Ontology for Preservation of Interactive Multimedia Performances

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Abstract. Preservation of interactive multimedia performances is becoming important as they are getting more and more popular in performing arts communities. A proper preservation does not only require keeping all the necessary components available at the time of reconstruction but also the knowledge about these components are assembled together for in performance. In digital preservation, metadata has been seen as a mean of enabling semantic processing, cataloguing and querying on preserved digital objects. However, as a record based approach, metadata is weak at describing interrelationships between digital objects in digital archives, which is one of the key requirements for preservation of interactive multimedia performances. In this paper, a domain ontology for describing the complex relationships amongst different components of a performance to support its preservation process is introduced.

1 Introduction

Interactive multimedia technologies are popularly used in contemporary performing arts, including musical compositions, installation arts, dance, etc. Typically, an Interactive Multimedia Performance (IMP) involves one or more performers who interact with a computer based multimedia system making use of multimedia contents that may be prepared as well as generated in real-time including music, manipulated sound, animation, video, graphics, etc. The interactions between the performer(s) and the multimedia system can be done in a wide range of different approaches, such as body motions [20] [17], movements of traditional musical instruments, sounds generated by these instruments [27] [23], tension of body muscle using bio-feedback [18], hart beats, sensors systems, and many others[1]. These "signals" from performers are captured and processed by the multimedia systems. Depending on specific performances, the "signals" will be mapped to multimedia contents for generation using a mapping strategy. Depicted in Fig. 1 is a typical IMP process based on the MvM

[1] See New Interfaces for Musical Expression (NIME) conference series - http://www.nime.org

(Music via Motion) interactive performance system, in which performer's motion is captured in 3D and translated into multimedia contents [20].

IMPs are usually *ad hoc*. Manipulating multimedia content using computers is an essential part of a live performance. Using simply performance outputs recorded in the form of audio and video media will not be sufficient for a proper analysis (e.g. for studying the effect of a particular performing gesture on the overall quality of the performance) or reconstruction of a performance at a later time. In this context, traditional music notation as an abstract representation of a performance is also not capable of storing all the information and data required to reconstruct the performance. Therefore, in order to keep a performance alive through time, not only its output, but also the whole production process to create the output needs to be preserved.

Preserving the whole production process of an IMP is a challenging issue. In addition to the output multimedia contents, related digital contents such as mapping strategies, processing software and intermediate data created during the production process (e.g. data translated from "signals" captured) have to be preserved, together with all the configuration, setting of the software, changes (and time), etc. The most challenging problem is to preserve the knowledge about the logical and temporal relationships amongst individual components so that they can be properly assembled into a performance during the reconstruction process.

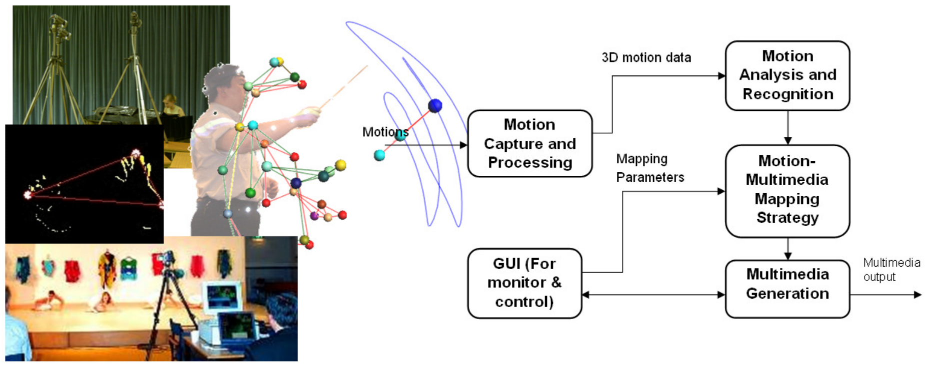

Fig. 1. An example of IMP production process using MvM (Music via Motion) system [20]

This paper introduces an ontology approach to describing an IMP and its internal relationships to support the preservation process. The proposed ontology is an extension of the CIDOC Conceptual Reference Model (CIDOC-CRM), which is an ISO standard for describing cultural heritage [9, 10, 14]. The next section of the paper discusses the context of requirements for the preservation of IMPs. The discussion in Section 3 is focused on metadata approaches to digital preservation. The applicability of CIDOC-CRM for modelling IMPs to support the preservation process and its limitations are analysed in Section 4. In Section 5, the proposed extension from CIDOC-CRM is presented.

2 Context and Requirements

Preservation of IMP is a part of the Contemporary Arts testbed dealing with preservation of artistic contents, which is one of the three testbeds of the EU project CASPAR [2]. The other two are Scientific and Cultural testbeds which are focused on very high volume and complex scientific data objects and virtual cultural digital objects respectively.

2.1 CASPAR Project and OAIS Reference Model

The major goal of CASPAR (Cultural, Artistic and Scientific knowledge for Preservation, Access and Retrieval) is to build a pioneer preservation environment for a wide range of digital resources of many different user communities. It is based on the full use of the OAIS (Open Archival Information System) Reference Model [4] and the exploitation of the latest developments in knowledge technologies. The target of preservation in CASPAR is not only the bits of digital resources but also the information and knowledge carried by the bits.

The very basic concept defined in the OAIS Reference Model is Information Object. As illustrated in the UML diagram of Fig. 2, an Information Object is composed of a Data Object and one or more layers of Representation Information. A Data Object can be a Physical Object (e.g. a painting) or a Digital Object (e.g. a JPEG image)[2]. Representation Information provides the necessary details for the interpretation of the bits contained within the digital object into meaningful information. For digital objects, representation information can be documentation about data formats and structures, the relationships amongst different data components. Representation information can also be software applications that are used to render or read the digital objects. Representation information itself also needs other representation information. The connections between different layers of representation information will form a network which is referred to in OAIS as Representation Network.

Together with representation information for interpretation of the digital object to be preserved, other information about the digital object i.e. Packaging Information, Preservation Description Information and Descriptive Information that also need to be documented are preserved. These types of information are described below:

- Packaging Information tells how different components of an information package are packed together.
- Preservation Description Information consists of information about Reference Information for identification of the preserved information object, Context Information that documents the relationship between the preserved information object and its environment, Provenance Information that documents the history of the preserved information object and Fixity Information for performing integrity checks on preserved data.

[2] In the context of CASPAR digital preservation, only digital objects are of interest.

- Descriptive Information is information that can be used for cataloguing and query on the preserved information object. It generally can be derived from the preserved information object and its preservation description information.

In a summary, as specified in OAIS Reference Model and also adopted in CASPAR, digital preservation is not only dealing with keeping the bits through time but also other related information for interpretation of the bits and for positioning the preserved information in a usage context.

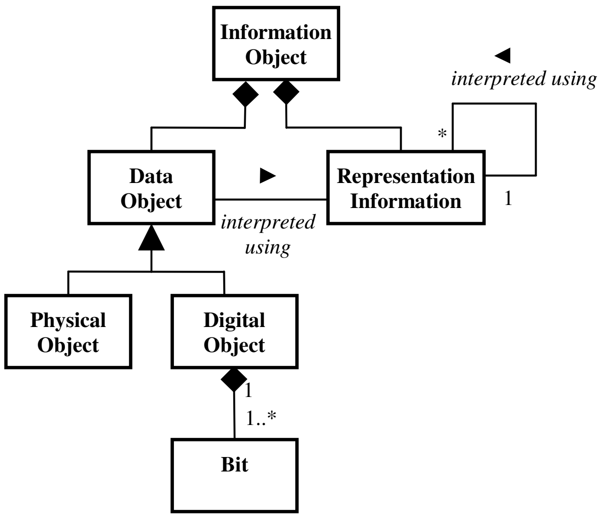

Fig. 2. Basic concept of OAIS Reference Model – Information Object [4]

2.2 IMP Object for Preservation

Basically, preserving an IMP is to keep it alive through time. A performance is an abstract entity. It can be sensed, but cannot be physically got hold of and stored directly. A greedy solution is to preserve everything that is necessary for a performance. In theory, this solution seems to be a good choice as the whole performance can be authentically recreated using the preserved components. Practically, for long term preservation, this will not be feasible due to the amount of storage required for all the hardware used in all the preserved performances. In addition, the lifetime of the hardware and particularly human beings are limited. A more feasible approach is to preserve the digital parts of a performance and digitalised versions of all the documentation about its production process, related equipment and instruments. The performance will be recreated using the preserved digital components and digitally encoded knowledge with available functionally equivalent equipment and instruments at the time of recreation.

With this approach, a performance object for preservation will consists of preservable digital objects. Preserving these digital objects will follow the general conceptual model defined in the OAIS Reference Model. This means, each digital object will be accompanied by its representation information (possibly a representation network), preservation description information (i.e. reference, context, provenance and fixity) and descriptive information. The information accompanying each digital object is specific to the object itself. In addition to the digital objects and their accompanying information, the performance object also needs another layer of information about itself as a whole. This layer of information can be seen as representation information, preservation description information and descriptive information for the performance object. In particular, this information layer includes:

- General information about the original performance, such as, time, data, place, composers, directors, performers, technicians and its various activities.
- Information about various activities necessary for the performance and their temporal relationships. For example, it is necessary to identify what are the activities required for a performance or the order in which these activities need to be carried out.
- Information about roles required for the performance.
- Information about necessary components (including physical and digital components) of the performance and how these components can possibly be linked together to create the performance.
- Information about activities actually performed in the original performance (the actual activities performed during a performance can be different from the necessary activities mentioned above).
- Information about people involved in the original performance and their roles.
- Information about specific components used and produced in the original performance and how these different components were linked together and their usage in different stages of the original performance. Although it is possible that there can be similar applications and tools that can deliver the same functionality as the applications and tools were actually used in the original performance, keeping the original tools and applications and their configuration as in the original performance is important, as "look and feel" of the tools and application is also a part of the artistic content of a performance.

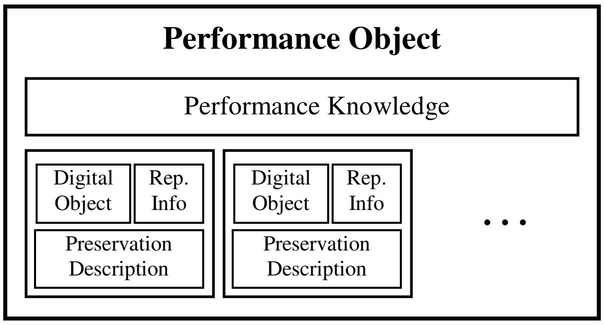

Fig. 3. IMP Object for preservation and its components

Generally, this information layer must provide enough information about the original performance (e.g. for keep a history of the performance, for cataloguing and querying, etc.) and the knowledge on how to recreate the original performance from preservable components. These types of information are specific to the performance and are referred to as Performance Knowledge. The performance object for preservation and its components are illustrated in Fig. 3.

3 Metadata and Ontology for Digital Preservation

Metadata has been proven to be an important factor in digital preservation regardless of preservation methods used [6]. Internally within a preservation archive, metadata are used to describe digital objects, its internal and external relationships, history, access rights for managing, processing, cataloguing and querying. Externally, a standardised metadata set can help to enabling semantic interoperability, which is seen as an important requirement for digital libraries [24], amongst distributed digital archives.

Current most popular metadata used in digital archives are possibly Dublin Core [8]. It was developed as a basic metadata set for discovery of digital records on the Internet. It is now widely used in digital library community for interoperability. However, it is descriptive and too simple for use in a digital preservation process due to the lack of mechanism for describing the relationship amongst digital objects. This is one of the key requirements for digital preservation, such as in the case of preserving IMPs as described in this paper.

Metadata element sets designed specifically for preservation purposes includes those developed by RLG Working Group on Preservation Issues of Metadata (RLG) [1], CURL Exemplars in Digital Archives (CEDARS) project [3, 7], the metadata of the National Library of Australia (NLA) [19] and the Networked European Deposit Library (NEDLIB) [16]. The RLG elements are for describing structure and management of digital image files in preservation archives. The scope of applicability of RLG elements is therefore limited. It also lacks the capability to describe the relationships amongst related digital objects. CEDARS, NLA and NEDLIB element sets are more comprehensive and also compliant to OAIS Reference Model. A comparative analysis has shown that these three elements sets have a high level of convergence in their objectives and rationales [22]. In addition to supporting the OAIS Reference Model, these three sets are aimed at supporting the management of archived digital objects and can be applicable to a broad range of digital contents. CEDARS and NLA also have elements for describing the relationships amongst digital objects. Despite their convergence, as using different set of vocabulary, interoperability between these metadata sets is a problem. A consensus effort was carried out by the OCLC/RLG Working Group on Preservation Metadata to develop a common Metadata Framework to Support the Preservation of Digital Objects, which was based largely on CEDARS, NEDLIB and NLA element sets [21]. The Preservation Metadata Implementation Strategies (PREMIS) Working Group later built on this framework a PREMIS data model and a data dictionary for preservation metadata [25].

Different from its predecessors, the PREMIS data model explicitly defines five basic types of entities involved in digital preservation activities: Intellectual Entities, Objects, Events, Rights and Agents. Vocabulary for describing properties (e.g. entity types, identifiers, characteristics, etc.) of these entities and their interrelationships are defined in the PREMIS data dictionary. By explicitly separating the different types of entities involved, it is easier to describe and manage the relationships amongst the entities. However, as using record based approach, the PREMIS is still weak at describing relationships amongst entities, particularly the temporal relationships. In addition, extensibility of this core element set for domain specific requirements can also be an issue, due to its capability of dealing with inheritance.

Relationships and dependencies can be better described in an object oriented way using ontologies. In the Fedora project, a small simple set of relationship ontologies was used together with Dublin Core [12]. An ontology has been developed based on MPEG-7 standard [15] for describing structure and conceptual related aspects of audio-visual contents [26]. The CIDOC Conceptual Reference Model (CRM) is being proposed as a standard ontology for enabling interoperability amongst digital libraries [9, 10, 14]. CIDOC-CRM defines a core set concepts for physical as well as temporal entities. This is very important for describing temporal dependencies amongst different objects in a preservation archive. A combination of core concepts defined in CIDOC-CRM and multimedia content specific concepts of MPEG-7 for describing multimedia objects in museums has also been introduced. A harmonisation effort has also been carried out to align the Functional Requirements for Bibliographic Records (FRBR) [13] to CIDOC-CRM for describing artistic contents. The result is an object oriented version of FRBR, named FRBRoo [11].

4 CIDOC-CRM for Digital Preservation

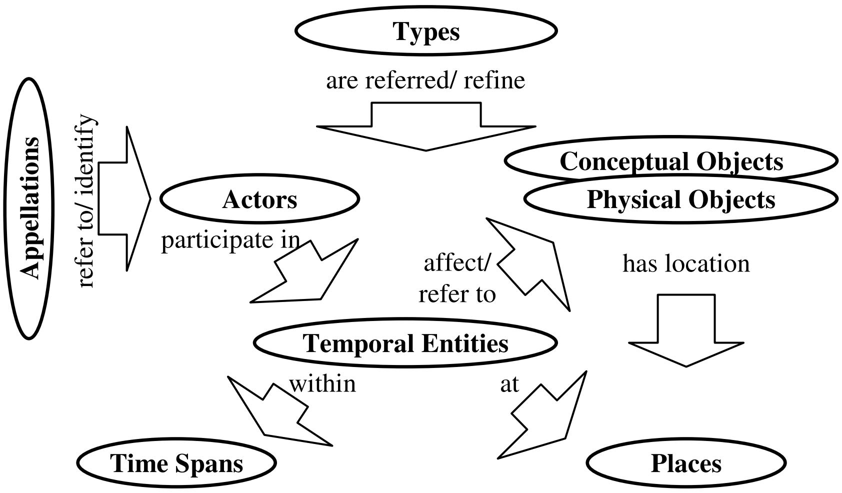

Fig. 4. The meta-schema of CIDOC-CRM [9]

CIDOC-CRM was originally designed for describing cultural heritage collections in museum archives. In museums, CIDOC-CRM is used to describe things and events from the past. Similarly, in preservation domain, today's things and events are documented for the future. Due to this similarity and its wide coverage, CIDOC-CRM has attracted attention from preservation communities as core ontology for enabling semantic interoperability amongst digital archives.

The meta-schema of CIDOC-CRM is illustrated in Fig. 4. CIDOC-CRM's conceptualisation of the past is centred on Temporal Entities (e.g. events). People (Actors) and objects (Conceptual Objects and Physical Objects) involved, time (Time-Spans) and Places are documented via their relationships with the Temporal Entities. Appellations and Types are generally used for identification and classification. For example, an MvM performance can be described as an event. Participants of the performance are Actors, tools and instruments used in the performances are Physical Objects, etc. The mapping of a performance to the meta-schema of CIDOC-CRM is shown in Fig. 5. Appellation and Types are omitted in this diagram. An MvM performance can be described in more details using entities and properties defined for CIDOC-CRM, as shown in Fig. 6.

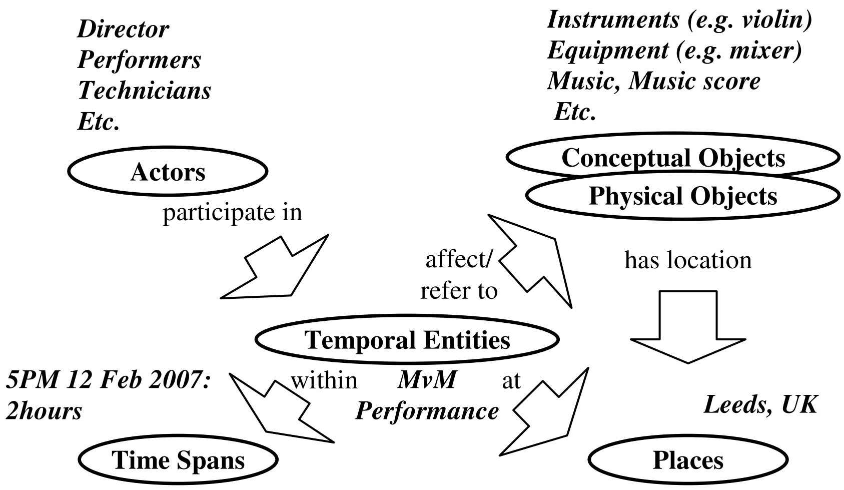

Fig. 5. Mapping an MvM performance details to CIDOC-CRM meta-schema

The CIDOC-CRM vocabulary can be used to describe a performance at a high level. However, more specialised vocabularies are necessary for the interactive performing art domain to precisely describe the relationship amongst the elements of a performance. For example, it is necessary to model how equipments are connected together in the performance. The CIDOC-CRM currently also lacks of concepts for digital objects, which are the target of digital preservation. The relationships amongst software applications, data, and operating systems need to be documented. Furthermore, CIDOC-CRM is designed primarily for documentation of what has happened, whereas in digital preservation, it is also required to document the reconstruction of a past event from preserved components.

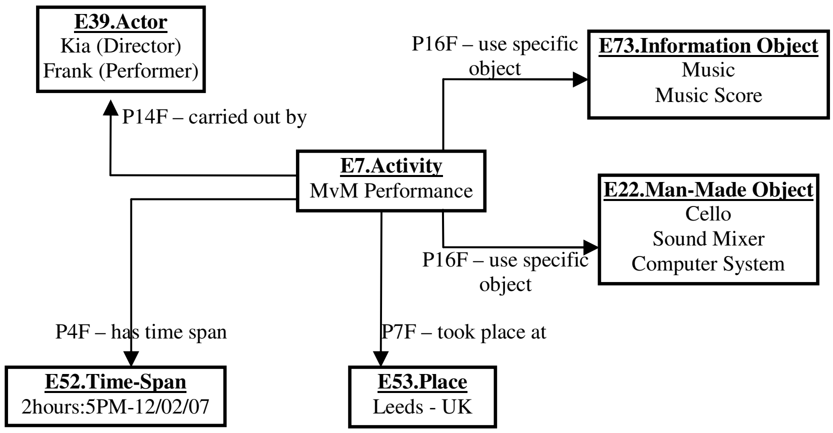

Fig. 6. Simple description of an MvM performance using CIDOC-CRM vocabulary: CIDOC-CRM entity names are underlined and bold; instances of the entities are listed in below the entity names.

5 Extending CIDOC-CRM for Preservation of IMPs

The CIDOC-CRM ontology is being extended for describing IMP in digital preservation context. The extended ontology is domain specific. It does not alter any concepts defined in CIDOC-CRM. Instead, the extended ontology is a specialisation of CIDOC-CRM concepts for IMP and digital preservation domain. Specifically, the extension is developed for the following objectives:

- To provide a domain specific vocabulary for describing an IMP. The description includes details on how the archived performance was carried out and how possibly it can be recreated.
- To provide vocabulary for describing digital objects, their interrelationships and operations performed on them in the digital preservation context.

The extension is aimed specially at describing performance knowledge to be archived with performance objects as discussed in Section 2.2 and illustrated in Fig. 3. It is currently built on and compatible with CIDOC-CRM version 4.2.1, the latest release from CIDOC-CRM Special Interest Group [5].

5.1 Describing Performances

The scope of description is the information about the performance, its various activities, actors, equipment, instruments and digital objects involved in the performance. Configuration – how different elements are associated with each other – is also of particular importance. The centre of the description is the "IMP1.Performance" object[3]. "IMP1.Performance" is a specialisation of CIDOC-CRM "E7.Activity" and also of "E63.Beginning of Existence". This means that a performance is an activity and it brings something into existence. Entities and properties for describing the relationships between a performance and its components are shown in Fig. 7.

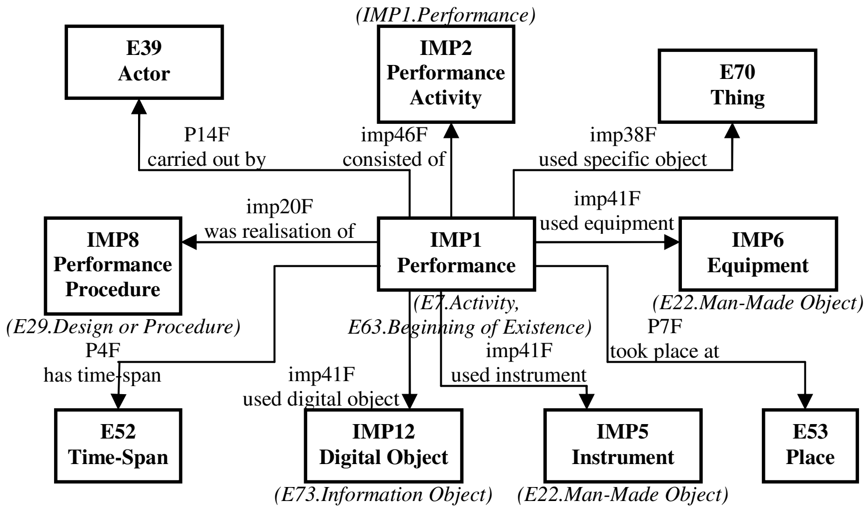

Fig. 7. "IMP1.Performance" entity and its components: new concepts are attached with the names (in brackets) of their direct parent from CIDOC-CRM.

In comparison with the description using CIDOC-CRM as shown in Fig. 6, the following concepts have been introduced, in addition to "IMP1.Performance":

- "**IMP2.Performance Activity**": for describing activities of a performance. For example, in an MvM performance, "capturing of 3D motion data" can be modelled as an activity. "IMP2.Performance Activity" is designed as a specialisation (subclass) of "IMP1.Performance" as any activity within a performance can be seen as a performance itself. The temporal order in which performance activities were carried can be modelled using properties inherited from "E7.Activity".
- "**IMP5.Instrument**": a specialisation of CIDOC-CRM "E22.Man-Made Object" for modelling musical instruments (e.g. cellos, violins, drums, etc.) used in a performance.
- "**IMP6.Equipment**": a specialisation of CIDOC-CRM "E22.Man-Made Object" for modelling equipment used in a performance. Equipment can be a microphone, a sound mixer or a computer, etc. Computer related equipment is further classified into "IMP7.Computer_Hardware" in the extended model to better describe their relationships with computer software.

[3] The extended concepts are prefixed by IMP and an identification number. The original CIDOC-CRM entity and property names are prefixed by E and P respectively.

- “**IMP8.Performance Procedure**”: a specialisation of CIDOC-CRM “E29.Design or Procedure”, which is a subclass of “E73.Information Object” for describing the procedure in which a performance should be carried out. A performance procedure may consist of other performance procedures. Similar to performance activities, the procedures need to be executed in a particular temporal order in order to achieve the desired performance. However, as CIDOC-CRM is aimed at describing what has happened, whereas performance procedures usually tell what is supposed to happen, CIDOC-CRM does not have precise vocabulary for describing temporal order of execution of performance procedures. New properties have been introduced for “IMP8.Performance Procedure” to deal with this requirement.
- “**IMP12.Digital Object**”: a specialisation of “E73.Information Object”. “IMP12.Digital Object” and its specialisations are discussed in detail in Section 5.2.

Configuration of a performance, e.g. assignment of actors to roles, connections of tools, or association between data and processing applications, can be described using “IMP29.Performance Attribute Association” and its subclasses: “IMP3.Data Application Association”, “IMP4.Actor Role Association” and “IMP30.Equipment Pairing”. “IMP29.Performance Attribute Association” is a specialisation of “E7.Activity”.

5.2 Describing Digital Objects

Digital objects are not well covered by CIDOC-CRM. In essence, a digital object is a stream of bits. This bits once interpreted carry some kind of information, e.g. a text document, a picture or a set of instruction. Strictly under CIDOC-CRM definition, the stream of bits is an information object (“E73.Information Object”). However, by itself, it does not have much meaning to a human being. Only the information it carries, once interpreted by a computer, is understandable. From this point of view, a digital object is an information carrier, which is a characteristic of physical objects under CIDOC-CRM definition. In this extension, digital objects are classified under “IMP12.Digital Object”, which is a subclass of “E73.Information Object”. Information carrying characteristic of digital objects are modelled using properties of “IMP12.Digital Object” and its specialisations. Hierarchical structure of “IMP12.Digital Object” and its subclasses is shown in Fig. 8.

“IMP12.Digital Object” has two direct subclasses: “IMP17.Digital Data Container” and “IMP18.Digital Data Object”. A digital data container (“IMP17.Digital Data Container”) is a container of one or more digital data objects (“IMP18.Digital Data Object”). An example of digital data container is a file. The bit stream contained within the file is considered as a digital data object. This separation is necessary to model a bit stream in memory or in cases where multiple bit streams carrying different information carried by a single digital data container. A special type of digital data object is a computer program (IMP13.Computer Program). In this case, the bit stream is a set of instructions to be executed by a computer. There are two specialisations of computer programs: “IMP14.Operating System” and “IMP15.Software Application”.

Relationships between digital objects are modelled through their types. An example of such a relationship is between software applications and operating systems.

Each class under “IMP12.Digital Object” has a type, which is specified under CIDOC-CRM “E55.Type”, associated with it. With the above example, suppose that there is an operating system type “Windows” and a software application type “Microsoft Office”, and it is described that software application type “Microsoft Office” “can run on” operating system type “Windows” then it can be inferred that any application having type “Microsoft Office” can run on operating system having type “Windows”. Modelling the relationships between digital objects using type will reduce the complexity when handling individual instances.

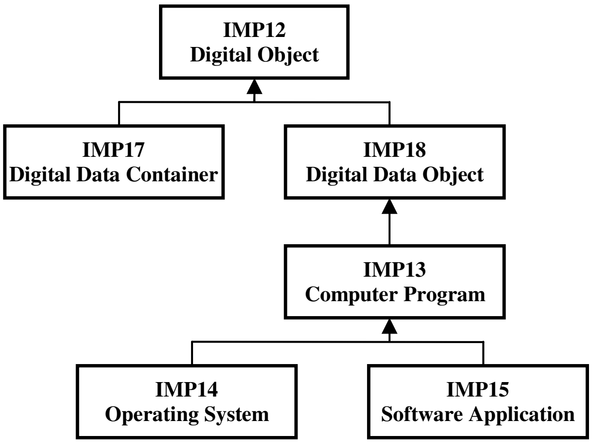

Fig. 8. Classification of digital objects

Operations on digital objects can be described using “IMP26.Digital Object Operation”, which is a specialisation of CIDOC-CRM “E5.Event”. A number of subclasses of “IMP26.Digital Object Operation” have also been defined to deal with common operations such as creation, duplication, transformation, modification, access and deletion. This is necessary in preservation context, where history of a digital object (provenance information) needs to be documented.

6 Conclusion

This paper introduces characteristics of IMPs and their requirements for digital preservation. It notes that metadata and ontology play a very important in digital preservation process, particular for describing representation information, provenance and other information related to a digital object as defined by the OAIS Reference Model. The limitation of metadata approach is that it views an object as a record with a set of attributes. This makes metadata inefficient for describing the inter-dependencies that exist amongst digital objects in an archive, particularly in the case of IMPs. An ontology approach has been considered, by extending the current concepts defined in CIDOC-CRM, for preservation of IMPs. A number of concepts for performing art domain as well as for digital objects have been proposed. This extension is designed specifically for describing an IMP and its internal relationships. It can also be used together with FRBRoo if there is the need for describing the conception process of the performance (the process of translating the initial idea of the composer into a performance plan).The new concepts are evaluated using performance data available at ICSRiM and further in the contemporary arts testbed of the EC IST CAPSAR project [2]. As a nature of ontology development, it is necessary that the newly proposed concepts need to be examined and verified by relevant communities for acceptance and for successful implementations in the future.

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