Active preservation of analogue audio documents: A summary of the last seven years of digitization at CSC

Niccolò Pretto
Institute for Computational Linguistics
CNR, Pisa, IT
niccolo.pretto@ilc.cnr.it

Alessandro Russo
Dept. Information Engineering
University of Padova, Padova, IT
russoale@dei.unipd.it

Federica Bressan
Art Department
Stony Brook University, NY, USA
federica.bressan@stonybrook.edu

Valentina Burini
Dept. Information Engineering
University of Padova, Padova, IT
burini@dei.unipd.it

Antonio Rodà
Dept. Information Engineering
University of Padova, Padova, IT
roda@dei.unipd.it

Sergio Canazza
Dept. Information Engineering
University of Padova, Padova, IT
canazza@dei.unipd.it

ABSTRACT

During the last 40 years, a large number of musical works was composed and recorded at the Centro di Sonologia Computazionale (CSC) of the University of Padova. The problem of how to preserve this increasing amount of audio documents arose and, in order to meet this need, the CSC started to carry out a research to develop a scientific methodology for preservation. In the last 7 years, this methodology was refined and applied to the digitization of more than 2,500 audio documents both from Italian and international audio archives, mainly stored on analogue magnetic carriers such as open-reel tapes and cassettes. Their content consists of electronic, folk and other kinds of music, as well as speech recordings. The methodology provides for collecting numerous metadata about the original carrier on which the audio information was stored, i.e. flange diameter, brand and material, its physical state and the related preservation copy, necessary for a correct preservation of the content and the contextual information. This work aims to extract and interpret the information from this wealth of data and metadata, which was collected and structured through the software PSKit. This may be useful for audio technicians, archives and policy makers to plan future preservation projects.

1. INTRODUCTION

"Why digitize?". This question was the title of Abby Smith's contribution for the Council on Library and Information Resources in 1999 [1] and an avenue of reflection for the scientific community on what were the best ways to act to preserve memory. A question that later resonated with other libraries and archival institutions. In 2004, International Federation of Library Associations and Institutions (IFLA) "Guidelines for Audiovisual and Multimedia materials in libraries and other institutions" reported: "Preservation of long-term access to the information on unique analogue materials often involves copying that information to the same or a different medium. [...] Nowadays, the preferred means of copying such information is digitization." [2]

In the early 2000s, the concept of digitization and all that this entailed was thus being defined by entities such as United Nations Educational, Scientific and Cultural Organization (UNESCO) [3], International Association of Sound and Audiovisual Archives (IASA) [4] and IFLA. In 2017 IASA published its 4th edition of IASA TC-03 "The Safeguarding of the Audiovisual Heritage: Ethics, Principles and Preservation Strategy." [5] After a debate two decades long, it represents a clear sign of the open questions that the scientific community has been asking while reflecting on possible scenarios from digitization to born-digital documents, and strategically planning the interventions.

Following the example of the IASA Technical Committee, the Centro di Sonologia Computazionale (CSC hereafter) in Italy keeps reflecting on its preservation strategy, centered on digitization, sharing the results of the last few years' worth of work with the scientific community.

The CSC was founded in 1979, after the first researches on digital and electronic technologies applied to sound and music computing took place during the 1960s at the University of Padova. Musical production and research activity in the field of electronic music, especially electroacoustic, [1] led to the interest in investigating strategies and methodologies for the preservation of analogue recordings produced and stored at CSC during the years, in order to save this heritage from the deterioration they have inevitably to face. The research work at CSC led to the development of a scientific methodology mainly focused on the importance of metadata and contextual information that has been gradually improved during the years. [7] This methodology was supported by the software Preservation Software Kit (PSKit) [8], developed to assist and semi-automate the correct creation of the preservation copy. Thanks to this

[1] Electronic music, concrete music, electroacoustic music, tape music, experimental music, acousmatic music, live electronics, computer music and informatics music are terms used to denote the musical work that makes use of modern electronic technology [6].

software, adopted in 2013, a remarkable amount of information was collected and it allowed to identify most common issues, typologies and usage practices for each type of audio archive. Archives and scholars could plan future interventions based on the results obtained during these years of CSC activity in the field. This paper summarizes the wealth of data and metadata stored during the last seven years at CSC and compares them for different typologies of audio archives. The next section provides an overall description of the collections that were digitized at CSC in the last seven years. Due to confidential agreements, the authors can not share the data and metadata, nor the name of the archives. In order to analyze different kind of collections and, at the same time maintain anonymity, five classes of audio recordings are defined, based on their genre. Then, Section 3 presents PSKit and its peculiarities. A summary and an interpretation of the data and metadata collected through this software is illustrated in Section 4, and discussed in the final section.

2. DESCRIPTION OF DIGITIZED COLLECTIONS

The CSC started its first experience in the field of preservation of audio documents with the digitization of the internal archive of electronic music of the centre, formed by records made by several Italian and international composers over the past years. For this reason, this genre was the one of main interests during the first years of activity, with the sharpening of specific skills within this field. From the early days of activity, the developed methodology has been gradually improved working on several collections of this genre of music, facing the most common typologies and issues that may affect them. In a second phase, the digitization activity at CSC faced other types of audio archives, such as the ones containing speech recordings of historical and cultural value and music in a broad sense, with other genres, for example pop-folk and opera music. Each type of audio archive introduced specific variables and issues and helped the development of a methodology that could be suitable for all the cases. In fact, a tape recorded in a studio with professional equipment, containing music, differs in many respects from a speech recording made with portable devices in an untreated audio environment, where often audio quality has been considered less important than mobility and an extended recording time. In particular, the data reported in the following sections concern 4 collections of electronic music, 5 of ethnomusicological content, 1 of Operas and contemporary pop music performed in a theatre and 10 of speech recordings that were taken into consideration. The electronic music collections (referred as "Electronic" in Table 1) play a role of great importance from a musicological point of view, because they are formed for the most part of sketches and unpublished materials, used then in the final cut of the musical works. The collection of opera and contemporary pop music is made of live recordings of concerts in a theatre setting, mostly on open reel tapes with a semi-professional equipment (referred as "Various Music" in Table 1). The collections that include pop-folk music and contents of other ethno-musicological interest are formed for the most part of field recordings of popular Italian songs (referred as "Ethnomusicology" in Table 1), often in dialect language, made with portable devices in a live setting, and they bear witness to a huge heritage that ought to be preserved for its enormous cultural value. The 10 digitized speech collections (referred as "Oral Sources" in Table 1) are formed for the most part of audio cassettes of heterogeneous contents, such as interviews with witnesses of war, linguistic and pedagogical studies. In fact, the 60s and the 70s coincided with the beginning of field recordings of dialectal speech, folk music and other orally transmitted material, such as legends, proverbs, folk medicine formulas, etc. [9], and these collections are often characterized by the lack of written records. The digitization of these collections play a role of great importance both from a cultural and a historical point of view. Few other small archives of other genres (referred as "Other" in Table 1) were also digitized, but their dimension is not significant for statistical purposes. Table 1 describes the kind of audio documents that composed the classes.

3. BRIEF DESCRIPTION OF PSKIT

PSKit (Preservation Software Kit) is an open-source software system (GNU GPL v.3) made of independent modules that combine different programming languages and technologies (mainly Java, MySQL, PHP, shell scripting, LaTeX). Its main purpose is to support the process of active preservation of audio documents according to the workflow described in this paper. The intended users are members of the preservation and of the cataloguing team. The PSKit module called PreservationPanel, relevant to this paper, assists the operator in:

1. the creation of the preservation copies;
2. metadata extraction and ingestion into the database.

The strength of the module is that it ensures the alignment between the data on disk and the metadata in the relational MySql database [10]; and that it minimizes the cognitive load of the operator while at the same time reducing the processing time required by each preservation copy. For audio-specific metadata extraction, PSKit relies on a modular tool for file format identification, validation and characterisation developed by Harvard University. [2] Audio metadata, along with contextual information, is formatted by PSKit in a descriptive sheet that is included in each preservation copy. [10]

PSKit 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 digital preservation archive – where data integrity checks are run periodically. Besides assisting the preservation process, PSKit is a "time machine" of the preservation workflow, allowing backward analyses of the processing times, dates, data flow, etc. PSKit is designed to be extended with new modules: the last to appear in chronological order was the de-

[2] About JHOVE: `jhove.openpreservation.org` (last visited April 30, 2020).

Class	Tape	Cassette	Microcassette	Minidisc	Vinyl Disc	Dimafon	Tot.
Electronic	661	3	0	0	0	0	664
Ethnomusicology	711	499	0	0	0	0	1210
Various Music	200	0	0	0	0	0	200
Oral Sources	91	343	8	2	0	0	444
Other	10	0	0	0	2	1	13
Tot.	1673	845	8	2	2	1	2531

Table 1. Number of audio documents for each class of contents divided by carrier. See the end of Section 2 for a detailed description of the indicated classes.

scription of the signs and symptoms of degradation at carrier level. [11]

Since 2010, PSKit has been used and is still in use in research projects in Italy, Portugal, and Argentina.

4. DATA AND METADATA ANALYSIS

During the last seven years, 2,531 preservation copies were created using PSKit at CSC. Most of the digitized audio documents were open-reel tapes (1,673) and cassettes (845), but some other analogue formats were digitized: microcassette (8), vinyl discs (2), minidiscs (2) and Dimafon magnetic disc (1).

The related preservation copies are formed by 4,661 uncompressed audio files in .wav format, for a total amount of 5.88 TB and 4,867 hours of recordings (more than 200 days). In addition to the audio files, the preservation copies include 15,035 pictures (61.29 GB), taken in order to minimize the loss of information and keep trace of visible details, such as notes written on the boxes and degradation symptoms that may affect the carriers. On average, each preservation copy contains around 2 (1.84) audio files and 6 pictures. The methodology developed at CSC provides for filming tapes while they are winding on the reading head of the playback device, especially for those documents that contain electronic music [8], where splices, signs and other alterations of the tape are relevant for musicological studies. 726 videos (4.46 TB) were recorded for 649 audio documents. As for wave files, the difference between the two numbers is because several times the original audio documents were recorded with variable speeds and/or sides [12], therefore, multiple signal transfers were performed. As shown in Table 2, the count of audio documents recorded with variable speeds is 278, the 16.6% (no one in the open-reel tapes of "Other" group). Almost the half of the open-reel tape, 742 (44.35%), have two sides. Furthermore, 28 tape recordings are quadraphonic or recorded on 8 tracks. The same is for cassettes, which are usually recorded on two sides.

These documents come from 22 different collections of Italian and international institutions. As described in Section 2, we carried out this work gathering different collections and their related audio documents. Thirteen recordings were excluded from the statistics because they came from collections of other genres. This classification aims to infer trends and peculiarities between different kinds of audio recordings. Table 1 shows the kind of carriers where the four classes of different audio contents have been stored. As expected, speech recordings were mainly stored on cassettes (lower quality portable devices are easier to carry out on the field), while musical content was stored on open-reel tapes (for these recordings, higher audio quality was considered more important). However, about 44% of our documents with ethno-musicological contents are in cassettes.

Tables 2 shows that the most used speed standard in open-reel tape recordings is in general the 7 1/2 ips (41.8% of the considered audio documents). But, the trend is different for "Etnomusicology" where most of the tapes require a 1 7/8 ips standard (45.6%). Another peculiarity is the high number of recordings with different speeds on the same tape (34.5%). Main part of the 15 ips tapes (87% of the total) and all the 30 ips tapes are part of the "Electronic" archives.

Some other interesting information can be extracted by the Table 3. Most of the considered recordings (61.1%) have a flange with a diameter smaller than 5 in (12.7 cm). This parameter is not directly related to the tape pack (usually it can be only considered as an upper bound), but could be useful for a first estimation of an archive. Most of the bigger flanges ($\geq$ 24 cm) are part of the "Electronic" (54.9 %) and "Various music" (33.5%) archives. Most of the "Oral Sources" and "Ethnomusicology" archives have flanges of small (83.7%) or medium size (5.5%), with a diameter between 14.5 and 18 cm. This characteristic, as well as the usage of slow recording speeds, probably is because was preferable the use of portable devices for these kind of field recordings.

During the digitization of an audio document, several other kinds of information [10] are gathered, such as the equalization standard that was selected to digitize the tape, [3] [4, 13] the brand and model of the tape, the symptoms that may affect the analog carrier and compromise its replay (for an extensive explanation, please see [11]), as well as the relation between different characteristics. Nevertheless, this kind analysis goes beyond this preliminary work.

5. CONCLUSION

This work provided valuable statistics for 2,531 digitized audio documents and their related preservation copies. This information can be precious for archives, audio technicians

[3] Several standards exist and the correct curve must be selected to compensate the (inverse) equalization curve applied during the recording of the tape.

Speed Standard	Electronic	Ethnomusicology	Various Music	Oral Sources	Tot.
15/16 ips (2.38 cm/s)	1	33	0	0	34
1 7/8 ips (4.75 cm/s)	2	324	0	6	332
3 3/4 ips (9.5 cm/s)	10	80	0	6	96
7 1/2 ips (19 cm/s)	416	25	177	77	695
15 ips (38 cm/s)	194	4	23	2	223
30 ips (76 cm/s)	5	0	0	0	5
Various	33	245	0	0	278
Tot.	661	711	200	91	1663

Table 2. Number of open-reel tapes for each speed standard, grouped by content type. The label "Various" indicates the use of different speed standards in the same audio document.

Flange Diameter	Electronic	Ethnomusicology	Various Music	Oral Sources	Tot.
8 cm	6	6	0	1	13
10 cm	13	3	0	1	17
11 cm	10	60	100	2	172
12 cm	159	593	0	62	814
14.5 cm	13	26	0	3	42
18 cm	314	12	11	2	339
24 cm	6	0	34	0	40
25 cm	4	0	4	0	8
26.5 cm	136	11	51	20	218
Total	661	711	200	91	1663

Table 3. Number of open-reel tapes for each flange diameter, grouped by content type.

and policy makers to plan future preservation projects. Furthermore, this work can be useful to delineate the needs that archives can have and further directions for several research disciplines, such as sound and music computing.

For example, considering the recording speeds, it can be seen that 16.7% (278 out of 1663) of the tapes were recorded using different speeds from section to section. This implies that a tape cannot be read and digitized in a unique step, but it requires many actions (start, stop, rewind, speed change, etc.) and two or more signal extraction sessions because it is impossible to know the speed of each section before playing the tape (generally this information is not reported on the containers and attachments, and even if it is present, it often proves to be inaccurate). This percentage has a clear impact on the duration of the digitization process and consequently on the time/costs estimation, that is a fundamental aspect for archivists who need to plan future interventions. On the basis of our experience (see e.g. [14, 15]), a tape recorded with different speeds requires a working time that is, on average, 2.5 times greater than usual. It is worth noting that tapes with various speeds are definitely more frequent in ethno-musicological collections (0.34%, 245 out of 711) than electronic music collections (0.05% 33 out of 661), probably due to the difficult technical conditions that can often occur during field recordings. Consequently, user interfaces for the access to digitized audio documents have to be designed keeping in mind that the original analogue document may have been recorded with various speeds (see [7, 16] for some examples of user interfaces for the access to audio documents).

A further aspect related to the time/costs estimation is the recording duration, that depends both on reel size and speed. While size can be evaluated with a simple visual inspection, for the reasons seen above, it is necessary to play the tape in order to know the correct speed. Therefore, an average speed can be estimated by statistics: in our case, we can estimate an average speed (computed as weighted mean on the number of tapes) of 25.1 cm/s for electronic music, 6.4 cm/s for ethno-musicological recordings, and 17.9 cm/s for oral sources.

This work is only a preliminary analysis of data and metadata, that will be studied in-depth with future works. A complete analysis of symptoms as well as equalization standards has to be taken into consideration. In particular, the latter requires a more complex analysis, both of data and metadata, that will be also important for the development of automatic tools for equalization detection. [13] A complete set of data and metadata is fundamental for the creation of ground-truth datasets, which are the input for machine learning or deep learning algorithms, as in [17], for complex musicological tasks such as stemmatics [18] and more generally for musicological analysis based on computer science techniques.

Collecting, managing, and preserving such an amount of data and metadata has of course a non negligible cost, in terms of working hours of specialized operators and technologies such as long-term storage devices and/or cloud services. Moreover, new professional figures with a multidisciplinary view on audio signals (both analogue and digital) and digital asset management are required.

In conclusion, the authors report the sentence which inspire this work: "Though no choice is a final one, a well informed decision will consider the process for navigating to the new." [5]

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