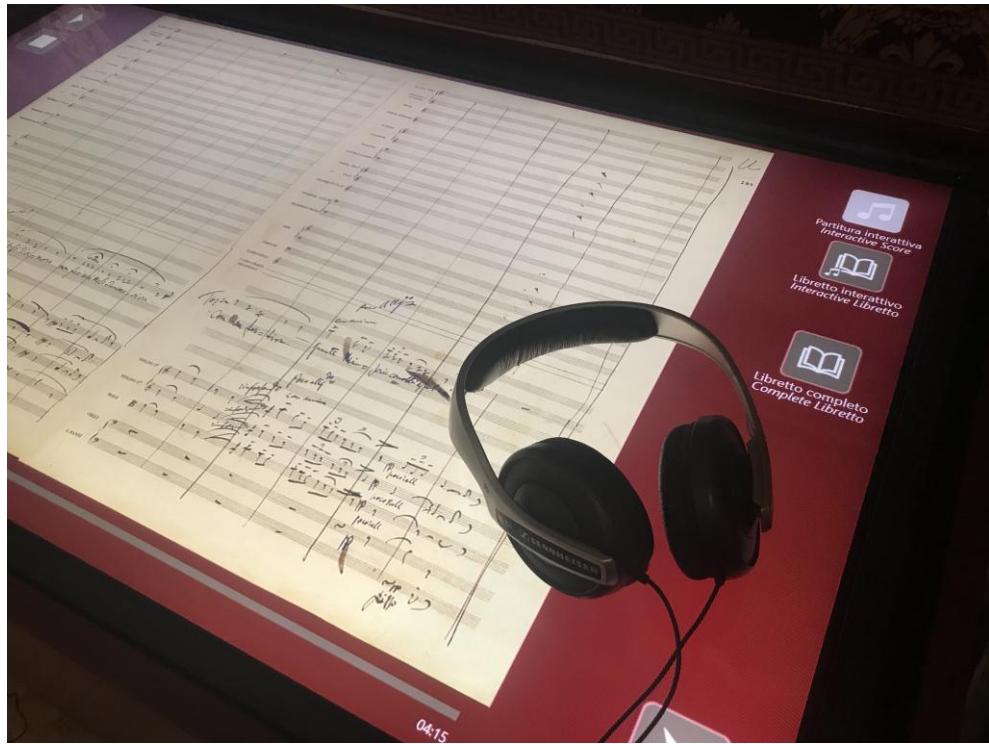
Figure 3. A multimedia installation based on IEEE 1599 at the exhibition "Tosca, primadonna all'opera", Museo Teatrale alla Scala, Milan, November 2019.

Example of an IEEE 1599 Document

In this section, we will show an XML skeleton illustrating a typical IEEE 1599 document's overall structure. For a more detailed discussion, the interested reader is invited to refer to the official documentation or several papers dealing with this subject [22]. The aim here is to present the main syntactic features and approaches adopted in the format, in order to demonstrate its applicability to the field of Inclusive and Accessible Music Archives. This aspect will be further explored in the following section.

The six-layer model mentioned above finds a direct correspondence in the six sub-elements of the root node <ieee1599>. To satisfy the XML validity requirement, it is not necessary for all layers to be present. This flexibility allows for the creation of documents in which, for instance, a traditional musical notation (Logic layer) does not exist or is intentionally omitted, while alternative forms of score representation (Notational layer) and audio or video objects (Audio layer) are provided.

It is worth noting that the *spine*, part of the Logic layer, contains a list of unique identifiers to which the other layers refer, thus providing alternative descriptions of the same musical events. This concept, already explored in several other publications concerning innovative multimedia experience and music education, is here analyzed for the first time from the perspective of musical content accessibility and inclusion. The presence of symbolic descriptions (for example, musical symbols of the Common Western Notation) easily allows their translation (for instance, the writing of pitches according to the letter-name system or solmization syllables) and alternative representation (such as in the form of color notation or Braille).

```xml
<?xml version="1.0" encoding="UTF-8"?>
<!DOCTYPE ieee1599 SYSTEM "http://www.lim.di.unimi.it/IEEE/ieee1599.dtd">
<ieee1599 version="1.0" creator="Luca A. Ludovico">
    <general>
        <description>
            <main_title>Gottes Macht und Vorsehung</main_title>
            <author type="composer">Beethoven, Ludwig van</author>
            <author type="poet">Christian Fürchtegott Gellert</author>
            <number>5</number>
            <work_title>6 Geistliche Lieder Von Gellert</work_title>
            <work_number>op. 48</work_number>
        </description>
    </general>
    <structural>...</structural>
    <logic>
        <spine>
            <event id="clef_1" timing="0" hpos="1"/>
            <event id="timesig_1" timing="0" hpos="5"/>
            <event id="keysig_1" timing="0" hpos="NULL"/>
            <event id="v1_e0" timing="0" hpos="6"/>
            <event id="v1_e1" timing="4" hpos="6"/>
            ...
        </spine>
        <los>
            <agogics event_ref="timesig_1">Mit Kraft und Feuer.</agogics>
            <staff_list>
                <staff id="staff_1">
                    <clef shape="G" event_ref="clef_1" staff_step="2"/>
                    <time_signature event_ref="timesig_1">
                        <time_indication num="2" den="2" vtu_amount="8"/>
                    </time_signature>
                    <key_signature event_ref="keysig_1">
                        <flat_num number="0"/>
                    </key_signature>
                </staff>
                ...
            </staff_list>
            <part id="soprano">
                <voice_list>
                    <voice_item id="soprano_voice1" staff_ref="staff_1"/>
                </voice_list>
                <measure number="1">
                    <voice voice_item_ref="soprano_voice1">
                        <rest event_ref="v1_e0" staff_ref="staff_1">
                            <duration num="1" den="2"/>
                        </rest>
                        <chord event_ref="v1_e1">
                            <duration num="1" den="2"/>
                            <notehead staff_ref="staff_1">
                                <pitch step="C" octave="6"/>
                            </notehead>
                        </chord>
                    </voice>
                </measure>
                ...
            </part>
            <part id="piano">...</part>
            <lyrics part_ref="soprano" voice_ref="soprano_voice1">
                <syllable start_event_ref="v1_e1" end_event_ref="v1_e1">Gott</syllable>
                <syllable start_event_ref="v1_e2" end_event_ref="v1_e2">ist</syllable>
                ...
            </lyrics>
        </los>
    </logic>
    <notational>
        <graphic_instance_group description="Finale">
            <graphic_instance file_name="gottes/gottes_finale.tif"
                file_format="image_tiff" encoding_format="image_tiff" position_in_group="1" measurement_unit="pixels">
                <graphic_event event_ref="v1_e0" upper_left_x="646" upper_left_y="616" lower_right_x="702" lower_right_y="648"/>
                <graphic_event event_ref="v1_e1" upper_left_x="764" upper_left_y="608" lower_right_x="818" lower_right_y="712"/>
                ...
            </graphic_instance>
        </graphic_instance_group>
        <graphic_instance_group description="Dover">...</graphic_instance_group>
    </notational>
    <performance>
        <midi_instance file_name="gottes/gottes.mid" format="1">
            <midi_mapping part_ref="soprano" track="1" channel="1">
                <midi_event_sequence division_type="timecode" division_value="1024" measurement_unit="ticks">
                    <midi_event event_ref="v1_e0" timing="0"/>
                    ...
                </midi_event_sequence>
            </midi_mapping>
        </midi_instance>
    </performance>
    <audio>
        <track file_name="gottes/gottes_midi.mp3" file_format="audio_mp3" encoding_format="audio_mpeg">
            <track_indexing timing_type="seconds">
                <track_event start_time="0.00" event_ref="v1_e0"/>
                <track_event start_time="1.00" event_ref="v1_e1"/>
                ...
            </track_indexing>
        </track>
    </audio>
</ieee1599>
```

Multilayer Formats for Inclusive and Accessible Music Archives

Traditionally, multilayer formats have been designed and applied to offer integrated and complementary representations of musical information to users without impairments. In the context of this work, however, the multilayer approach serves a different and equally important purpose: it enables alternative access channels that can accommodate users with sensory, cognitive, or motor impairments. This shift in perspective from enhancement to enablement highlights the potential of multilayer structures as tools for accessibility.

The IEEE 1599 format holds significant promise for improving accessibility in music interaction, particularly for individuals with physical and cognitive impairments. Thanks to its multilayer structure and support for synchronized, multimodal content, IEEE 1599 enables tailored user experiences that can accommodate diverse abilities and needs. By decoupling the various dimensions of musical information, it becomes possible to provide alternative or complementary representations of the same musical content. This flexibility opens new possibilities for inclusive archival access, making music more reachable to those who face sensory, motor, or cognitive barriers. IEEE 1599's capacity to host multiple instances within each layer supports personalization and adaptability, essential principles in inclusive design.

For individuals with visual impairments, traditional sheet music, typically rendered as printed notation, presents an obvious barrier. IEEE 1599 addresses this by allowing the symbolic layer to be interpreted and rendered in alternative modalities. For example, the symbolic content can be sonified through screen reader–compatible software or converted into Braille music notation via specialized transcription tools. Moreover, since the format supports synchronized playback of audio and symbolic data, it becomes possible to navigate a score using auditory cues alone, with the system announcing measure numbers, note names, dynamics, or other relevant annotations as the music progresses. This facilitates both passive listening and active learning, and it enables users with visual impairments to engage with music independently and interactively.

In addition to supporting users with complete vision loss, IEEE 1599 can accommodate the needs of individuals with low vision or color vision deficiencies. As an example, it is possible to dynamically adjust the visual representation of the score without compromising the integrity of the underlying musical data. Users with low vision, for instance, may benefit from high-contrast rendering, enlarged notation, or simplified layouts tailored to their specific visual capabilities. Similarly, for colorblind users, color schemes used in annotated scores or educational overlays, such as pitch-color mappings, can be customized to ensure perceptual accessibility, avoiding problematic color pairs (e.g., red-green) and replacing them with alternatives or patterns.

For individuals with aural impairments, especially those who are deaf or hard of hearing, traditional music experiences centered on listening are often inaccessible or limited. However, IEEE 1599 offers tools to reframe musical content in ways that are not exclusively reliant on auditory perception. By leveraging the symbolic and graphical layers, users can engage with music visually through animated scores, gesture-based representations, or real-time visualizations of rhythm, pitch, and dynamics. A deaf user might follow a synchronized graphic score while receiving haptic feedback for rhythmic elements, or watch an animated cursor highlighting the current note in the symbolic layer as it progresses in time, or enjoy an alternative graphical representation based on the logic layer (see Figure 4). Furthermore, the lyrics sub-layer can be rethought to enrich the musical experience with textual annotations, descriptions of expressive intent, or contextual information about the composition. In this way, IEEE 1599 promotes a multimodal approach to music that expands participation beyond hearing-based modalities, supporting inclusive music appreciation and education for the aurally impaired.
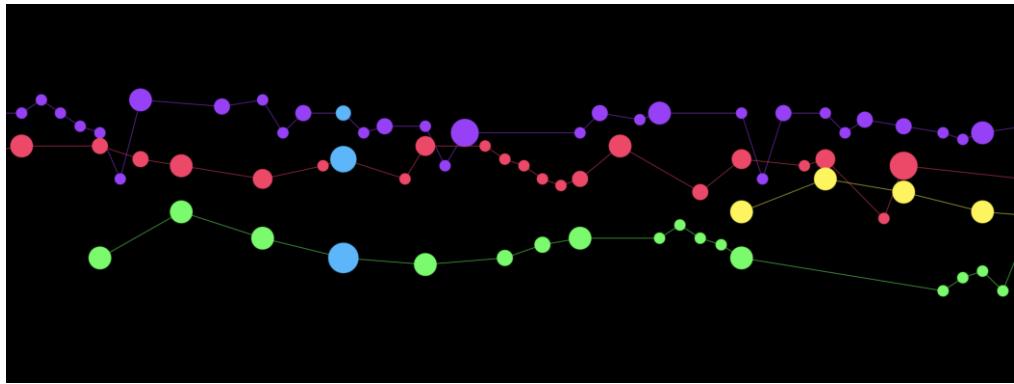
Figure 4. An example of an alternative graphical representation for logic-layer content.

Motor impairments can significantly limit a person's ability to interact with traditional musical instruments, printed scores, or even standard user interfaces for digital music systems. IEEE 1599 helps address these barriers by enabling alternative modes of interaction with music that do not rely on fine motor skills. For instance, its multilayer structure allows for simplified or adaptive control interfaces (e.g., switches, eye-tracking devices, and single-button systems) that trigger synchronized audio, symbolic, and visual outputs. A user may, for example, navigate through a piece of music using a single switch input, receiving auditory feedback from the audio layer while simultaneously viewing note information or performance cues from the graphical or symbolic layers [23]. Moreover, the integration of logic and structure layers can enable the creation of simplified versions of a composition suited to the user's physical capabilities while preserving musical coherence. In educational and rehabilitative contexts, this can empower users with motor impairments to explore, understand, and even perform music in meaningful and personalized ways.

For individuals with cognitive impairments, such as difficulties with memory, attention, language processing, or executive functioning, engaging with music can present unique challenges. Traditional scores may be too dense or complex, and standard presentation methods may not align with their expectations. IEEE 1599 provides a flexible framework to mediate this interaction by allowing the creation of simplified, multimodal, and customizable representations of musical content. For example, the symbolic layer can be used to extract and highlight structural elements, like repeating sections, thematic material, or simplified melodies. Furthermore, an ad-hoc encoding can support textual cues, icon-based annotations, or step-by-step instructions adapted to the user's cognitive profile. Finally, the temporal synchronization across layers makes it possible to create guided listening experiences, where visual cues, audio playback, and interactive elements are tightly coordinated. These features reduce cognitive overload and can help maintain focus and motivation. As such, IEEE 1599 facilitates the design of music-based applications that are not only more accessible but also more effective for users with diverse cognitive needs.

Inclusivity is also promoted through the format's neutrality with respect to representation hierarchies: no single layer is privileged over others. This allows for the coexistence of Western classical notation with alternative notational systems, oral traditions, or contemporary multimedia compositions. Moreover, the ability to integrate culturally specific metadata and diverse performance practices aligns with the goals of inclusive heritage preservation.

6. Conclusion

Unlocking music archives holds great value across several areas, including cultural heritage, scholarly research, education, and personal enrichment. Making these archives accessible not only fosters broader engagement with music but also promotes deeper insight into its societal impact.

In this context, the design of user interfaces is crucial. Well-designed interfaces can greatly enhance usability, support inclusive access, and reflect cultural diversity. As digital technologies continue to evolve, it becomes essential to prioritize accessible platforms that eliminate barriers in the exploration of music archives.

The concepts of openness and accessibility are gaining increasing attention. While open access to scientific knowledge and public data has been widely discussed, accessibility, especially for users with impairments, is now equally prominent. Encoding techniques like braille music, enabling technologies such as screen readers, and software environments such as the Web Speech API demonstrate the potential to make digital music collections more inclusive.

To truly realize these goals, archive managers, institutions, and policymakers must embrace inclusive strategies that ensure open and enjoyable access for all users, including those with disabilities.

One promising avenue to address these challenges lies in adopting multilayer formats, which represent a promising foundation for the development of inclusive music archives. By enabling synchronized, multi-perspective representations of musical works, they allow for richer, more accessible, and more equitable interactions with musical heritage.

It is important to clarify that these formats do not directly provide assistive interfaces but rather structure musical information in a way that greatly enhances the design and functionality of such interfaces. By organizing music into distinct yet synchronized layers, they enable developers to build adaptive systems that respond to a wide range of user needs and abilities. Assistive technologies such as eye trackers, screen readers, or switch-based input devices can leverage their rich, structured content to present music in alternative forms that match individual preferences and capabilities. In this sense, multilayer formats act as an enabling foundation: their expressiveness and modularity support the development of inclusive applications that go far beyond conventional music consumption, making it a powerful resource for improving accessibility in music education, performance, and cultural heritage dissemination.

Compared to traditional formats such as PDF scores or standalone MP3 files, multilayer formats offer significant advantages in terms of flexibility, interactivity, and support for multimodal access. They enable the construction of digital archives that are not only comprehensive in scope but also responsive to the diverse needs of users: students, scholars, performers, and members of marginalized communities alike.

7. Acknowledgements

References

[1] Faschi, Vanessa, Federico Avanzini, and Luca Andrea Ludovico. 2025. Unlocking Music Archives: Openness and Accessibility. IRCDL 2025: 21st Conference on Information and Research Science Connecting to Digital and Library Science, February 20-21 2025, Udine, Italy 3937: 1–13.

[2] Dillon, Cy. (2014). The Virtues of Openness: Education, Science, and Scholarship in the Digital Age Michael A. Peters and Peter Roberts. portal: Libraries and the Academy. 14. 656-657. 10.1353/pla.2014.0024.

[3] Kulkarni, Mukta. (2018). Digital Accessibility: Challenges And Opportunities. IIMB Management Review. 31. 10.1016/j.iimb.2018.05.009.

[4] Andŕe Kilchenmann, Flavie Laurens, Lukas Rosenthaler, "Digitizing, archiving... and then? Ideas about the usability of a digital archive" in Proc. IS&T Archiving 2019, 2019, pp 146 - 150, https://doi.org/10.2352/issn.2168-3204.2019.1.0.34

[5] Nemer, David. (2015). From Digital Divide to Digital Inclusion and Beyond. The Journal of Community Informatics. 11. 10.15353/joci.v11i1.2857.

[6] K. Jones, Metadata, digital museum spaces and accessibility for persons with impairments, Pathfinder: A Canadian Journal for Information Science Students and Early Career Professionals 3 (2022) 111–115. URL: https://journals.library.ualberta.ca/www.pathfinderjournal.ca/index.php/pathfinder/article/view/58.

[7] S. Kawanaka, M. Kobayashi, H. Takagi, C. Asakawa, Accessibility commons: a metadata repository for web accessibility, SIGWEB Newsl. 2009 (2009). URL: https://doi.org/10.1145/1514984.1514985.

[8] Casario, M., Elst, P., Brown, C., Wormser, N., Hanquez, C. (2011). HTML5 Structural and Semantic Elements. In: HTML5 Solutions: Essential Techniques for HTML5 Developers. Apress. https://doi.org/10.1007/978-1-4302-3387-9_3

[9] J. Memon, M. Sami, R. A. Khan, M. Uddin, Handwritten optical character recognition (ocr): A comprehensive systematic literature review (slr), IEEE access 8 (2020) 142642–142668.

[10] G. Retsinas, G. Sfikas, B. Gatos, C. Nikou, Best practices for a handwritten text recognition system, in: International Workshop on Document Analysis Systems, Springer, 2022, pp. 247–259.

[11] A. Sai, K. S. S. Harshith, B. Ommi, G. Y. Kiran, A. T, Advanced handwritten text recognition for cursive writings with spelling correction module, in: 2023 IEEE 9th International Women in Engineering (WIE) Conference on Electrical and Computer Engineering (WIECON-ECE), IEEE, New York, 2023, pp. 1–6.

[12] J. Calvo-Zaragoza, J. C. Martinez-Sevilla, C. Penarrubia, A. Rios-Vila, Optical music recognition: Recent advances, current challenges, and future directions, in: International Conference on Document Analysis and Recognition, Springer, 2023, pp. 94–104.

[13] L. Tuggener, R. Emberger, A. Ghosh, P. Sager, Y. P. Satyawan, J. Montoya, S. Goldschagg, F. Seibold, U. Gut, P. Ackermann, et al., Real world music object recognition, Transactions of the International Society for Music Information Retrieval 7 (2024) 1–14.

[14] A. Ríos-Vila, J. Calvo-Zaragoza, T. Paquet, Sheet music transformer: End-to-end optical music recognition beyond monophonic transcription, 2024. arXiv:2402.07596.

[15] V. Danielson, Stating the obvious: lessons learned attempting access to archival audio collections, Folk heritage collections in crisis (2001) 4–14.

[16] S. Calamai, V. Ginouvès, P. M. Bertinetto, Sound Archives Accessibility, Springer International Publishing, Cham, 2016, pp. 37–54. URL: https://doi.org/10.1007/978-3-319-29544-2_3.

[17] A. Tovell, Audio preservation and access: Overcoming the challenges, in: Audio Engineering Society Conference: 2018 AES International Conference on Audio Archiving, Preservation & Restoration, P-8, Audio Engineering Society, 2018.

[18] J. W. Suter, B. R. Buckley, D. Carmicheal, J. Corsaro, E. McHale, S. O'Brien, K. Roe, F. J. Stielow, Working with Folk Materials in New York State: A Manual for Folklorists and Archivists, New York Folklore Society, 1994.

[19] S.-A. Zimmermann, Modified stave notation–an approach to making stave notation more accessible to users who are partially sighted, in: Computers Helping People with Special Needs: 9th International Conference, ICCHP 2004, Paris, France, July 7-9, 2004. Proceedings 9, Springer, Berlin, 2004, pp. 236–239.

[20] H.-Y. Park, How useful is braille music?: A critical review, International Journal of Disability, Development and Education 62 (2015) 303–318.

[21] Haus, Goffredo, and Maurizio Longari. 2005. "A Multi-Layered, Time-Based Music Description Approach Based on XML." Computer Music Journal 29 (1): 70–85. https://doi.org/10.1162/comj.2005.29.1.70

[22] A. Baratè, G. Haus, L.A. Ludovico, A Critical Review of the IEEE 1599 Standard, Computer Standards & Interfaces 46 (2016) 46–51.

[23] Ludovico, Luca Andrea, Vanessa Faschi, Federico Avanzini, Emanuele Parravicini, and Manuele Maestri. 2025. "From Push Buttons to Notes: A Hardware/Software Ecosystem for Inclusive Music Education." *CSEDU 2025. Proceedings of the 17th International Conference on Computer Supported Education* 1: 650–660. https://doi.org/10.5220/0013489300003932