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A multilevel dynamic model for documenting, reactivating and preserving interactive multimedia art

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Preserving interactive multimedia artworks is a challenging research field due to their complex nature and technological obsolescence. Established preservation strategies are inadequate since they do not cover the complex relations between analogue and digital components, their short life expectancies, and the experience produced when the artworks are activated. The existence of many projects in this research area highlights the urgency to create a preservation practice focused on the new multimedia art forms. The paper introduces the *Multilevel Dynamic Preservation* (MDP) model, developed at the Centro di Sonologia Computazionale (CSC) of the University of Padova, which aims to preserve multimedia artworks through different levels of information (about the components, their relationship and the activated experiences) through various exhibitions and thus as a process or a dynamic object. The model has been developed through several case studies. This paper reports a specific and complex one: the "hybrid reactivation" of the *Il caos delle sfere*, a 1999 interactive installation by Italian composer Carlo De Pirro. The entire reactivation process aims at preserving its identity, rather than simply replicating the original installation, and consists of both the replacement of old and non-functioning components components ("adaptive/update approach") and the reactivation of original parts ("purist approach")-hence the name "hybrid reactivation". Through this case study, it was possible to test and optimize the model in all aspects: from collecting old documentation and using it for reactivation to creating new documentation and archiving the entire artwork. The model allows us to preserve the artwork as a process of change, minimizing the loss of information about previous versions. Most importantly, it lets us rethink the concept of the authenticity of interactive multimedia art, shifting the focus from materiality to the experience and function that artworks activate. The model avoids recording both the last reactivation and the first exhibition as authentic. It records the process of transformation between reactivations. It is through this process that the authenticity of the artwork can be inferred.

KEYWORDS

preservation of multimedia art, multimedia, interactive art, computational model, reactivation methodology, music installations

1 Introduction

Over the past century, art has undergone a radical transformation in its forms of production and experience, breaking the principle of *medium specificity* (Lopes, 2009) and gaining the idea of the *Gesamtkunstwerk* (Wagner) or *total artwork* (Kandinsky), toward the definition of the neologism *Intermedia* art (coined by Dick Higgins in the 1960s) or the more common term multimedia art (Friedman and Diaz-Kommonen, 2018). The coexistence of different mediums - also facilitated by newer and more performative technologies - has become one of the main features of contemporary artistic production. Nowadays, different art forms can be distinguished by the technologies being used (artificial intelligence, virtual reality, robotics, *etc.*) or by the ways they are experienced (installation, performance, interaction, *etc.*). In contemporary art, time and space context acquire a central role in the realization of the artwork, together with the mutations that it could face due to internal or external factors (e.g., audience experience and interaction). New multimedia artworks lack fixity. These artworks are radically different from analogue fixed ones, such as paintings, sculptures and architecture, which have a long life expectancy (Besser, 2001) Multimedia artworks, "whether they are film-, video-, or computer-based, have extremely diverse characteristics. Aspects including variability, reproduction, performance, interaction, and being networked are incorporated in many works. Media art is not one static, unique object, but often a collection of components, hardware, and software which together create a time- and process-based experience" (Wijers, 2013). Besides being based on experiments with new technologies, new multimedia artworks often emerge from the collaboration and co-participation of multiple artists, technicians, curators, performers, and audiences (as in the case of interactive installations) and with a strong relationship with the original surrounding environment.

In this scenario, it is important to adopt new strategies for preserving contemporary art that specifically take into account the technological, multimedia, and the mutable nature of the artwork, as well as the role of the audience and the interactive experience. Strategies for preserving and digitizing video, film, photos and audio (Salvati and Canazza, 2014; Bressan et al., 2016; Verde et al., 2018) as well as hardware and software components should converge in a unique preservation model with the aim of preserving and reactivating the artwork.

During the last years, experimental preservation strategies have been adopted in the reactivation of several multimedia artworks. Furthermore, multimedia archives are growing by collecting contemporary artworks through original and different approaches. Since the 2000s, the archival community, universities, museums, and artists, have become more aware of the specific issue of preserving multimedia art. In Europe, many archives are dealing with the preservation of new multimedia artworks and several projects have been carried out in this research field. Among them there is the ZKM (*Zentrum fur Kunst und Medien*)[1] in Karlsruhe, with the collections of video, sound and interactive art, the organisation of symposiums (e.g., *Digital Oblivium*[2] in 2010 and 2011) and projects regarding preservation; the *Archive of Digital Art* (ADA)[3] and the free-access art and researcher database *Basis Wien*[4]. The EU more and more often funds projects focused on the development of new strategies of preservation, such as the Horizon's projects *Dynamic Preservation of Interactive Art: The next Frontier of Multimedia Cultural Heritage* and *New Approaches in the Conservation of Contemporary Art* (NACCA)[5]. An extra-Europan example is the Guggenheim Museum in the US, with the *Variable Media Initiative*, which aims to create a new preservation strategy for media-based and performative works. The initiative now comprises a large group of international institutions and consultants who have created new archives by using the proposed strategy[6].

Despite the wide amount of experiences in this field, a shared methodology for the preservation and reactivation of new art forms is still missing. These practices are still too closely linked to traditional ones and thus have not been developed adequately yet. Often, the ephemeral nature of contemporary art is not taken into consideration in practical terms. A contradiction often emerges: on the one hand, multimedia artworks are conceived as time- and process-based objects; on the other hand, new preservation practices still aim to capture the artwork as a fixed object with a unique and unaltered authenticity.

In this article, we will outline a specific preservation and reactivation strategy called the *multilevel dynamic preservation* (MDP) model. A prototype of this model has been developed by the Centro di Sonologia Computazionale (CSC - the Computer Engineering for Music and Multimedia laboratory) of the University of Padova (Canazza and De Poli, 2020; Canazza et al., 2022) during the preservation of Carlo De Pirro's multimedia artworks (Bressan and Canazza, 2014). To date, the model has undergone further development from its original definition based on the results obtained investigating the case studies on which it has been tested. The fundamental principle of the model is that the artwork shall be considered as a complex object of multimedia instances, which is not fixed in time, but rather defined by a process. To accomplish this, the model consists of horizontal layering, representing the phases of reproduction of the artwork (so its transformation process), and vertical one, from which it is possible to zoom from the detailed features of a single exhibition (performance or installation) to the relations between all the exhibitions of the artwork. The two-dimensional layering aims to register both the multimedia nature of the artwork and its dynamic authenticity.

1 ZKM and conservation of Media Art https://zkm.de/en/keytopic/conservation-of-media-art (last accessed 6 March 2023).

2 Digital Oblivium 2010 https://www.e-flux.com/announcements/36340/the-digital-oblivion-international-symposium/(last accessed 6 March 2023).

3 ADA archive: https://www.digitalartarchive.at/nc/home.html (last accessed 6 March 2023).

4 *Basis Wien* database https://www.basis-wien.at/db/advsearch?show=advsearch (last accessed 6 March 2023).

5 Horizon projects: https://cordis.europa.eu/project/id/703937 and https://cordis.europa.eu/project/id/642892 (last accessed 6 March 2023).

6 The variable Media Initiative https://variablemedia.net/e/index.html (last accessed 6 March 2023).

FIGURE 1
Graphic representation of the principle behind of the proposed model: preservation is strictly dependent on reactivation, which depends on documentation while producing new one.

The paper is organized as follows: Section 3 outlines the main features that have to be considered in new art forms, through the perspectives of documentation, reactivation and preservation; Section 4 describes the MDP model, illustrating both its conceptual framework and computational structure; Section 5 investigates a case study on which the model has been applied. The case study consists of the reactivation and preservation of a 1999 computer-based musical installation called *Il Caso delle Sfere* (English: *The sphere's chaos*) by Italian composer Carlo De Pirro. The reactivation of this installation was challenging from several points of view and was an important testing ground for the model. This section will take a close look at both reactivation strategies, multimedia instance storage and subsequent preservation.

2 Documentation, reactivation and preservation

Within the context of complex art preservation, a fundamental statement is needed: preservation can only take place if the artwork is active or can be reactivated. If is not, and the instances of its reactivation are missing, preservation is not possible, but the artwork can exists only through its related documentation (if present). An artwork (e.g., an interactive installation) is active when all its instances are organised and operate according to the intent of the artist. The reactivation of an artwork is possible only in those cases in which all the necessary information is provided. In fact, this allows to organise and activate the artwork according to the original intent of the artist. Figure 1 shows the close relationship between documentation and reactivation, the two main concepts in the preservation of complex artworks.

2.1 Contemporary art documentation

"[. . .] in visiting contemporary museum exhibition, we are confronted with the irreversibility of time [. . .] the only things that remain will be the documentation: a catalogue, or a film, or a Website" (Groys, 2016). In his essays, Borys Groys focuses on the ephemeral nature of contemporary art which contrasts with the claim of organised digital society—where everything is under control, safe and reversible—and promotes the effectively transitory character of the present order of things and the rules that govern contemporary social behaviour. When we talk about art as fluid - or "art rheology", as proposed by Groys - we should move away from traditional principles of relating to it, both in terms of contemplation and especially in terms of preservation. Although art does not produce objects anymore, we can create information about art events, performances, temporal installations and exhibitions. "Traditional art produce art object. Contemporary art produces information about art events" (Groys, 2016). Since the temporal fragility of art rarely allows for the preservation of art itself, documentation of what and how it was produced has become essential to securing and thus preserving the activities of artists. The documentation process covers the artwork through a multidimensional perspective, from technical information about its physical and performative features to its actual activation. In fact, for the past several decades, the art world has been churning out new documentation strategies to cover all the different aspects of the work. Multimedia documentation is a fundamental component of information: photos, audiovisual recordings, and many other formats of multimedia documentation allow to access the original form of the artwork, how it was displayed and how the public interacted with it. "Oral history" - often mentioned as a fundamental source of the artwork description - is strictly related with the multimedia documentation, joining testimonies of the multiplicity of individuals who experienced it. In addition to the "sanctions" (Irvin, 2005) and "intentions" of the creator(s), it also includes statements of people who contemplated or partecipated in the artistic event. In this context the interview has become a powerful tool for documentation art. In the creative workflow, the interview stands as a modern art manifesto (Miller, 2009), a tool with which artists can state a theoretical framework to contextualize their artworks and, in some cases, assert their artistic intention (Lichtin, 2016). Interviews cover an important role also in the experience and contemplative workflow. Since new art forms often bring the public to the center of the artwork as a former part of the art content, its testimony can not be left unnoticed. Information acquired from audiences can fill the gap left by multimedia documentation and be related to sanctions and intentions of the creators by enriching the overall knowledge about artworks (Costello et al., 2005; Muller E., 2008; Muller L., 2008; Jones and Muller, 2008).

All these elements of documentation are essential for returning high-level information about the artwork and describing the behavior of some kind of organism in relation with time, space and other living organisms, but they do not provide (or only partially) information about its constitution and the rules that govern it. In this perspective, we need to provide technical documentation about various components of the artwork and their relationships and functions. In other words, information about needed ingredients and how they should be used to bring the living organism to life. Because of the complexity of artworks and especially their ephemeral nature, as early as the 1990s the concept of

"score" is being used to describe the documentation inherent in the technical and realization aspects (Laurenson, 2004; Laurenson, 2006; Phillips, 2015) "When working with media in the context of art, parallels to music are inevitable. Exhibition becomes like a performance or re-creation, an enactment. Active components must be assembled into a complex system to function together according to the artist's intentions. In the absence of the artist/creator, a person with previous training or experience with the piece and/or a "score," or set of instructions, is required" (Viola, 1999).

Documentation is sometimes the only evidence of the artwork's existence (Depocas, 2013) and—even when it is not—should always cover a central role in determine how decisions can be made and action taken in order to protect its authenticity from the fabrication of history and prevent its loss.

2.2 Reactivation through reinterpretation

One of the practical goals of documentation is the reactivation. Reactivation means to re-assemble, re-set off, re-start and so activate again the multiple and heterogeneous instances of the artwork, while preserving its authenticity. Given the heterogeneous composition of a single artwork and the formal and physical diversity among the artworks, an universal approach to reactivation can not exist and several have been developed and studied. It is possible to identify two main approaches to reactivation: the "purist/original" and the "adapted/update" one (Wijers, 2013) The first one uses the original components for activating the artwork as close as possible to its original appearance. The second one is based on the use of new components (especially technological ones) with possible changes in the artwork's appearance. Reactivation (and then preservation) activities related to the first approach require to pay special attention to the artwork's materiality, to which the work must be closely related (especially in term of life expectancy). While the second approach allows for a broader consideration of the artwork, beyond its materiality, toward its functionality, concept, and identity. Several strategies belong to this approach, such as emulation, migration, and virtualization, each one with its advantages and disadvantages. However, there is no one best approach to choose. In most cases, the best practice is to let the artwork choose the right reactivation approach on the basis of its identity. Many times a hybrid approach is required. The artwork always needs to be interpreted, analyzed, studied (through its documentation) and then represented in an intelligible way, in order to be understood and then reactivated. Therefore, a reactivation should always be understood as a re-creation (Mellado, 2019), or rather a reinterpretation (Wijers, 2017), even when it is done by the author of the artwork herself/himself. Reinterpretation may seem like a dangerous act but it is rather a powerful operation to highlight the fundamental properties of authenticity and identity of the artwork. One of the practical goals of documentation is the reactivation. Reactivation means to re-assemble, re-set off, re-start and so activate again the multiple and heterogeneous instances of the artwork, while preserving its authenticity. Given the heterogeneous composition of a single artwork and the formal and physical diversity among the artworks, an universal approach to reactivation can not exist and several have been developed and studied. It is possible to identify two main approaches to reactivation: the "purist/original" and the "adapted/update" one (Wijers, 2013) The first one uses the original components for activating the artwork as close as possible to its original appearance. The second one is based on the use of new components (especially technological ones) with possible changes in the artwork's appearance. Reactivation (and then preservation) activities related to the first approach require to pay special attention to the artwork's materiality, to which the work must be closely related (especially in term of life expectancy). While the second approach allows for a broader consideration of the artwork, beyond its materiality, toward its functionality, concept, and identity. Several strategies belong to this approach, such as emulation, migration, and virtualization, each one with its advantages and disadvantages. However, there is no one best approach to choose. In most cases, the best practice is to let the artwork choose the right reactivation approach on the basis of its identity. Many times a hybrid approach is required. The artwork always needs to be interpreted, analyzed, studied (through its documentation) and then represented in an intelligible way, in order to be understood and then reactivated. Therefore, a reactivation should always be understood as a re-creation (Mellado, 2019), or rather a reinterpretation (Wijers, 2017), even when it is done by the author of the artwork herself/himself. Reinterpretation may seem like a dangerous act but it is rather a powerful operation to highlight the fundamental properties of authenticity and identity of the artwork.

2.3 Preservation of a process-based authenticity

As a consequence, we can do nothing but re-think the art preservation practices. Preservation mainly strives to slow down the process of degradation and obsolescence and then ensure the permanent accessibility to documentary heritage (Edmonson, 2002). Traditional conservation principles were closely linked to the physical integrity of the artwork, but today it is not longer guaranteed as an artwork cannot be considered a fixed and unchangeable object. As introduced by Factor et al. (2009), authenticity cannot be evaluated by means of a Boolean flag, but rather as the result of a process. In fact, new forms of art define mutable and multiple authenticities, rather than a single fixed one (Castriota, 2019). Therefore, a contemporary art preservation strategy should not only consider the initial exhibition of an artwork or artist/creator's explicit "sanctions" at a given moment, nor only the last exhibition, but rather all the exhibitions that represent the development of the work over time.

The specific approach shall be determined *ad hoc* for each artwork, in order to preserve all its instances through a process-based model and minimize the loss of information. Such a model shall be mainly based on documentation and capable of capturing, organizing, and preserving all the information related to the artwork and its mutation over time.

3 A multilevel dynamic preservation model

The *multilevel dynamic preservation* (MDP) model aims to preserve multimedia artworks through different levels of information and various exhibitions and thus as a process or a dynamic object. This model was conceived as an expansion of the methodology for the preservation of audio documents defined by Bressan and Canazza (2014). The key concept, in this preservation method, is the *preservation copy*. For an audio-visual document, the

preservation copy is "the artifact designed to be stored and maintained as the preservation master" (Miliano, 1999), and it consists of an organized dataset containing all the information represented by the original document, accompanied by the metadata and by the documentation about the preservation process. The MDP introduces the concept of the *Digital Preservation Object* (DPO). The artwork's DPO is a digital file that encapsulates a set of digital and analogue inter-related items[7], organized according to a logical architecture, and with the aim of representing a single exhibition of the artwork (the first exhibition or any reactivation). Therefore, the preservation copy defined by the MDP is designed to group and connect all the DPOs of a single artwork with the aim of representing it as a process rather than a single fixed work.

3.1 Conceptual framework

The overall structure of the model is based on the *General Instruction Standard for Archival Description* ISAD(G) (ICA, 1999). The model defines three levels arranged in a hierarchical structure: as with ISAD(G), all metadata records can be inherited from the highest to the lowest level. The highest level of the model represents the artwork that internally groups all its activations. The artwork can be compared with the *series* in the ISAD(G). Each exhibition is a new manifestation of the artwork and constitutes the unity of the *series*. The intermediate level consequently represents the single exhibition (performance, installation, event, *etc.*), that forms the DPO. The DPO is a container - or a *folder*, to use the analogy with the ISAD(G)'s *file* - in which all the items related to a single exhibition can be gathered. The lowest degree represents the single item of an individual exhibition. The items are all the analogue and digital elements that make up the artwork, the distinct elements of its score, and any other kind of documentation that testifies to the experience of each activation. The *item* level in the ISAD(G) is the "smallest intellectually indivisible archival unit". However, we define three different kinds of items with distinct functions for the artwork and thus different roles within the preservation model. Items can be classified as *components* (those parts of the artwork which have been used in a specific reactivation, such as hardware, software, performance objects, digital multimedia file, *etc.*), *score* (useful information about the realization and the performance of the artwork, such as musical scores, technical notes, comments, instructions, *etc.*), and *documentation* (any document that bears witness to some aspect of a specific reactivation, such as interviews, multimedia documentation, *etc.*).

A graphic representation of the model is shown in Figure 2. It is important to underline how *components* and *score* items can belong to multiple DPOs. If some (or even all) parts of the original or previous exhibition are reused in an ongoing reactivation, those will also be registered as elements of the new DPO. The *multiple belongingness* of items is an important property of the presented model, which differs from the general structure of the ISAD(G) in which each archival *item* only belongs to a unique *file*. The multiple belongingness can be applied only to *components* or *score* type items since *documentation*-type ones are designed to gather information about the ongoing exhibition and therefore must belong to a unique DPO. This property allows the artwork to be represented not only as a group of delimited records, but rather as a process or a dynamic object.

It should be noted that the order of DPOs is not given. In fact, even though the model shows a well-defined vertical structure, it does not define any kind of association between DPOs, in order to avoid pre-established discursive formulations and interpretations. For instance, the physical integrity and/or the definition of a fixed object is not denied by this model. The physical persistence of an artwork can be deduced from the delineation of a process, if several exhibitions define the same physical properties. The model aims to promote a high degree of freedom in searching and managing information. It allows to filter the information and arrange narrative paths for several users' requirements.

3.2 Preservation copy

Figure 3 shows the logical structure of the preservation copy, based on the definition of the conceptual framework described in Section 3.1. Due to the complex nature of new forms of art, the preservation copy model follows a multilevel structure. The archival structure for each artwork includes a first separation between data storage (*data*) and multimedia files (*file storage*). The data section includes a first level containing metadata related to general information on the artwork, such as title, author, date, *etc.* This section also gathers bibliographic sources, publications and scientific papers about the artwork (*biblio item*), in order to keep track of its history and all of the relevant information for its correct preservation and subsequent reactivations. Metadata schemes related to the individual DPOs, described in Section 3.1, are grouped in a first sub-level, in which DPOs maintain their own uniqueness, while keeping their link with the original artwork. The storage system provides for the presence of (n) DPOs, maintaining the relationships between them and the artwork, in order to minimize the loss of information. Specific information related to individual DPOs is contained within the three sublevels.

- **Components** contains metadata schemes of the individual components of a particular installation, i.e., the individual units that make it up. Given the wide variety of components that can be used to create an artistic installation, the model provides for their grouping into four categories: *hardware*, *software*, *audiovisuals* and *various*. The hardware category contains separate records for main electronic devices that make up the installation, and secondary items, such as electronic connectors, cables *etc.*, That are used to link and operate the various devices. Software components metadata are collected in separate sections for the description of the source code, the app or software used, and the utilities (APIs, libraries *etc.*). If an artwork includes audiovisual sources, they are described in a separate section with dedicated

7 Analogue items are recorded in the DPO through descriptions and digitised processes (photo, 3-dimensional reproduction, etc.). E.g., A video screen is recorded in detail through a series of metadata with which we can define characteristics (inches, resolution, etc.) and information (brand, model, year of production, etc.) about the hardware. The record can be complemented with photos and/or 3D reproductions (especially in cases of less common or build-on-purpose devices) and where it can be found if it is still physically conserved.

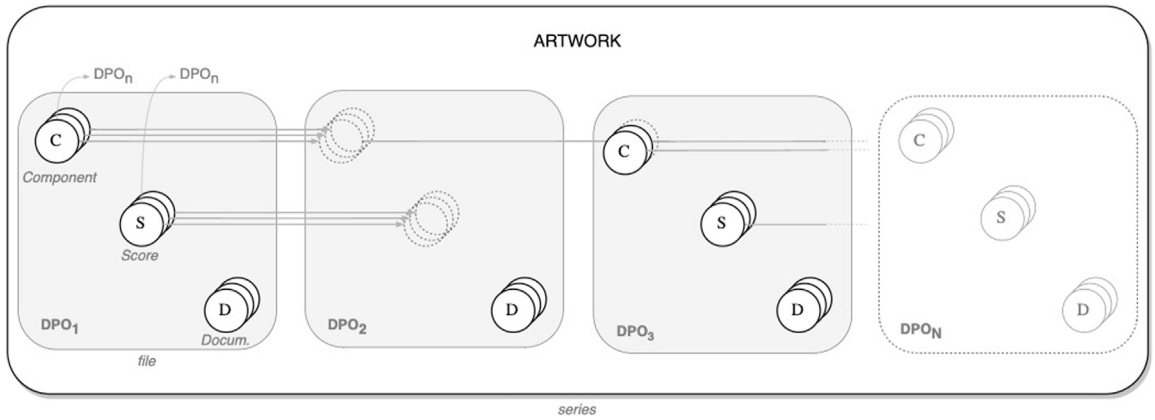

FIGURE 2
Graphic representation of the *multilevel dynamic preservation* (MDP) model. The dashed and linked items display the *multiple belongingness* property where by a specific component element and/or score can belong to several DPOs. If this is the case, the item is only recorded once (non-dashed item) and can be retrieved and linked (the dashed arrow) in subsequent DPOs.

metadata schemes. In this case, given the wide variety of formats and carriers that make up the audiovisual category, the model provides descriptive records for analogue or digital video materials (*video*), film material (*film*), sound (*audio*) and photographic material (*photo*). For the metadata description of audiovisual components, the proposed model is based on scientific protocols and methodologies developed over the past few years at specialized centers, such as La Camera Ottica Lab of the University of Udine for preservation strategies and data gathering related to film and video materials, and the CSC for the description and preservation of audio documents (Pretto et al., 2020). The last category (*various*) includes the medatada schemes of all those components that do not fall into any of the above-mentioned categories, such as common objects, paintings, statues, musical instruments *etc.*

- **Score** this section provides the metadata schemes related to a single or multiple files that make up the score of the artwork. The score documentation includes the high-level descritpion of algorithms and models used in the DPO realization, as well as operating instructions and technical notes describing how individual components work and are linked together within the artwork.
- **Documentation** includes metadata schemes related to those files that contain all the documentation related to the DPO, such as interviews, photos, audio and video recordings on the field concerning the single event or reactivation.

The proposed model provides for a separate storage space for multimedia files used in a particular artwork and in all its related DPOs. The file storage includes videos, audio recordings, source codes, docs, score document, *etc.*, Organized in different folders. Metadata schemes organized and stored in the *data* section are linked to each other and describe the files in the storage space. This solution has been chosen in order to prevent double instances of the same files while preserving multiple DPOs, reducing the storage space being used. In fact, as described in previous sections, the MDP model allows multiple DPOs to refer to the same files. An example of application of the proposed model is described in following section.

4 Case study: a computer-based music installation

The model described was born as part of the preservation intervention of a selection of interactive music installations by Carlo De Pirro (with specific case studies on the works *Carillon* and *Cassette dell imagine*) (Bressan et al., 2009) and an opera video by Adriano Guarneri (*Medea*) (Bressan and Canazza, 2014). A prototype of the model was first defined in Bressan and Canazza (2014) and during the last years it has been implemented by investigating its possible applications on several case studies, in order to optimize its structure. Among many, a relevant case study of its application is a video performance from the 1970s, *The time consumes* by Michele Sambin (Fiordelmondo and Canazza, 2023), which has fostered many interesting discussions and developments. In this paper, we report another case study: *Il caos delle sfere* by Carlo De Prior. This case study raised interesting questions on different reactivation approaches and, due to its complexity, it has been chosen for testing the model. The next paragraphs will present the reactivation of the artwork and the application of the MDP model.

4.1 Il caos delle sfere by Carlo De Pirro

The work *Il Caos delle Sfere: anche tu musicista con 500 lire* (*Be a Musician with 500 Italian Lire*) was first shown on 9 June 1999, at the *Biennale of Young Artists of Europe and the Mediterranean* in Rome. The artwork has been installed several times in Italy and Europe until 2004[8].

The main musical component of this installation is the Disklavier, a self-playing acoustic piano manufactured by Yamaha Corporation. The composer had already explored the

8 Two other reactivations were carried out in 2012 and 2014, finding several problems with some original parts of the installation.

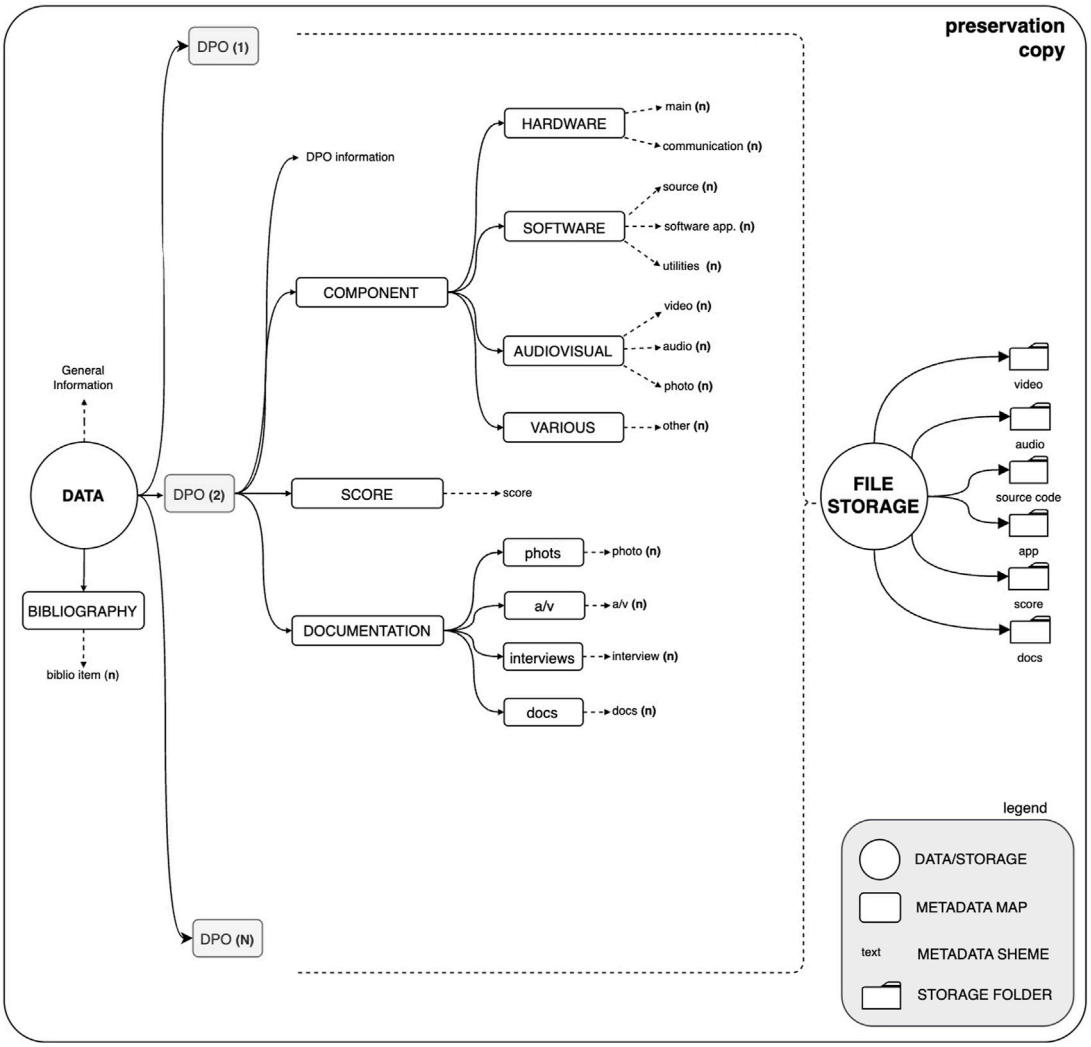

FIGURE 3
Structure of the preservation copy according with the MDP model.

possibilities of this instrument to play increasingly complex scores, otherwise impossible for a human performer. For example, in *Rifrazioni* (for accordion treated via MARS and Disklavier, 1997) and in *Di Vento e cristallo* (for flute and Disklavier, 1997), the author brought into dialogue and contrast the potential of the Disklavier with a solo instrument. *Il Chaos delle sfere* was the first attempt to use the Disklavier as a musical instrument within an art installation[9]. In this case, the instrument was combined with a pinball machine as an interactive component.

The main purpose of this installation was to bring contemporary music and musical research to the general public, and a pinball machine was one of the most popular games among people at the time. In addition, the electronic pinball turned out to be an interesting tool to create a musical structure: the wide variety of possible interactions could make each performance unique, besides combining sight, hearing and touch. The choice of a specific pinball model over a generic one was also relevant for this installation. In fact, the chosen model is the 1992 *Creature of the Black Lagoon*, the first one to add a story with different goals to achieve. This feature allowed the composer to create a more intricate relationship between the game and the music. Instead of simply matching each object hit by the ball with a single sound, the Disklavier plays increasingly elaborate musical sequences following the progress of the game, level after level. A better player will be rewarded with a longer and more complex performance, while remaining able to master the changes during the game play.

The composer realized the installation together with a research group of the CSC, composed by Nicola Orio and Paolo Cogo, in Figure 4. The group developed a dedicated software to implement the communication between the pinball (the interaction side) and the Disklavier (the playback side). The pinball machine sends the signal of its main components (switches to track targets hit by the ball and lights to monitor the game level) to a computer through a parallel port. The software interprets the signal and controls the

9 Later taken up in *Il tempo sospeso*, another 2007 installation featuring the Disklavier and a light system.

FIGURE 4
The first version of the installation.

Disklavier through a MIDI communication: it can choose between forty-three MIDI sequences, a selection of all the sequences written by De Pirro, elaborated further by the so-called "Controlled Refractions" (computer-generated musical gestures intertwined with real-time performance, studied in those years by the composer together with Nicola Orio at the CSC). The graphical user interface was minimal, only designed for testing purposes. Without any feedback from the computer, the player could explore the relations between the game and the music and get surprised by hitting a different spot or reaching a new level.

4.2 Reactivation methodology

The reactivation and preservation processes took place between March 2022 and February 2023 at the CSC lab. The research project was carried out by an interdisciplinary research group, composed of engineers, electronic music researchers and an audio-visual preservation expert. The assistance of some of the original installation technicians was essential since critical parts of the installation were left undocumented. Unfortunately, the project could not rely on the participation of the composer since he passed away in 2008.

The first step was to assemble DPOs from past activations of the installation. The gathering of almost all the original installation components (pinball machine and original computer) was straightforward as all of them were being preserved at the CSC at that moment, while the Disklavier was borrowed from the Sound and Music Processing Lab (SaMPL) of the Conservatory of Padua. Nevertheless, the elaboration of a score with the necessary instructions for the activation was challenging. During its many representations, the research team and the composer kept on updating the installation to best fit the exhibition's context, and refine and improve the final musical experience. For example, the software was developed with a trial-and-error approach, with almost no comments included (as witnessed by Nicola Orio). More than 10 versions of the same source code were developed, introducing uncertainty about the proper version to consider. The same goes for instructions on how to make the physical part of the system communicate. This shortcoming was overcome by a thorough study of the installation and the multimedia documentation acquired. Besides the existing documentation (of little technical use because it consisted mainly of photos and videos of the installation being performed), new resources were produced. The oral history resources, obtained from some of the technicians who worked at one of the representations of the installation (Nicola Orio, Sergio Canazza, and Antonio Rodà), were very useful. With this information, it was possible to define a work plan and choose an approach for reactivating the installation.

Given the physical and logical parts and the related documentation, the next step was to produce a high-level description of the artwork as a whole (shown in Figure 5). The goal was to analyse the overall performative system's rehabilitation, fielding the issues of the technological migration and recovery of analogue tools. The result was the organization of the elements composing the musical installation into *nodes*, i.e., subsystems where two or more elements contribute, cooperate and interact to perform a given task. For *Il Caos delle Sfere*, three main nodes can be defined.

- ***Interaction node***: the node where in-game data signals are generated for the selection of the sequences that are going to be reproduced;
- ***Communication node***: the node in which, starting from the data produced in the *Interaction node*, the sequences to be played are selected (or created in real-time) and corresponding events, named *MIDI events*, are generated;
- ***Playback node***: the node in which MIDI events sent by the *Communication node* are used to move Disklavier's keys.

The Interaction node is the part of the artwork where any user can interact directly to determine the final musical performance and it is formed only by the pinball. On the other side, the Playback node is the subsystem dedicated to the reproduction of the generated musical sequences and it is formed only by the Disklavier. Giving the elements involved in these nodes, the development team did not take into consideration any technological migration for them. The reason for this choice had to be found in the artistic relevance of these parts for the musical installation. They allow the interaction experience

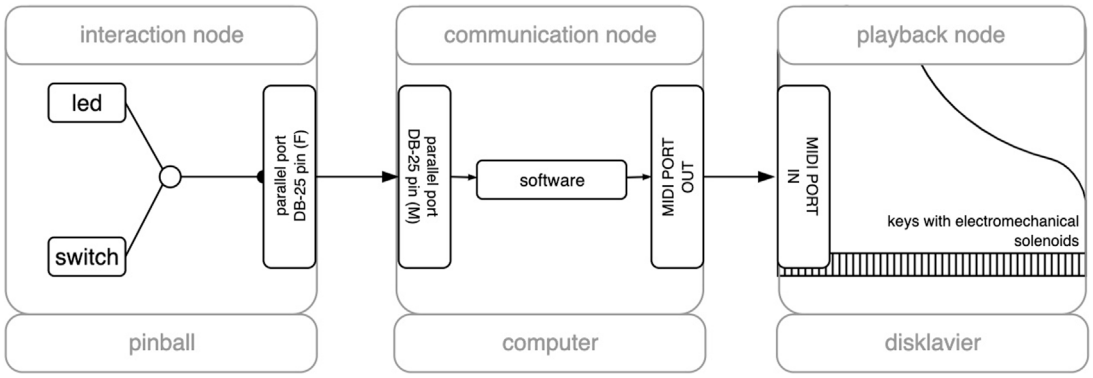

FIGURE 5
High-level description of the installation setup. The graphic representation displays the main components of the installation and how they are linked together. Such information can be used in defining the score item.

between the audience and the artwork. Furthermore, the choice to adopt a purist approach for the pinball and the Disklavier was also supported by their states of conservation.

The Communication node is the part of the artwork that makes the pinball and the Disklavier communicate. The original computer machine represents this subsystem of the installation. The computer is responsible for running the main software (whose source code is written in C) to process, generate, and modify melodic sequences that are played by the Disklavier in relation to what is happening in the pinball game. The original computer has never been updated over the years, due to the fast growth of better technologies. This made the computer obsolete and very unreliable to be used in public exhibitions (several parts of the hardware were damaged, such as the motherboard slots, graphic card, and the parallel connection). Furthermore, the software part of the communication node was particularly disorganized (as described above) and impossible to execute on a modern machine (even the source code cannot be executed on current machines due to backward incompatibility). Without any update on the communication node, there was no possibility for the artwork to be exhibited. Restoring its technological asset was not sufficient. For the computer, replacing its parts with spares of hardware used at the time of the artwork's development shall be considered only a short-term solution. For this reason, it was decided to apply a migration approach for the complete communication node.

The technological migration was carried out by replacing the original computer with a modern microcontroller board and by rewriting the entire source code with a compatible programming language. The microcontroller board chosen is the Arduino Mega 2,560, which offers a low-complexity compatibility with the DB25 parallel port interface, with Arduino programming language. In order to understand the "rules of the game" (i.e., how the pinball signal is processed by the software and how the musical events are related to the game) and then carry out the porting of the software, a deep archaeological analysis of the original source code was carried out. The results was the creation of a high-level routing description of the algorithm, shown in Figure 6.

This development approach allowed to carry out the porting of the source code, and thus the reactivation of the installation. Figure 7 shows the research group with the reactivation of the installation. The first version of the reactivation was exhibited during Science4all (in Figure 8), a scientific dissemination festival of the University of Padua, held on 30 September 2022. The current version faced some optimizations and is currently active at the CSC lab.

4.3 Application of the model and discussion

The last phase of the preservation process expects to record all the components and the documentation produced during the reactivation of the artwork. It results in a new DPO entry related to the other ones, which aims to provide the necessary information for future reactivations and allow the preservation of the artwork. In the first phase, components and documentation of the past artworks were inserted with correlated DPOs. The JSON entries[10] below show (partially) two examples of records (the pinball machine and the original Desktop Personal Computer) with essential metadata field:

```
"3nG62Dx0CsyH7IpCUTf5":{
    "name":"Creature from the black lagoon Pinball",
    "type":["Other","Electro mechanical pinball","Game"],
    "manufacturer":"Midway Games",
    "datePublished":"1992-12-01",
    "urlRelated":["https://www.ipdb.org/machine.cgi?id=588", ...],
    "description":"Creature from the Black Lagoon is a pinball ...",
    "image": ["gs://...1999cscpinball.jpg", ...]
    "creator": [
        {"__datatype__":"documentReference",
        "value":"organization/ZCGgXxKma41qbwf9g2u4"}
    ],
    ...
}

"MYZ7M7tHcbVx4TpkhkFn":{
    "name":"Desktop Personal Computer 1997 ",
    "type":["Hardware","Desktop Personal Computer"],
    "dateCreated":"1997-01-01"
    "description":"1997 Perosnal Computer used at the CSC ...",
    "components":["PCIset SB82371SB/SB82437VX","VIBRA 16C CT2505" , ...],
    "image": ["gs://...1997csccomputer-front01.jpg", ...]
    "creator": [
        {"__datatype__":"documentReference",
        "value":"organization/ZCGgXxKma41qbwf9g2u4"}
    ],
    ...
},
```

10 For this example, authors chose the JSON data format language for its ease of reading. The model is not limited to JSON entries, but it can be applied with different languages and systems.

In the context of the new reactivation, the Arduino Mega Board 2,560 and the new source code written with Arduino have been inserted:

```
"Y3wU7H5NwBHe6j4WyTAD":{
    "name":"Arduino Mega 2560 Rev3 Mircontroller Board",
    "type":["Hardware","Microcontroller Board"],
    "manufacturer":"Arduino.cc",
    "datePublished":"2020-03-26",
    "urlRelated":["https://store.arduino.cc/...", ...],
    "description":"The Arduino Mega 2560 is a microcontroller...",
    "components":["ATmega2560"]
    "image": ["gs://...2022arduinomega2560board01.jpg", ...]
    "creator": [
        {"__datatype__":"documentReference",
        "value":"organization/ZCGgXxKma41qbwf9g2u4"}
    ],
    ...
}

"tXoe6xqi5qUhHm1ktld8":{
    "name":"Il coas delle sfere Source Code",
    "type":["Source Code"],
    "dateCreated":"2022-12-12",
    "author": [
        {"__datatype__":"documentReference",
        "value":"organization/ZCGgXxKma41qbwf9g2u4"},
        {"__datatype__":"documentReference",
        "value":"person/aUcdDNOSHpTyK407psEx"},
        {"__datatype__":"documentReference",
        "value":"person/8h14KTOuIgDk6YvlmE2T"},
        ...
    ],
    "programmingLanguage": "Arduino",
    "runtimePlatform": "Arduino IDE 1.8.19",
    "description":"Arduino source code of il tempo consuma ...",
    "component":["ATmega2560"]
    "codeStorage": ["gs://...2022iltempoconsuma.ino", ...]
    "creator": [
        {"__datatype__":"documentReference",
        "value":"organization/ZCGgXxKma41qbwf9g2u4"}
    ],
    ...
}
```

In addition, both the score and the documentation for reactivations and exhibitions have been added. The score is the high-level representation of the entire system (in Figure 5) and the high-level description of the source code (in Figure 6). This information is essential in order to reactivate the installation and to port the software again, if necessary.

At this level, JSON entries represent individual elements (component, score or documentation) that are only recorded once. Each one of them has its own unique identifier (e.g., 3nG62Dx0CsyH7IpCUTf5 and MYZ7M7tHcbVx4TpkhkFn) that allows it to be called up within different DPOs. Within the single entry, it is possible to recall a multimedia source through a specific field (e.g., codeStorage in the source code entry). This reference allows metadata and the actual element within a archive (e.g., file storage, repository, *etc.*) to be linked via a URL.

The higher level is the artwork with its own unique identifier c9IK45cuYWCVAA4vjZoH. The artwork includes all DPOs that are grouped in an array within a specific field. Each JSON entry of the related DPO refers to other elements including components, score and documentation. The JSON entry below show (partially) the artwork with two DPOs, representing the first and the last activation:

```
"c9IK45cuYWCVAA4vjZoH":{
    "name":"Il caos delle sfere",
    "author":[
        {"__datatype__":"documentReference",
        "value":"person/Jfmcd1MK3KeWGDdHbhdW"}
    ],
    "description":"Il caos delle sfere is an installation...",
    "dateCreated":"1999-01-01",
    "creator": [
        {"__datatype__":"documentReference",
        "value":"organization/ZCGgXxKma41qbwf9g2u4"}
    ],
    "DPOs":[
        {
            "author":[
                {"__datatype__":"documentReference",
                "value":"person/Jfmcd1MK3KeWGDdHbhdW"},
                {"__datatype__":"documentReference",
                "value":"person/IX1tGHF1mHRK7zri8N5P"}
            ],
            "dateCreated":"1999-01-01",
            "description": "Premiere of the installation at the..."
            "creator": [...],
            "Component":[
                    {"__datatype__":"documentReference",
                    "value":"component/3nG62Dx0CsyH7IpCUTf5"},
                    {"__datatype__":"documentReference",
                    "value":"component/MYZ7M7tHcbVx4TpkhkFn"},
                    ...
            ],
            "score":[...],
            "Documentation":[...],
            ...
        },
        {
            "author":[
                {"__datatype__":"documentReference",
                "value":"person/aUcdDNOSHpTyK407psEx"},
                {"__datatype__":"documentReference",
                "value":"person/8h14KTOuIgDk6YvlmE2T"},
                ...
            ],
            "dateCreated":"2022-09-30",
            "description": "Reactivation at Science4All ...",
            "creator": [...],
            "Component":[
                    {"__datatype__":"documentReference",
                    "value":"component/3nG62Dx0CsyH7IpCUTf5"},
                    {"__datatype__":"documentReference",
                    "value":"component/Y3wU7H5NwBHe6j4WyTAD"},
                    {"__datatype__":"documentReference",
                    "value":"component/tXoe6xqi5qUhHm1ktld8"}
                    ...
            ],
            "score":[...],
            "Documentation":[...],
            ...
        },
    },

    "Bibliography":[...],
}
```

Each component and part of the score is recorded only once and recalled by more DPOs. E.g., in both DPOs listed above, the pinball component/3nG62Dx0CsyH7IpCUTf5 is recalled as a reference. The same applies to other items such as people (person/Jfmcd1MK3KeWGDdHbhdW is De Pirro), organizations (organization/ZCGgXxKma41qbwf9g2u4 is the CSC

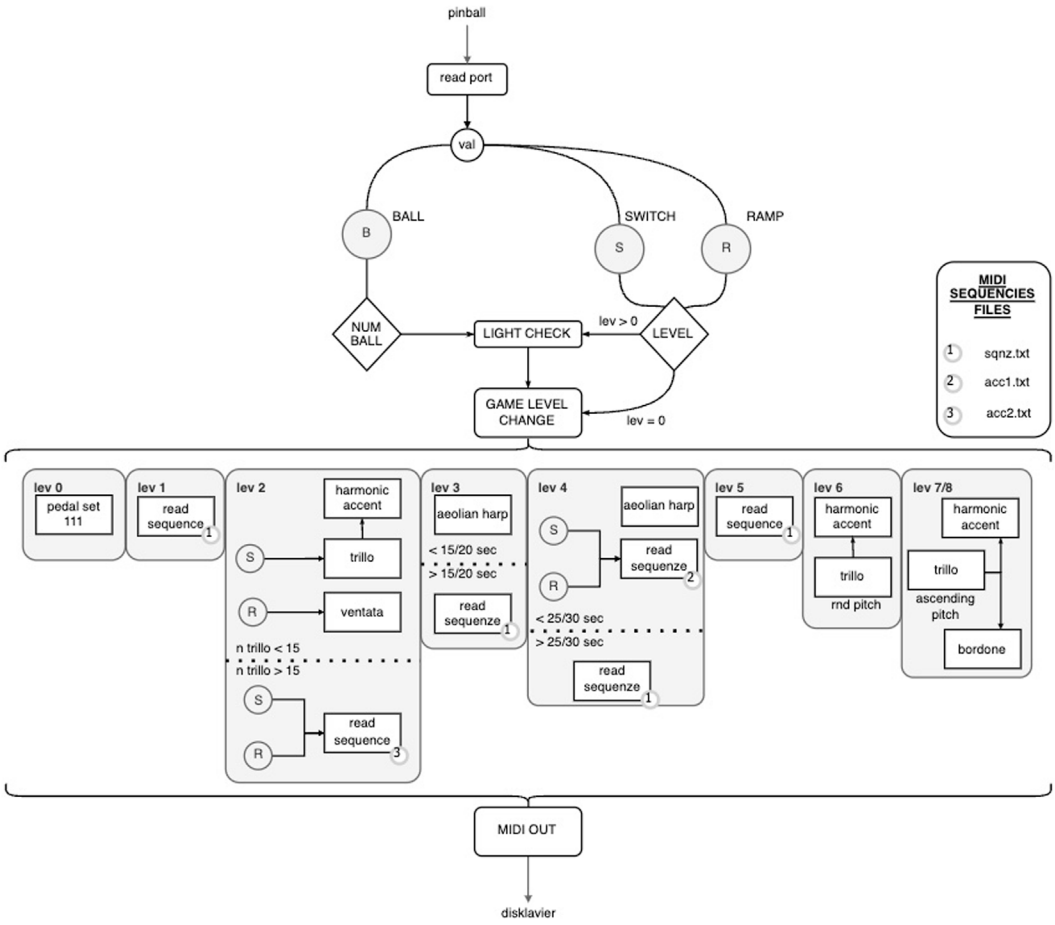

FIGURE 6
High-level description of the software. The graphic representation can help in reading and understanding the source code, as well as porting the software to a different system environment, if necessary. Such information can be used in defining the score item.

lab), bibliography entries, *etc.*, which will separately have their own data schema[11].

Multimedia records are stored separately in a dedicated storage. The model provides for different fields for recalling their related components: image (to retrieve any type of image, e.g., in Desktop Personal Computer or Pinball data schemas), video, sourceCode (for Arduino IDE source code), software, *etc.* The items (Components, Score, Documentation), as well as the highest levels of the model (DPOs and artworks) can be linked to external resources (e.g., images, archives, datasets, *etc.*) through their urlRelated fields.

Figure 9 shows a partial graphic representation of the artwork according to the MDP model. As described above, this new version of the artwork faced some technological changes applied through the migration of some of its parts. Although the reactivation was done with special attention in order to restore identity of the artwork, the MDP model allows to minimize the loss of information related to the original version. With the application of this model, we do not determine a fixed authenticity, neither for the last reactivation nor for the first installation (that is also particularly hard to define due to the lack of information on the original source code). The model allows to preserve the artwork's authenticity as a process of changes (implemented by the composer until 2004 and then by others) and provides the necessary information (archived with rich structured metadata schemas and digitally stored) for further reactivations.

With the application of this model, it is possible to rethink an original answer to the famous Theseus paradox. In brief: during the long voyage from Crete, Theseus and the Athenians had to replace all the wooden parts of their ship because they were gradually deteriorating. At the time of their arrival, all the parts of the ship were substituted. Was the ship that reached the shore the same one that left Crete? This paradox has fueled many discussions from the age of Greek philosophers to the present day. It is also often mentioned in the debate on the concept of authenticity in new forms of art (Groys, 1996; Starn, 2002; Van

11 The structure of the data for each typology of recorded item is based on Schema.org schemas.

FIGURE 7
Part of the research group at the CSC, with the reactivated *Il caos delle sfere*. From left to right: Luca Zecchinato, Mattia Pizzato, Sergio Canazza and Alessandro Fiordelmondo.

FIGURE 8
Installation exhibited at Scienece4all festival on 30 September 2022.

Saaze, 2013). Nevertheless, each artwork would require an individual answer to this paradox. In some cases, the authenticity of an artwork goes beyond its physical properties, while in others it lies precisely in its materiality (e.g., internet art can only exist within the internet). According to Boris Groys, we can answer "yes" to the paradox, since the function of the ship - bringing back Theseus and the Athenians—determine its identity (Groys, 1996). The MDP model would also come to a similar conclusion without giving a yes or no answer. The proposed

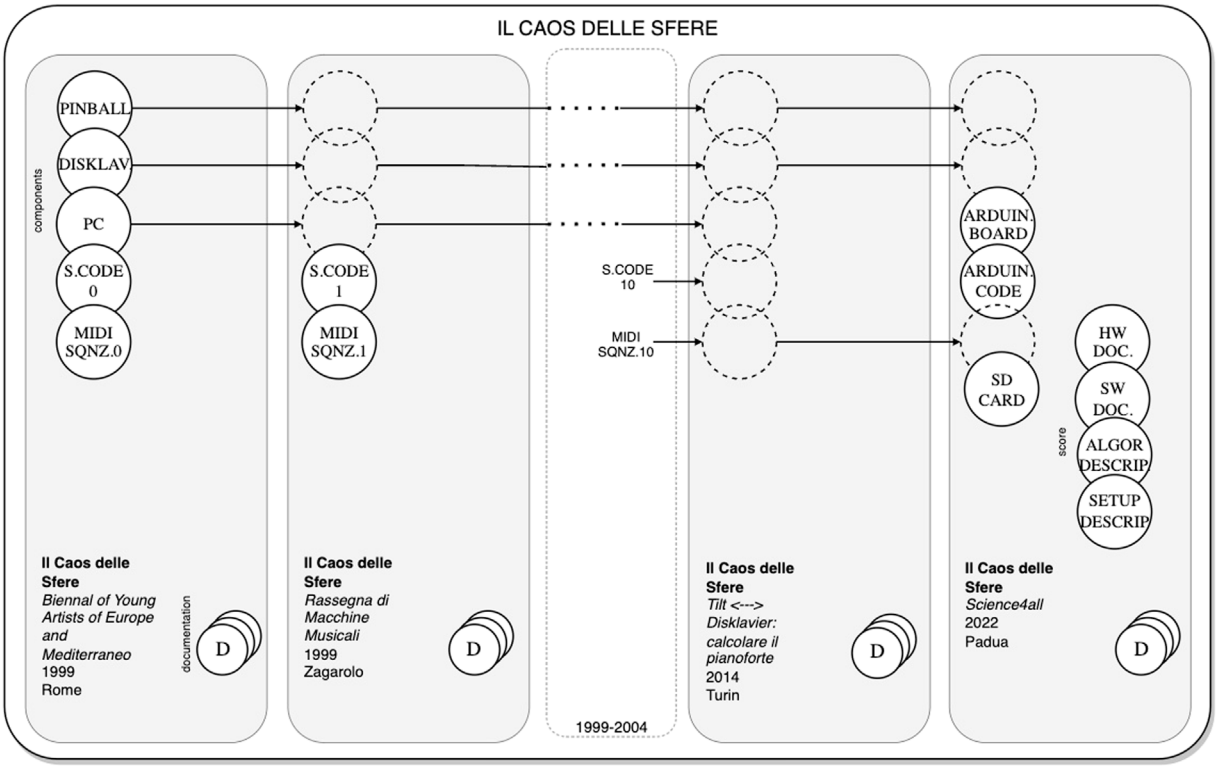

FIGURE 9
Approximate chronological representation of *Il caos delle sfere* according to the MDP model (in Figure 2). The *multiple belongingness* shows the component elements that remain unchanged (e.g., Pinball) and those that change reactivation after reactivation (e.g., source code). The figure shows that the score elements of the system were never produced until the last reactivation. Finally, documentation elements **D** are recorded for each reactivation to document and contextualise it. This representation helps visualise the authenticity of the installation as a process of change rather than fixed.

model changes the perspective from which to look at the case study. The MDP model would not record neither the ship in Crete nor the one in Athens as authentic, but rather it would record its transformation process between the two. Through the interpretation of this process, the authenticity of Theseus' ship can be naturally inferred. According with Groys statement, the authenticity of the ship lies in its function of bringing Theseus back.

5 Conclusion

This contribution focuses on the development of a preservation model for preserving and reactivating new art forms, Due to the shift of paradigm they faced in the last century, it was necessary to define new preservation strategies and develop a shared methodology to save contemporary art from the fabrication of history and preserve it for the generations to come. Artworks shifted away from the principle of medium specificity, embracing the definition of intermedia or multimedia art. In fact, traditional preservation strategies are inadequate for contemporary art, due to the fact that it requires dynamic models in which the technological development and the user experience cover a central role.

At the CSC lab, these requirements led to the development of the MDP (*multilevel dynamic preservation*) model. This model is characterized by a two-dimensional layering: horizontal, to allow the artwork-process to be recorded, and vertical, in order to move from a macroscopic level - artwork as a network of relations between reactivations - to a microscopic one - detailed representation of a single reactivation and all of its instances. The process of documentation covers a central role in the proposed model and it allows the artwork to be preserved and reactivated. On the other hand, each instance of the artwork produces new documentation that, in turn, will become fundamental for future reactivations. The proposed model has been applied to a case study, in order to test it in a real world scenario. In particular, the chosen case study is the reactivation of the 1999 computer-based music installation "Il caos delle sfere", by Carlo De Pirro. Given its complexity, this artwork required to investigate several reactivation approaches and the application of new preservation strategies. The reactivation process had to face several issues, such as the absence of the author, lack of documentation, unusability of some original parts, *etc.* For this particular case study, it has been chosen to proceed with a hybrid reactivation approach, since a technology migration was necessary, especially for the communication node (i.e., the computer), while for the pinball and the disklavier (especially due to their good state of conservation) was possible to proceed with a "purist" approach. The reactivation process produced new documentation that filled the gap present in the existing one, and that was archived in a database organized according to the MDP model, together with further instructions and digital multimedia. The MDP model has been revealed to be particularly efficient in dealing with this complex case study, thanks to its multi-layer and dynamic structure, which allowed to preserve the artwork while maintaining all the relations

between its various components. Therefore, it may be considered a starting point in the definition of a shared methodology for preserving complex artworks. Future improvement of MDP model will investigate the reactivation of the same artwork through different approaches, i.e., the emulation or virtualization of single components, in order to further test its validity. The MDP model will eventually converge in the creation of a database and *ad hoc* interfaces for preserving, archiving and reactivating complex artworks.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary Material, further inquiries can be directed to the corresponding author.

Ethics statement

Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

AF, AS, and SC contributed to the theoretical and practical development of the proposed model; AF wrote the first draft of the manuscript; AF and AS drafted the submitted version of the manuscript; AF, MP, and LZ worked on the case study; MP and LZ wrote some sections of the manuscript concerning the case study; SC proposed the case study reported in the manuscript. All authors contributed to the article and approved the submitted version.

Conflict of interest

The author(s) SC declared that they were an editorial board member of Frontiers, at the time of submission. This had no impact on the peer review process and the final decision.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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