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NOT ONLY PAPER: COMPUTER ENGINEERING TO CONTRAST THE ECLIPSE OF THE AUDIO DOCUMENTS. THE CASE STUDY OF A PERSONAL ARCHIVE

1. Introduction

The introduction of electronic and information technology into art gave rise to new challenges for archives and for the preservation of cultural heritage. If technology has been a stimulus to new forms of artistic creation, at the same time it also becomes the cause of their rapid deterioration and an ever shorter life expectancy. Their great dependence on technology makes them particularly vulnerable and there is a serious risk of losing an important part of today's culture. Music, also due to its immaterial nature, was one of the earliest types of art to explore the creative use of new technologies: new musical forms have assumed an increasingly artistic importance since the second half of the last century (Bressan, Canazza 2014).

The conservation of this heritage presents very different problems from those posed by traditional artworks. To safeguard this heritage, it is not enough to digitize the content of recordings and documents, but the performance practice must also be preserved. That is, it is necessary to preserve all the elements that allow us to understand and reconstruct the set of production processes of the work, from the specific details of the composition to the technological system and the operating practices used (Pretto *et al.* 2018).

Notice that the performative or behavioral aspect is rarely documented in detail, and when it is, the documentation refers to the technology of the time in which the work was produced. Often only the author's notes and annotations in his personal archive are available. Therefore, every effort must be made to keep and make accessible all information relating to the work, the equipment used and the performance practice. To this purpose it is very important to properly address the problems of personal archives preservation and access (Orio *et al.* 2009).

This paper is organized as follows: the first part discusses the main issues for the conservation of audio documents; then it presents a well-tuned *re-mediation* methodology, an artificial intelligence based approach to detect audio tape *discontinuities* and finally access tools for renovating the listening experience of old analogue media. The second part first discusses the issues for personal archive preservation in the digital age, focusing on archive content and inventory description and detailing how audio documents should be preserved. Then we present, as a case study, the design and development of an information management system allowing the long-time preservation

and the access to different documents, among them: audio, letters, musical scores, and manuscripts. Finally we draw some concluding remarks and give directions for further work.

2. Computer engineering and audio documents

Many documents are in the analog domain (e.g., paper, magnetic tapes, phonographic discs, film). These must be transferred in the digital domain, in other formats with different encoding (re-mediation), for public access (access copy) and long-term preservation (preservation master, stored in different copies and locations, locally and in the cloud).

The fifty years of experience gained at the Centro di Sonologia Computazionale (CSC) in music production has led to the definition of a scientific methodology of the audio documents active preservation (Fantozzi *et al.* 2017) based on two pillars: (a) the multidisciplinary nature of the team researchers involving engineers, musicians, musicologists, composers and archivists, and (b) the philological accuracy with which the digital tools developed preserve the history of the transmission of the audio document, thanks to the set of metadata and ancillary information included in the digital master conservation (Verde *et al.* 2018).

The original document active preservation phase must produce a digital conservation master that meets the requirements of reliability, accuracy and authenticity. An exhaustive documentation of the entire conservation process, including a description of any restorative interventions carried out on the original support, assumes particular importance in order to preserve the history of the transmission of the object under protection. In accordance with international provisions, the transfer process is divided into three phases: preparation of the support, transfer of the signal and processing of the collected data (Bressan, Canazza 2013). Each phase in turn includes many steps that involve different professional figures: archivists, chemists, composers, engineers, musicians, musicologists, audio technicians. The result is a multidisciplinary work whose success also depends on the dissemination and sharing of these practices among the archives.

Even before the analog/digital (A/D) transfer of the signal, complete photographic documentation must be collected to testify the conditions in which the material is concerned, and information on the support that would be lost with its future deterioration (any signs written on tape, size, etc.). The study of the degradation mechanisms of magnetic tapes is a wide and still open field that must take into account the chemical characteristics of each material (Bressan, Canazza 2015; Bressan *et al.* 2016). Equally complicated is the measure of a syndrome degree in a tape, some of which, such as Soft Binder Syndrome-Sticky Shed Syndrome (SBS-SSS), can only be diagnosed at the

time of A/D transfer. Actions such as the visual inspection of the document and any recovery treatments, cannot be underestimated and must be entrusted to specialized personnel able to access appropriately equipped chemical laboratories. It is necessary to objectively describe the state of conservation and define a priority order of intervention before proceeding with the A/D transfer of the signal. The use of modern reproduction machines appropriately calibrated and compliant with the recording format of the document in question is recommended. In particular cases, such as the collections of electroacoustic music archives, it is advisable to combine the audio monitoring of the document with the video recording of the tape running on the player. The video will integrate the series of ancillary information that complete the digital conservation master and may be future object of study, leaving traces of any corruption or signs of processing present on the tape (which can be extraordinarily informative from the musicological point of view). Extracted data must be validated with appropriate software in order to ensure the authenticity of the document and help in the philological study of the document.

The preservation of audio documents has as its natural objective of allowing scholars and/or the general public to access the information stored. This phase cannot involve the preservation master, which must be left unaltered: appropriate access copies must therefore be created. Only the latter can be used by third parties and can be subject to digital restoration for concert purposes or for a commercial edition.

2.1 *Re-mediation*

The archives must (i) minimize the information loss with respect to the original document (audio information, metadata and contextual information), and (ii) keep track of the document provenance, of the re-mediation process (Fig. 1) and of the re-mediation system.

The preservation master includes: (i) a list of all the files contained in it, information on the origin of the original document, the data relating to each audio file, the location where the A/D transfer took place and the technician responsible for the transfer; (ii) the audio data at high resolution (96kHz/24bit); (iii) photographic documentation of the support, its case, box or envelope and accompanying material, and a technical sheet describing the transfer; (iv) video recording of the tape running on the player; (v) first level metadata: three types of audio data checksum; second level metadata: technical specifications of the file formats included in the preservation master (BWF/WAVE, pdf, ...).

2.2 *Artificial Intelligence for musical cultural heritage*

An initial visual inspection of the original (analogue) document by the technician may show the presence of several alterations of the carrier (tape,

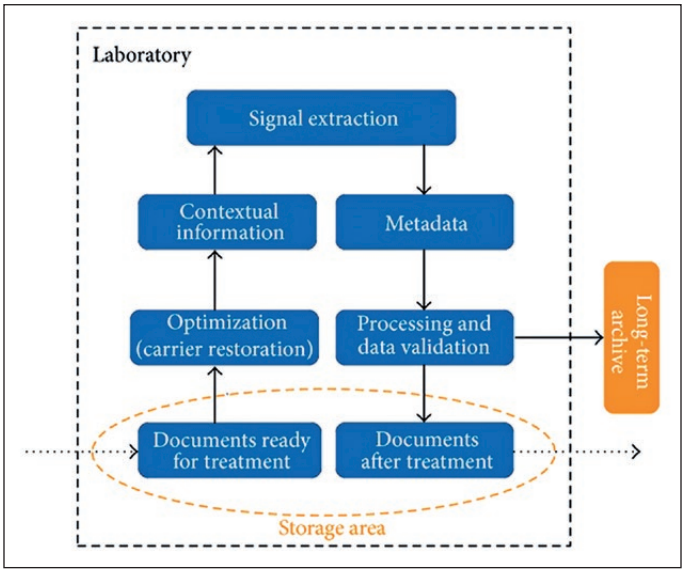

Fig. 1 – Scheme of the re-mediation process. Each step is articulated in procedures and sub-procedures.

film, paper) such as blocking, leafing, windowing, spoking, or embossing, fungi and molds. This first stage is essential to determine whether or not the carrier has to be restored prior to digitization. Nonetheless, some corruptions and other *discontinuities* can only be detected during the digitization process, after the visual inspection. Consequently, both these two stages become particularly important to evaluate the preservation condition of the document.

The term Point of Interest (POI) will be used henceforth to indicate all the carrier alterations (or discontinuity or irregularities) from its original manufacture state that are visually detectable. Although not strictly an alteration, manufacturers may print their brand name or logo on the carrier itself (on the back of the tape, on the box of the film, on the envelope of the paper). As necessary and useful information for the identification of the document, brand markings will also be considered a discontinuity.

All the POI included in the methodology defined at CSC during are listed below:

– L-M splices (*lmsp*). Splices of leader tape to magnetic tape (or vice versa).
– M-M splices (*mmsp*). Splices of magnetic tape to magnetic tape.
– Brands on tape (*b*). Most of the brands consist of the full name of the tape manufacturer, logo, or tape model codes. The brand changes in size, shape, and color, depending on the tape used, thus complicating the classification task.

Fig. 2 – Area of the tape recorder reading head.

– Ends of tape (eot). It refers to what happens when the tape reaches its end of playback, at which point it is neither under tension nor in contact with the capstan and pinch roller. The distinguishing visual characteristic of this class is the tape coming free – or completely detached – from the capstan.
– Damaged tape (*da*). It groups all kinds of damages on the surface of the tape and alterations of the tape shape. This class includes:
  a) Ripples. This is formally known in the cataloguing rules as "kink" or "wrinkle," these may be a single crease on a layer of tape or multiple creases in the tape. This class groups all the alterations in the shape of the tape, such as cuppings and damages on tape edges.
  b) Cupping. An abnormal flexure of the tape surface across or along its width, due to different rates of shrinkage along the substrate and recording layers.
  c) Damage to tape edges. It occurs when the edges do not appear flat or straight.
– Dirt (*di*). Tape contamination and dirt: presence of mold, powder, crystals, other biological contaminations, or similar sullying.
– Marks (*m*). Signs or words written on the back of the tape (i.e., the non-magnetic side) or on the adhesive tape of splices. Similarly, the presence of ink or dye on the surface of the tape, or writings on the back seeping through the tape to the front, comprise the phenomenon of "bleeding".
– Shadows (*s*). The class contains frames in which shadows or reflections are temporarily cast on the tape by external objects in motion.

The *Video Analyzer* software developed at CSC aims to detect the significant frames from the digital video. The detection is focused on two areas. The first one is the reading head of the tape recorder (Fig. 2). The second one is under the pinch roller (Fig. 3). The *eot* and *s* irregularities are detected

Fig. 3 – Area under the pinch-roller.

Fig. 4 – A POI pop-up with a frame of a splice correctly detected. The technician in the digitizing lab can confirm or reject the correctness of the result.

evaluating the pinch roller change of position. The others are evaluated in the first area. Significant frames are extracted comparing consecutive frames. If there are important color changes between the two frames (Fig. 4) the last one is indicated as significant. The implementation is based on OpenCV libraries.

The CSC proposes an algorithm that classifies the images provided by the video analyzer using the neural network GoogLeNet, Keras libraries and TensorFlow.

A good data set for supervised training must be large enough to cover the different circumstances that may occur. In addition, class imbalance should be minimal: the number of elements in each class must be similar. Our data set was built from more than 100,000 documents obtained from a number of preservation projects carried out at CSC. Among others, the most representative are: Paul Sacher Stiftung Archive, Luciano Berio's collection (tape music, electronic music); Luigi Nono Archive, all collections (tape music, electronic music); Teatro Regio di Parma, all collections (opera, Western classical music, pop/rock); Tullia Magrini Archive (ethnomusic); Istituto per i Beni Artistici, Culturali e Naturali of the Region Emilia Romagna (ethnomusic, speech), Fondazione Giorgio Cini, Venezia. Pretto *et al.* (2020) describes the projects and summarizes results, reporting statistical data.

The accuracy measured is in the range of 70% to 100%, depending on the carrier and on the discontinuity. It is the first approach of this kind in the scientific literature, and the positive results prove its potential. To obtain a more reliable tool, however, a larger and more balanced data set of frames is required to train the convolutional networks. Moreover, further research can improve the detection rate and the classification quality.

2.3 *Preservation is nothing without access*

The access methodology is complementary to that of active preservation (see Section 2.1), sharing its ultimate goal: to obtain a copy as faithful as possible to the original. Fidelity must be assessed according to three distinct criteria: (a) the reproduction of the audio content, (b) the simulation of the original listening experience, and (c) the completeness of metadata and contextual ancillary information. The first criterion is mainly determined by three factors: number of tracks, playback speed and equalization. The first factor is essential as an analog magnetic tape can accommodate 1 to 24 different sound tracks. It is evident, for example, that a stereo CD-A player is not suitable for the reproduction of audio coming from the dubbing of a multitrack electroacoustic music tape, not allowing the acoustic projection of the different tracks independently. As for the second factor, it is not uncommon to find sections of the same tape recorded at different speeds. The methodology perfected at the CSC in Padua foresees the memorization in the conservation master of several digital copies of the tape reproduced at different reading speeds: also in this case the passage from one speed to another is far from easy using general purpose digital readers. It is even impossible with CD-A players. The reproduction speed is also closely linked to the equalizations: as the first one changes, the characteristics of the filtering

curve also change. If this is not considered, the listening will no longer be faithful to the original document.

Since electroacoustic music on magnetic tape is strongly linked to the physical medium and the recording system, the virtual simulation of the peculiarities of the device and its use is a necessary step to satisfy the second criterion. Traditional access methods, such as the CD-A edition or listening through software jukeboxes, are inadequate to restore the listening experience of old analogue media, as they do not respect the characteristics of the original document, in addition to not providing adequate access methods to metadata and ancillary information. The reproductions of the appearance, of the commands (real-time modification of the speed and equalization) and of the moving parts of the tape recorder (running of the tape) are important to make the virtualization of the playback tool complete. CSC (Canazza, Fantozzi, Pretto 2015) has created various software for mobile devices and for web access to the most popular readers of analogue sound documents of the 20th c. (e.g., tape recorders, gramophones, turntables). An example is shown in Fig. 5. The main activity of REMIND app provides a skeuomorphic representation of the Studer A810-VUK 2-track audio recorder. The overall appearance of the tape recorder is virtualized with touch buttons (play, stop, fast forward, rewind and reset of the timer) and knobs (allowing to change replay speed and equalization). A video shooting, synchronized with the audio signal, of the original magnetic tape is shown. Several other features are represented, such as the movement of the tape with the rotation speed of each reel that is proportional to the amount of tape left in the reel and the timer. The user interface (UI) is implemented with a custom Java subclass of the

Fig. 5 – The main activity of REMIND app. A video of the original tape is shown outside the body of the tape recorder to improve its readability.

standard Android class View. Nearly all of the UI classes that appear in the main activity are custom: not only for the personalization of the appearance and behavior of the UI elements, but also to exploit hardware acceleration. The custom UI elements are 3D objects rendered into a Canvas allowing a consistently high frame rate for moving objects, and, at the same time minimizing the impact on the CPU. This choice also simplifies the scaling of the elements to support multiple display resolutions.

Looking ahead, these algorithms will be implemented online and will be able to virtually reproduce an analog player. Users will thus be able to benefit from access copies, free of charge or with subscription services, and these software applications will be useful in the musicological analysis.

3. The case-study of a personal archive

3.1 *Personal archives*

Personal archives represent a particular type of private archives whose characterizing and unifying element is the individual who produced them. This peculiarity makes them organic complexes, within which the individual parts acquire full meaning. All media – not only paper – are considered to be relevant sources as long as this relates to the life, memories and experiences of a person. The material is no longer exclusively of a written, photographic, audio or video nature; more and more new kinds of materials are present with specific conservation problems. The archives of certain professional categories can be peculiar for the type of material stored: for example, the architects' archives generally preserve, in addition to letters and other documents commonly found in private archives, materials such as drawings, sketches, tempera, collages and other materials referable to project drawings, as well as, in the most fortunate cases, collections of models. The musicians' archives store musical instruments and audio documents. The heterogeneity of the materials stored in the private archives requires particular care and a well-tuned scientific methodology.

Until a few decades ago, personal archives were not objects of archival interest: considered *different archives*, they aroused historical, historical-artistic, or literary attention for a particular preserved document. Personal archives as independent nuclei developed at the moment in which the greater awareness of each individual to be able to be an *artifex* of his own destiny and that his life experiences can be a potential source of historical and cultural interest. Traditionally, documents that are maintained by an organization vs. by an individual or a family have been considered distinct entities. Today's archivists recognize that both are bodies of interrelated materials that have been brought together because of their function or use. Archivists respect and seek to maintain the established relationships between individual items in records groups and in personal papers (Daniels 1984).

This recognized importance poses new challenges to the management and preservation of personal archives, which are often born without the long-term preservation aim. The heterogeneity of the materials stored, the peculiarities of each archive, the differences in the criteria and purposes of the individual, who produced the archive, requires a specific effort for the analysis, management, preservation and access of the archive content.

Many see the digital age as bringing an opportunity to leave an important legacy for future generations. During the past decade archives embraced digital technology to enhance user access and experiences and long-term preservation. The use of digital technologies encourages visitors to actively engage with the archive in a remote way. Due to the lower economic profitability compared to large archives, due to the lack of attention of national and international archival associations, due to the scarcity of funds, due to the difficulty, for a small archive, of getting to use archival/IT experts, and despite the archival/cultural importance of the documents in their possession, personal archives often have not yet adopted information technology. Existing systems are very often specific to the archive for which they were made. For instance, the database management systems included in http://www.archivi.beniculturali.it/ (Italy) and in http://www.archivesportaleurope.net/home (Europe) only allow to trace where a particular personal archive is kept, whose existence is already known; there is a lack of standardized tools for searching within archives.

The consolidated methodologies for institutional archives are not always sufficient to manage this new type of archives, with their peculiarities. It is therefore worth discussing the most appropriate methodologies. The methodology, in addition to considering the analysis of the content and the organization of the archive, must also oversee the design and development of the computer system for the management and the access to the archive, also in view of the evolution of information technology. Standardized tools must be provided for interoperability between different systems.

3.2 *Inventory description*

The term *fond* is often used in the Continental system to indicate the entire body of records of an organization, family, or individual that have been created and accumulated as the result of an organic process reflecting the functions of the creator (Pearce 2005). It should be viewed primarily as an *intellectual construct* and thus as the conceptual *whole* that reflects an accumulation process of the records which themselves exhibit a natural unity (Cook 2011).

Before addressing any description, a global examination of the fond, a sort of overview from above, is particularly indispensable for personal archives. These archives are generally devoid of repertoires but lacking in indications on the criteria adopted in the conservation of the papers. Dealing

diligently with one document after another, neglecting the archival ensemble, its history and internal stratifications at various levels limits the correct historical-biographical placement of the papers, making the description incomplete, if not downright misleading. In all cases in which a personality has kept private documents accumulating them without apparent organization or directions, the archivist can and must try to immerse himself in the subject's working method through the traces that may have remained, then bringing him back to the organization of his papers. The archive should also keep track of the organization that the person had given himself.

Especially for personal archives, the inventory description must provide information both on the archival unit in question as well as on the producer subject and on the historical context, and at the same time make clear and explicit the relationships between the units and the complex they belong to. Librarian-economic descriptions, often managed through software designed for book cataloguing, which in the past were used for personal archives, present this main shortcoming: they do not sufficiently highlight the links between an archival unit and another. Often, the literary or artistic importance of individual documents preserved in personal archives, such as can be considered *artistic objects* even beyond the historical context in which they are located, requires an analytical description. The inventory structure proves to be the fundamental tool for a global vision of the archive. A specific search can then be very well supported by descriptions managed on a database, the more appreciable the more the computer tool is able to reproduce the complexity of the documents. Today there is a tendency to consider as *objects* archival documents that were once divided between archives, libraries and museums (books, photographs, prints, collections of postcards, ornaments, relics, medals). The information management system should allow the virtual recomposition of personal archives divided among several institutions, cities or countries. Alongside the classic juxtaposition of multiple inventories, it should be possible to achieve a real virtual integration of both descriptions and documents in digital form. Without forgetting, however, that the inventory description has a completely different purpose from digital reproduction: it is a *mediation tool* allowing the scholar to trace, define, identify, understand the document, where digital reproduction is the very useful and perfect copy of the original document.

4. Case-study: electronic music

4.1 *Luigi Nono and Luigi Nono Archive*

Among the various activities that CSC is carrying out (Canazza, De Poli 2019), the personal archive of the Luigi Nono Archive Foundation (ALN) is an important case-study, because both the interest raised by the Archive at

the musicological and cultural level, and the heterogeneity of the materials contained, but also because Luigi Nono worked at the CSC in 1984 to create the computer part of his last opera *Prometeo-Tragedia dell'ascolto* (1984-85).

Musical language of Luigi Nono (Venice, January 29, 1924-Venice, May 8, 1990) in the 1950s clearly places him as one of the major exponents of the post-Webernian avant-garde, but his artistic personality expresses the desire to overcome the formalisms of serialism in order to re-propose the unity of the sound phenomenon in a highly original way. In 1956 *Canto sospeso* (for solo voices, chorus and orchestra, based on texts from letters of members of the European Resistance movement who were condemned to death) was the first of his works to gain international recognition.

In the 1960s he began working at the Studio di Fonologia Musicale of the RAI in Milan, discovering the musical potential of the electronic medium, used both independently and as part of compositions for soloists, ensembles, large orchestras and in musical theatre works. In those years his research on sound and electroacoustic space merged with a very strong ideological drive on a political level, intensely felt, which was reflected in the compositions of this period and which placed him in a unique position on the post-war musical scene. These works include *La fabbrica illuminata*, *Ricorda cosa ti hanno fatto in Auschwitz*, *A floresta é jovem e cheja de vida*, and the opera *Al gran sole carico d'amore*, premiered in 1975.

The composition ... *sofferte onde serene* ... (1977) marked the turning point towards a new, more introspective creative period, which evolved in the 1980s into a research path with the Live Electronics of the Experimental studio der Heinrich Strobel Stiftung des Südwestfunks E. V. in Freiburg (Breisgau). In the space of a few years, Nono renewed his compositional technique, conditioned by the rigidity of magnetic tape, creating a group of soloists specialised in the technique of 'mobile sound', in the use of micro-intervals and in interaction with live electronics. Starting with *Das atmende Klarsein* (1981), for bass flute, small choir and live electronics, the journey towards the opera *Prometeo, tragedia dell'ascolto* with texts chosen by Massimo Cacciari, for soloists, choir, four instrumental groups and live electronics. The first performance took place in 1984 in the Church of San Lorenzo in Venice, where Renzo Piano built an architectural structure with the aim of gathering performers and audience inside a *new instrument* for listening to music in space[1].

ALN was created in December 1993 in Venice, through the efforts of his widow, Nuria Schoenberg Nono, for the purpose of housing and conserving the Venetian composer's legacy. ALN was declared "of local interest" in

[1] For an in-depth study of Luigi Nono's work, see De Benedictis, Rizzardi 2018.

1994 by the Veneto Region (Italy) and 'of considerable historical interest' in 2000 by the Archival Superintendence, Italian Ministry of Cultural Heritage.

The Archive was founded as an Association, later transformed into a Foundation (FALN) in 2007 and thereafter placed in its current location, the ex-convent Saints Cosma e Damiano, on the island of Giudecca in Venice. The Archive's activities are supported by public bodies, national and international sponsors, and by the generous contributions of the Friends of the ALN.

The Archive preserves manuscripts of Nono's compositions, in particular sketches and preparatory studies (2300 sheets); a collection of open reel tapes (230) and audio-cassettes (90) consisting of recordings of Nono's works as well as preliminary studies and material for his electronic compositions (sound sketches of considerable importance), and several interviews; manuscripts of essays, articles, lectures and lessons (12,000 sheets); Nono's correspondence; Nono's library encompassing over 10,000 volumes (many with marginalia) reflecting the breadth of his interests: music, literature, politics, philosophy, fine arts and sciences; concert programs, reviews and magazine articles; video tapes documenting his life and works and a collection of photographs and slides (6500); Nono's LP record collection of more than 1200 records[2].

4.2 *Documents storage*

ALN stored all data in the cloud, keeping a copy locally (on redundant NAS), both of the documents in high resolution and of the compressed files. The aims are: performance, scalability, availability, and long-term preservation. The storage resources are scaled to adapt the possible fluctuations in demand (by the ALN) without upfront investments or resource supply cycles, automatically creating and storing copies of all audio-video-images-documents objects. The data are available at any time to both the Archive and to the users (with different access levels) and are protected from failures. Data are stored and protected from unauthorized access with encryption features and access management tools developed on purpose. Public access is blocked to all objects at the account level and the system operates compliance programs, such as the General Data Protection Regulation, adopted in April 2016, that has superseded the Data Protection Directive and became enforceable on 25 May 2018 (Blackmer 2016). The storage system offers robust capabilities to manage access, cost, replication and data protection. Because the system works with AWS Lambda, the archive stores log activities and defines alarms. The system is able to perform big data analysis across objects inside the archive with query-in-place instruments.

[2] See Dal Molin 2016 for an exhaustive report of the personal papers included in the ALN.

4.3 *Archive management software system*

An archive management software system was developed, combining independent modules and using different programming languages and technologies (mainly Java, MySQL, PHP, and shell scripting). The main purpose is to support the process of active preservation of the documents according to the methodology described above. The expected users are archivists of the archive and scholars and in this sense the user interface assists the operator in (i) the creation of the digital preservation copies and (ii) metadata extraction and ingestion into the database.

The strength of the module is that it ensures the alignment between the data on documents (audio/video/manuscript/etc.) and their metadata in a relational database, minimizing the cognitive load of the operator and reducing the processing time required by each preservation master. The software implements redundant data integrity verification procedures, and optimizes the workflow by batch processing large sets of data and metadata, progressively storing the complete preservation copies in the cloud digital

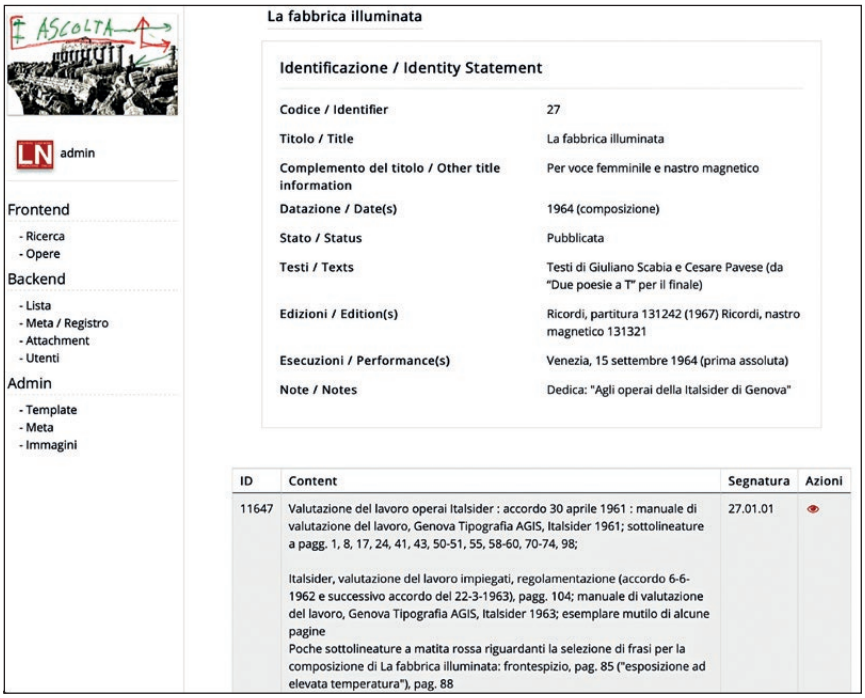

Fig. 6 – Identity statement of *La fabbrica illuminata* (a musical work by Luigi Nono, 1964).

preservation archive. The software is designed to assist the preservation process, and to preserve the entire workflow, allowing backward analyses of the processing times, dates, data flow, etc. It includes several modules: particularly innovative is the module for the description of the signs and symptoms of degradation at the audio-video carrier level. The information system has been online since July 2021. All users can access the database locally in ALN. Users are able to carry out their queries remotely as well, through a web interface linked to the Fondazione ALN website (http://www.luiginono.it/en/). Figs. 6, 7 e 8 show examples of the *La fabbrica illuminata* (a musical work by Luigi Nono, 1964): 1) identity statement; 2) manuscripts digitized; 3) audio tracks.

Italian legislation strives to guarantee access to the documents, safeguarding the rights of the creators, persons or organizations involved. In line with these principles, first of all, one needs permission either from the creator or his/her heirs and (for letters that are not part of the Luigi Nono's collection) from the preserver. Where the Fondazione ALN does not have a written release, users must obtain authorization themselves, with the eventual mediation of the Foundation. It should be noted that preservers have sometimes only provided copies of letters for cataloguing purposes and not for consultation. On presentation of the required authorization, the ALN staff check and eventually censor the text of the letters, removing any sensitive or classified data from consultation, in accordance with Chapter III of the 2004 Legislative Decree 42 (*Codice dei beni culturali e del paesaggio*). The user does not receive originals but photocopies of the selected documents for consultation only, which confirms the usefulness of the description of the original document offered in the database. The publication of a part or the whole of a transcript is subject to approval from the copyright owners. This also applies to the publication of photographic reproductions.

Following methodology described above, the link between the preservation copy (and therefore the original document) and the *re-mediated* access unit is maintained by means of the relationship between the audio track associated with the unit and all the audio tracks coming from the preservation copies that were used by Luigi Nono and co-workers to produce it. With this structure, the presentation of the data can concern the general public (interested in the content of a unit), as well as musicologists willing to study the philological reconstruction of the source, or the physical characteristics of the original carrier. Obviously, and very important, the users can trace the information of a preservation copy starting from the result of the queries on the content and vice versa. For each carrier (audio: magnetic tape, phonographic disc, wax cylinder, etc.; paper, in the case of manuscripts), all the relevant characteristics have been identified, which have been formalized in a set of

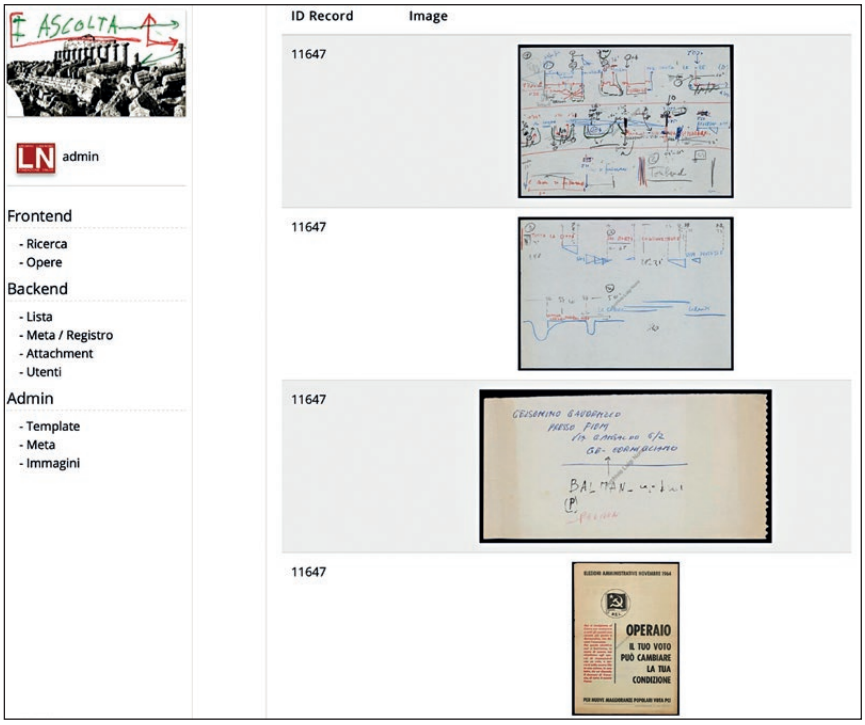

Fig. 7 – Access to digitized manuscripts.

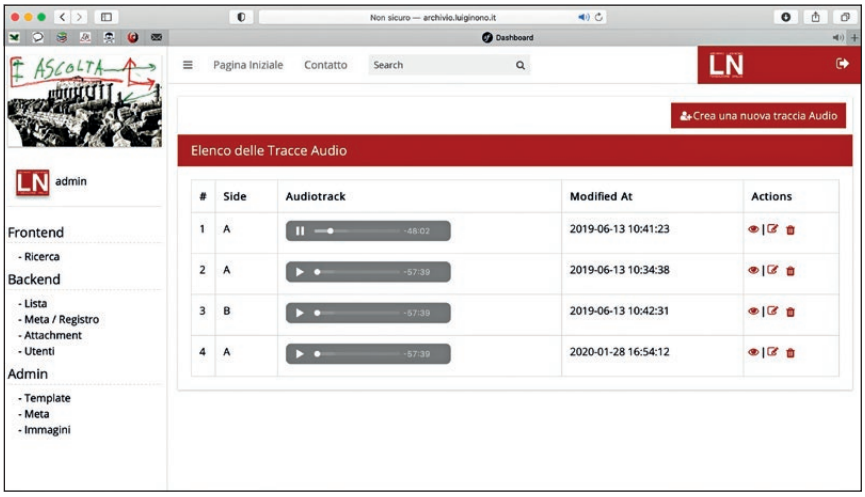

Fig. 8 – Audio file (an example of four channels tape).

attributes represented in the database project. There are some intersections among the attributes of different types (e.g., for all the audio documents, the registration technique must be specified); the superset of all attributes constitutes the original document table in the database.

In some cases, no control is required in the user interface (where a component that allows the user to make a selection from a controlled vocabulary). In these cases, the most appropriate value will be entered in the database in a transparent way to the user, to deprive her/him to insert a not valid value, because of distraction or incompetence. In this sense, the user interface includes a limited number of components.

The system is able to minimize the introduction of errors, not only by filtering the interface components, but also by filtering the values that are presented in the components, and which depend on the type of support considered. For example, the *speed* attribute is shared by the compact-cassette, micro-cassette, open reel and phonographic disc. For the first three, the tape speed, for the last one, the angular speed of the disc. The component for selecting the speed is not included in the interface even if the user is working on a compact-cassette, since it is assumed that the tape speed for the cassettes is always 4.75 cm/s; for the micro-cassettes is 1.2 cm/s and 2.4 cm/s. These values are not valid for the open reels, for which valid values are 4.75 cm/s (intersection with audio cassettes), 9.5 cm/s, 19 cm/s, 38 cm/s and 76 cm/s. Finally, the valid values for phonograph records, expressed in revolutions per minute (rpm): 16 rpm, 33 1/3 rpm, 45 rpm, and 78 rpm.

The software is able to create preservation copies of the documents, to share access copies; to catalog the mediated resources for access; to check the integrity and internal consistency of the archive documents; create backup copies of data and metadata.

5. Conclusions

In this article, we first presented a scientific methodology for the audio documents active preservation and access, developed thanks to the fifty years of experience gained at CSC in music production: a well-tuned *re-mediation* methodology, an artificial intelligence based approach to detect audio tape discontinuities and access tools for renovating the listening experience of old analogue media. Then the problem of preserving and accessing all the information related to the artworks stored in the author's personal archive was addressed. We presented in detail, as a case study, the design and development of an information management system allowing the long-term preservation and the access to different documents, among them: audio, letters, musical scores, and manuscripts of the personal archive of Luigi Nono. Our approach is based on two pillars: (a) the multidisciplinary nature of the team researchers

involving engineers, musicians, musicologists, composers and archivists, and (b) the philological accuracy with which the digital tools developed preserve the history of the production and transmission of the audio document.

Multimedia and interaction technologies have promoted the creation of new artistic typologies that integrate the various forms of communication in a single artwork and that allow the performer (or the public in the case of installations) to modify the structure and response according to their own behavior. The sector that encompasses these experiences is called media art. We can observe that media art is both material and performative: it is as artifactual or object-centric as performative or behavior-centric and it exhibits a variable form, much like music.

We believe that our methodology has general value, therefore can be fruitfully applied to other forms of media art and to other personal archives, different from electronic music composers, but also the practical findings we illustrated for our system can be inspiring in a wide range of contexts. One of the strengths of this project consists in having defined an original scientific methodology in the field of digital preservation, characterized by the fact of targeting the type of European personal archives, and having successfully applied it to a real archive, obtaining concrete results. The majority of the personal archives of the 20th c. are nevertheless kept outside the State Archives by a myriad of public or private institutions, often with few funds and personnel. The consolidated methodologies for institutional archives are not always sufficient to manage this new type of archives. An interesting open issue, not sufficiently discussed yet in the literature and archival practices, concerns the standardization of these small, personal, multimedia archives. Standardized tools must be provided for interoperability between different systems. Our proposal can be a step toward the possibility that personal archives interconnect with each other, creating a large network.

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REFERENCES

Blackmer W.S. 2016, *GDPR: Getting Ready for the New EU General Data Protection Regulation*, Information Law Group. Archived from the original on 14 May 2018 (https://web.archive.org/web/20180514111300/https://www.infolawgroup.com/2016/05/articles/gdpr/gdpr-getting-ready-for-the-new-eu-general-data-protection-regulation/).

Bressan F., Canazza S. 2013, *A systemic approach to the preservation of audio documents: Methodology and software tools*, «Journal of Electrical and Computer Engineering», ID 489515 (https://doi.org/10.1155/2013/489515).

Bressan F., Canazza S. 2014, *The challenge of preserving interactive sound art: A multi-level approach*, «International Journal of Arts and Technology», 7, 4, 294-315.

Bressan F., Canazza S. 2015, *Honey, I Burnt the Tapes!, A study on thermal treatment for the recovery of magnetic tapes affected by Soft Binder Syndrome-Sticky Shed Syndrome*, «IASA Journal», 44, 53-64.

Bressan F., Bertani R., Furlan C., Simionato F., Canazza S. 2016, *An ATR-FTIR and ESEM study on magnetic tapes for the assessment of the degradation of historical audio recordings*, «Journal of Cultural Heritage», 18, 313-320 (https://doi.org/10.1016/j.culher.2015.09.004).

Canazza S., De Poli G. 2019, *Four decades of music research, creation, and education at Padua's Centro di Sonologia Computazionale*, «Computer Music Journal», 43, 4, 58-80.

Canazza S., Fantozzi C., Pretto N. 2015, *Accessing tape music documents on mobile devices*, «ACM Transactions on Multimedia Computing, Communications, and Applications», 12, 1s, 1-20.

Cook T. 2011, *The archive(s) is a foreign country: Historians, archivists, and the changing archival landscape*, «The American Archivist», 74, 2, 600-632.

Dal Molin P. 2016, *Accessing Luigi Nono's correspondence: A user's perspective*, in P. Dal Molin (ed.), *Musicians' Correspondence and Interaction Between Archives*, Venezia, Fondazione Giorgio Cini, 101-111.

De Benedictis A.I., Rizzardi V. (eds.) 2018, *Luigi Nono. Nostalgia for the Future - Luigi Nono's Selected Writings and Interviews*, Oakland (CA), University of California Press.

Daniels M.F. 1984, *A Modern Archives Reader: Basic Readings on Archival Theory and Practice*, National Archives Trust Fund Board, Washington D.C., Chapter Introduction to Archival Terminology, 336-342, (https://hdl.handle.net/2027/mdp.39015011587063?urlappend=%3Bseq=8).

Fantozzi C., Bressan F., Pretto N., Canazza S. 2017, *Tape music archives: From preservation to access*, «International Journal of Digital Libraries», 18, 233 (https://doi.org/10.1007/s00799-017-0208-8).

Orio N., Snidaro L., Canazza S., Foresti G.L. 2009, *Methodologies and tools for audio digital archives*, «International Journal of Digital Libraries», 10, 4, 201-220 (https://doi.org/10.1007/s00799-010-0060-6).

Pearce-Moses R. 2005, *Glossary of Archival and Records Terminology*, Archival Fundamentals Series II, Chicago, Society of American Archivists.

Pretto N., Fantozzi C., Micheloni E., Burini V., Canazza S. 2018, *Computing methodologies supporting the preservation of electroacoustic music from analog magnetic tape*, «Computer Music Journal», 42-4, 59-74.

Pretto N., Russo A., Bressan F., Burini V., Rodà A., Canazza S. 2020, *Active preservation of analogue audio documents: A summary of the last seven years of digitization at CSC*, in S. Spagnol, A Valle (eds.), *Proceedings of the 17th Sound and Music Computing Conference 2020, SMC'20 (Torino 2020)*, Axea sas/SMC Network.

Verde S., Pretto N., Milani S., Canazza S. 2018, *Stay true to the sound of history: Philology, phylogenetics and information engineering in musicology*, «Applied Sciences», 8, 2, 226 (https://doi.org/10.3390/app8020226).

ABSTRACT

Music was one of the earliest kinds of art to explore the creative use of electronic and information technologies: new musical forms have assumed an increasingly artistic importance since the second half of the last century. Technology, at the same time, also is the cause of their rapid deterioration and risk of disappearance. The conservation of this heritage presents very different problems from those posed by traditional artworks. To this purpose this paper first presents some results for the conservation of audio documents: a well-tuned re-mediation methodology, an artificial intelligence based approach to detect audio tape discontinuities and access tools for renovating the listening experience of old analog media. To safeguard this heritage, it is not enough to digitize the content of recordings and documents, but all the related information, collected on the author's personal archive, must also be accessible. The second part of this paper presents in detail, as a case study, the design and development of an information management system allowing the long-time preservation and the access to different documents, among them: audio, letters, musical scores, and manuscripts of the personal archive of an important electronic music composer.