Making the Europeana Data Model a Better Fit for Documentation of 3D Objects

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Abstract. The current effort in 3D digitisation of heritage items poses new challenges in accommodating more and higher quality information to be associated with the 3D models that are of interest to users and stakeholders. The Europeana Data Model (EDM) is a metadata schema that distinguishes between the information related to the cultural heritage object as such (represented by the class edm:ProvidedCHO) and the information related to its digital representation (edm:WebResource), brought together in the class ore:Aggregation. Work done in the context of the new common European data space for cultural heritage collected inputs from various experts and initiatives working on 3D data, metadata and paradata, in the light of studying requirements for the extension and adaptation of EDM classes to the more complex scenario of representing and sharing 3D digitised cultural heritage collections.

Keywords: 3D digitisation · 3D models · metadata schema · paradata · cultural heritage collections

1 Introduction

This paper presents an analysis of the Europeana Data Model (EDM) from the perspective of enhancing representation of 3D in Europeana, both in terms of accommodating a larger quantity of items and representations, and higher quality of information, considering the growing recognition of the importance of paradata in 3D documentation in the light of supporting reuse. it is the product of a working group gathering representatives from the Europeana Initiative, most of whom are also involved in data space projects[1] currently ongoing on 3D (5D Culture [2] and EUreka3D [3]).

[1] The common European data space for cultural heritage [1] is an initiative of the European Union.

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In the process, we have looked at relevant related work - some of which involving the members of the group producing this report: EC 3D studies [4], deliverables of the 4CH initiative [5], other past Europeana outcomes and work, like the report of the EuropeanaTech task force on 3D content in Europeana [6], and concrete examples of metadata coming from projects like Share3D [7] and WEAVE [8].

2 Basic Modelling Principles for 3D in EDM

2.1 Modelling Distinctions that Matter: Cultural Objects, Digital Representations and the One-to-One Principle

As shown in Fig. 1, the basis of EDM's modelling approach is the distinction between a Cultural Heritage Object (represented by the class `edm:ProvidedCHO`[2]), digital representations of that object (`edm:WebResource`) and the "package" that brings them together (`ore:aggregation`). The one-to-one principle [10] is then applied with the aim that each resource "carries" information that belongs to it and not to another resource. This means, for example, that the date of when a "real-world" object was digitised, which resulted in the creation of some media (an image, an audio file…), is attached to the `WebResource` that stands for the resulting media file, while the date of creation of the original object is attached to the `ProvidedCHO`, even though both are expressed using a same metadata element (`dcterms:created`).

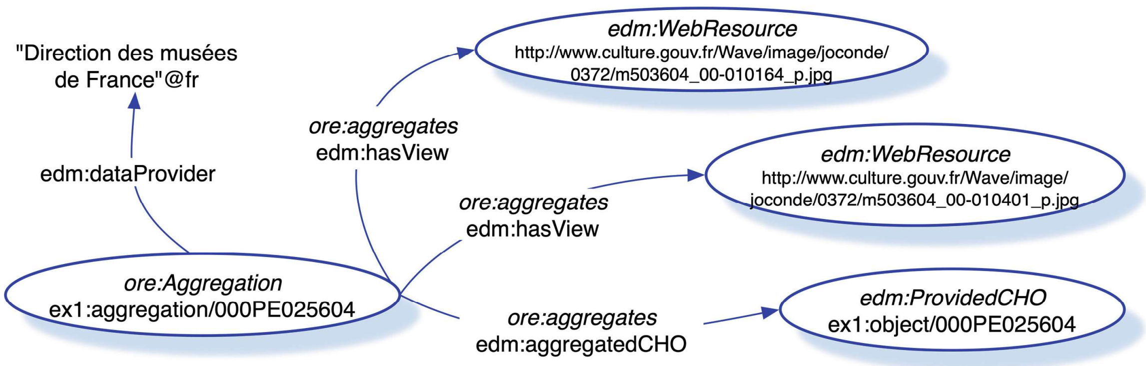

Fig. 1. Basic EDM pattern representing an aggregation of a cultural object together with digital representations.

There are some known issues with the application of the one-to-one principle in EDM. Especially, there is a long-standing issue in that the `ProvidedCHO` carries the `edm:type` attribute that belongs on the `WebResource` (cf. Sect. 3).

We argue that better applying the one-to-one principle can be the basis for handling the case of 3D representations of cultural objects in EDM. Our approach has taken into account relevant work such as (1) 4CH's analysis of 3D data generation and creation for Cultural Heritage (cf. [11], Sec. 2) and (2) previous experiments in preparing for

[2] EDM is based on the RDF(S) model [9], where resources are represented as instances of *classes* and attributes and relationships of resources are represented using *properties*.

Europeana objects that have been represented by 3D models, notably in the Share3D project. Let us exemplify it with the example of a Japanese Arita Ware porcelain figure from the Hunt Museum, whose 3D model has been published on Sketchfab [12]. This case corresponds to a "reality-captured" 3D model in the 4CH report, as "the source data are directly coming from the original asset". We propose to represent the "real world" porcelain figure as an instance of `edm:ProvidedCHO`, whose metadata can include a title like "Japanese Arita Ware porcelain figure of a puppy" and "17th century" as date of creation. The 3D model itself can be represented as an instance of `edm:WebResource` carrying metadata statements like "Models processed using Meshlab and Blender" under description with "2022" as date of creation. The different metadata statements for the date of creation, especially, exemplify the application of the one-to-one principle, as they use the same property `dcterms:created` but with different values when they are used for different resources (Fig. 2).

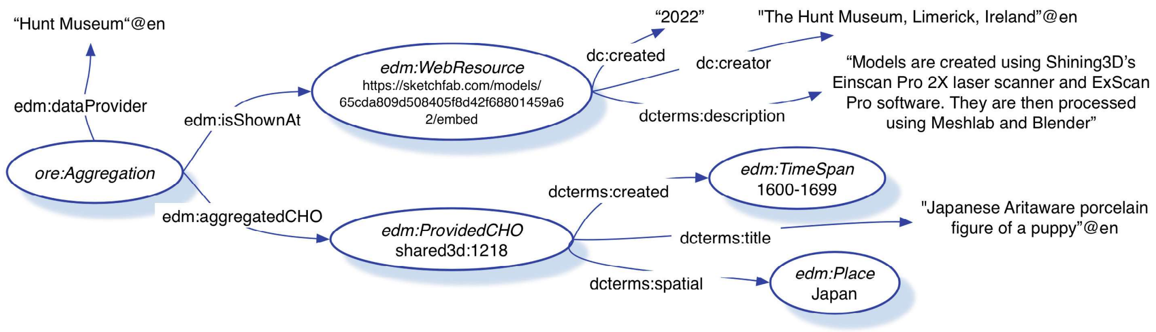

Fig. 2. Distribution of some metadata values onto the main EDM classes.

A main motivation for following the one-to-one approach strictly is its consistency and wide applicability: the same pattern can be employed for various types of 3D model, and is compatible with the approach undertaken in EDM for non-3D representations. As a matter of fact it also allows for "mixed" situations where an object is provided with 3D representations and non-3D ones[3]. It seamlessly enables the representation of objects that are provided with different 3D models, or versions of a 3D model (for example with different numbers of polygons or points, and different rights).

Note that the distribution of (meta)data onto the various resources brought together in the EDM `Aggregation`, and with descriptions of digital representations separate from the description of the heritage asset, is very much in line with ontological approaches to *digital twins*[4] in Cultural Heritage. See for example [14], which defines a digital twin as "the digital representation of the complex of knowledge about [an] heritage asset" and proposes to model it as a resource that points both to the asset and includes various documents, e.g., 3D models and other visual imagery.

[3] For example when a building is provided both with a 3D model and "traditional" 2D photographs.

[4] A Digital Twin can be generally defined as "a virtual replica of a physical product, process or system" [13].

2.2 From Reality-Captured 3D Models to Born-Digital Objects

The pattern can extend to the process of creating a 3D reconstruction of a heritage asset at a moment in time in the past. In the case of 3D, as the 4CH report elaborates, some 3D models include elements that are not directly extracted from reality but instead come from interpretations of cultural objects, for example based on historical documentation (see Appendix "Sample metadata for 3D reconstruction" in our technical report [15]). In this case we speak of 3D reconstructions or "born-digital-reconstructions".

These models have a more complex workflow in comparison to reality-captured models. For example, the workflow may include data capture on the surviving fragments of a CHO, followed by data processing and modelling to reconstruct aspects of a building based on information from plans or drawings which show how it may have looked like in the past. A reconstruction is a representation of the object at a moment in time in the past.

Take for example a digital reconstruction of Wojsławice town in the 1930s [16]. A first EDM interpretation of this case would be to claim that the historical town itself is the CHO, and the 3D model is a digital web resource that is directly associated with it (i.e., linking an instance of an `ore:Aggregation` to the 3D model via one of the properties `edm:isShownBy`, `edm:isShownAt` or `edm:hasView`). However, the nature of the reconstruction (i.e. not purely based on captured reality) would argue for not only focusing on the "original" real-world object as the CHO. The reconstruction of the original object – as an "information object" created following research and interpretation – could also be treated as CHO. There would be CHOs for both the town and the reconstruction related via the `edm:isRepresentationOf` property, or the more general property `dc:subject`. The `edm:ProvidedCHO` resource would carry metadata that applies to the representation (information object), i.e. the creator would be the creator of the model, not the founder of the town. Note that this still does not mean that the `ProvidedCHO` resource should have metadata that belongs to the level of a specific `WebResource`. In fact the reconstruction may not be entirely born digital: there might be analog or digital archives that were employed during the process of creating the (3D) representation, which are also contributed as web resources. In this case, the "reconstruction CHO" should not have metadata statements that hint that it is only a 3D representation. For that to happen, a provider would have to distinguish between distinct CHOs for the 3D representation and the analog sketches (Fig. 3).

The same approach applies similarly to other important cases where the object itself is born digital, as for an abstraction of a design or the work of an artist's imagination that does not represent any pre-existing real world object (this may also include AI-generated objects). This can happen, among others, for architectural (and other) design drawings. For example, in the case of a competition to design a major public building[5], only one of the designs is built. The other designs are proposals which do not represent a real-world object but which may be preserved as part of an architect's archive - ideas that may be reused and re-interpreted in future buildings. In the past the designs would have been done on paper, as with the analogue room design at [18]. Today more and more are born-digital.

[5] E.g., the Re-imagining Cappadocia as an Eco-District Architecture competition mentions 3D visualisations among the media that can be submitted [17].

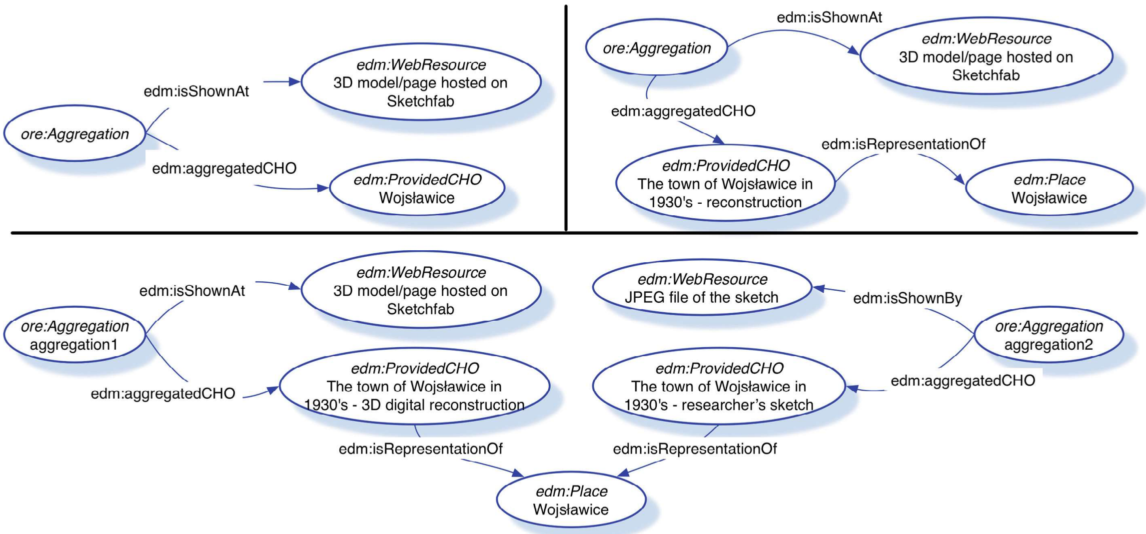

Fig. 3. Variants for reconstructions of an object: (top left) with a cultural object representing the town, (top right) treating the 3D reconstruction as a cultural object; (bottom) With both 3D reconstruction and 2D sketches as cultural objects.

In this case of a born-digital object the CHO is also described at a conceptual level and the digital representation is the "materialisation" of it, e.g., as a file. One object/concept/intention may have different representations and different media files - for example providing different views, offering different types of 3D modelling, different quality, different rights.

3 Identifying and Addressing Basic Limitations for 3D in EDM

When we started discussing the approach above, we knew that there are discrepancies between the current EDM - and especially, the way it is often applied - and the theoretical approach. To further identify limitations, we have applied the above principles to an example from the Share3D project (see appendix in our technical report [15]). The metadata shown there tries to respect the one-to-one principle and the distinction between the original object and the 3D representation. It also represents some data that we believe is important, either present in the original example or mentioned in the literature.

First, we observed that some important information like description or file format are already supported in EDM.

Other requirements would be met by relatively straightforward additions to the current EDM `WebResource` class:

- allowing the representation of types of model by high-level categorisation between "reality captured" models and "3D reconstruction"
- allowing the representation of types of model by technical aspect of the representation (cf. slide 13 of [19]): point cloud, mesh with higher or lower polygon count, with or without textures, BIM and parametric models, etc. (from a controlled list of types, preferably)
- (maybe) enabling `dc:title` and `dcterms:provenance`

For the first two requirements, the example in the appendix at [15] uses `dc:type`. However, we have made this choice merely to illustrate the matter at hand. Both could be addressed by using a different property, either reused from an existing namespace or newly created in the EDM vocabulary (similarly to `edm:type`). This will have to be discussed in the next steps of our work. In any case, both requirements probably require establishing a controlled vocabulary of possible values. Such endeavour relates to a more general effort to inspect whether existing EDM properties need to be provided with recommendations on using controlled vocabularies that are specific to the 3D context - for example on foreseen file formats.

We then identified a fundamental issue with the usage of the existing property `edm:type`, which is meant to reflect the general media category of an object, like `TEXT` or `IMAGE`, for Europeana purposes. This type should not be attached to `ProvidedCHO` as it is currently. For example, in the case of a statue that has some digital images, `edm:type` is set to `IMAGE`. But if the same statue in a different context would have been provided with a 3D model, `edm:type` should be set to `3D`. It would be more appropriate to attach the type of media to the resource that stands for the media representation of the cultural object, i.e., the `edm:WebResource`.

As an alternative (or in addition), the property could be attached to the `ore:Aggregation`[6]. But we should then probably allow for multiple `edm:type` statements on the `ore:Aggregation` class, to cater for the cases where an object has representations of different types (say, a 3D model and some more classical photographs that dictate using `IMAGE` as value for `edm:type`). However, even though this option meets simple user information needs like "retrieve objects that have at least one 3D representation", it would complicate rather than improve the model. If `edm:type` is moved to the level of `edm:WebResource`, the type of each representation for an object is clear. If it is moved to the `ore:Aggregation` and we allow multiple types, the type of each representation is not clear.

4 Advanced 3D Requirements for EDM

The previous section seeks to address common, basic needs of characterization of 3D objects. We identified more advanced requirements that can play a crucial role, too.

The first category regards the intended usage of representations available on the web for 3D objects. When sharing 3D models in a context like that of the data space, it makes a big difference whether a representation is meant for a specific (technical) purpose, (such as preservation) or for viewing. This distinction could be made explicit in EDM. A specific case is that of content accessed via a viewer, for example Sketchfab's, which can be embedded in another page, for example on europeana.eu. Another example is when a provider would like to give a link to the raw/full version of a 3D model instead of relying on re-users asking for it via another process. From a user perspective it would be useful to have access to information about how such - often very large - resources may

[6] This case would be similar to what happens for the `edm:rights` property, which is used to express controlled rights statements. An `edm:rights` statement must be attached to the `Aggregation` in order to apply as a "default" to the `WebResources` attached to it, in case these do not have their own `edm:rights` statement.

be consumed (e.g., the software, media bundles, contexts etc.). We do not know yet from the perspective of the data space, how best to support this access. These requirements are not specific to 3D but they can play a significant role in the 3D context.

The second category of desirable extension of EDM regards context and especially the paradata; "auxiliary information [..] that describe the data acquisition process" [4]. For us, paradata is a kind of metadata that can be crucial to some types of data space users, especially those who rely on rich and trusted provenance information on the 3D content for professional research or re-use. While the collection and management of paradata is highly valued by the scientific community, in cultural heritage it often represents an innovation in the institutions' workflows, which brings added value in terms of enabling the digital transformation of the sector.

We do not foresee that EDM will be extended to cope with all the possible paradata collected at source, which can be very rich and specific. Yet, we recognise that a subset of this information can be very useful in the data space for access and re-use scenarios, especially to inform about the authenticity of the model, relevant technical aspects of the model's creation process and re-use conditions. For example information on motivation (e.g., "research") and limitations of digitisation projects give hints about the quality and trustworthiness of the 3D model. Examples of such provenance aspects could include the indication that a model results from a general "research" (project) motivation, that it is generated from AI training datasets and has not been curated, or that it was created photogrammetrically from user-generated images.

A survey of existing metadata schemas for 3D objects has led us to identify the general categories of paradata that are most relevant for the data space: identification of creation process, methodology followed, people involved, temporal and spatial information, and identification of the various digital resources produced as well as their lineage. Based on this survey, a "core" set of elements from these paradata categories will be considered for inclusion in an EDM extension for 3D for easier consumption. EDM already provides a generic mechanism that allows the creators of 3D content to provide a relation to the full paradata (e.g. in a document expressing the information in the relevant standards or more specific formats) where it can be accessed by data re-users.

Note that some "simple" provenance requirements such as capturing the roles of the people or organisations involved in the life cycle of 3D models[7] may need significant extensions of EDM. The issue of representing roles of agents, for instance, has been identified for a long time as a general limitation of EDM, and it requires non-lightweight solutions such as introducing events [20].

5 Supporting Work Needed

This section gathers issues that are not about data modelling proper, but, which should be addressed so that providers are encouraged to follow best practices.

[7] This is especially important to give indication on the authenticity and trustworthiness of the model, e.g., whether it is created by a research team based on data with high geometric accuracy, or by a project with other motivations and more limited resources.

Review of Documentation and Guidelines. Our experience tells that more guidance on specific (mapping) points will be useful. Many issues relate to the one-to-one principle. EDM provides the ability to distinguish the cultural asset (`ProvidedCHO`) from its specific digital representations. Statements that apply to the asset or the digital representations should be attributed to the specific EDM resources that stand for it. It is crucial to decide whether the `ProvidedCHO` is the original object or a digital representation[8]. Metadata statements such as the creation date should follow that choice. Note that we do not claim that statements of one kind are more important than others. Of course, users will often benefit much from knowing the date of creation of the original CH asset. But some users will also need to know when the 3D model of that asset was created.

Consider an item that represents a real-world object/monument, as hinted by the use of "church" in the `ProvidedCHO`'s `dc:title` (without any mention of a "3D model" in it) and a date like "13th century" as the date of creation. Here are some examples of possible other statements for the `ProvidedCHO` that would raise a discrepancy issue:

- a `dc:subject` with "3D model": in this example the church is the subject of the `ProvidedCHO`, the format of the digital representation is best entered into the `WebResource`.
- a `dcterms:extent` describing the number of polygons in the 3D model: technical data about the model is best entered into the `WebResource`. A church's extent would rather consist of its physical dimensions.
- a `dc:rights` that mention the creator of the 3D model in some project, not the creators of the church. Here it is best to include rights information about the 3D model in the `WebResource`.

These metadata statements should be present on an instance of the `WebResource` class, not the `ProvidedCHO`, when that `ProvidedCHO` is meant to stand for an (analog) heritage asset[9]. These are not specific to the case of 3D, but for 3D their impact can be significant - especially as they could happen very often.

It is worth noting that the existing EDM guidelines can be confusing. Echoing the issue of `edm:type` mentioned in the previous section, the EDM mapping guidelines for `dc:format` on the `edm:ProvidedCHO` include the instruction "Use the value `3D-PDF` if appropriate". This is actually not compatible with following the one-to-one principle and should be removed.

Separating these elements of information would require creating a new instance of the EDM `WebResource` class when it is not present in the provided metadata. This is an extra effort, but it is very much in line with the needs to represent valuable, 3D-specific information (type of model, digital provenance) introduced in the earlier parts of this report. Guidelines should emphasise this.

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8 This concern also holds in the case of objects with non-3D representations, where attributes of the digital representation should not be mixed with those of the original cultural object.

9 The situation of a ProvidedCHO standing for a born-digital object would be different. There, for example, the dc:creator of the ProvidedCHO is likely to be also the creator of the model itself (which should still be also represented on the WebResource).

Recommendations for the Delivery of 3D. Specific care is needed to articulate recommendations on the web resources themselves, which are provided for an object. For example, it is sometimes not possible to give access to a "raw" 3D model, due to the size of these files. In any case, it is important to provide alternatives to the raw model, such as with an `edm:isShownBy` linking to an embeddable viewer which is supported by Europeana, and/or an `edm:isShownAt` pointing to a view of the objects at the data provider's website. In case the provider wants to point to the raw model (e.g., for specific types of professional users, such as architects or conservators), this is possible by including a relation in the metadata, for example to an archive published on Zenodo or to the provider's own website.

Exploitation of Enhanced Metadata on 3D Representations. Several of the issues that we have observed for representing 3D objects can be traced back to concerns of display in the Europeana website. For example a record can have the `dc:format` and `dc:type` duplicated across a `WebResource` and the `ProvidedCHO`. This is certainly not because these attributes cannot be used with `WebResources`. It is rather because they are not displayed on the europeana.eu portal when they are used only on the `WebResource`. Even the `dc:creator` field is not displayed when it is attached to the `WebResource`. This is a barrier for data providers that seek to convey to users information that they feel is important. Adapting display and search (indexing) to better surface information about (3D) web resources should be implemented at the same time as the data model is deployed and documentation is updated.

6 Roadmap for Future Work

As next steps, we will work on confirming the proposals and progress on their implementation. The main elements of work are:

Identify Requirements for Paradata and Technical Metadata on 3D Models in the Data Space. These requirements will include the representation of:

- types of model by high-level categorisation ("reality captured" vs. "3D reconstruction")
- types of model by technical aspect of the representation (cf. Slide 13 of [19]): point cloud, mesh with higher or lower polygon count, with or without textures, etc. (from a controlled list of types, preferably)
- types of model by project/motivation/limitations (esp., provenance info that could give hints about the quality and trustworthiness of the 3D model)
- intended usage of 3D models, especially, for links to embeddable viewers
- any other context information (digital provenance) is relevant to capture for basic access and re-use scenarios in Europeana (including and beyond dcterms:provenance). This could focus on elements which are in existing established schema for paradata (e.g., CIDOC-CRM dig, CARARE 2.0 etc.) or which can be detected automatically.

We will seek to identify these requirements from studying (re-)user applications[10], earlier reports[11], more record examples[12], existing and coming metadata schema inventories and mappings. We will check whether additional requirements would arise from other efforts in the data space that are not specific to 3D but may have a relation, such as work on enrichment, provenance and annotations.

Identify which new elements should be included in the EDM model, trying to re-use as much as possible existing metadata standards used in the domain. E.g., for context/provenance, re-using Dublin Core's `dcterms:provenance`[13] (for more EDM classes), the proposed extension for events in EDM and/or specific modelling support for software processes, like `dcterms:Software`. Emphasis should be given on use of Linked Open Data data models and vocabularies.

Identify first 3D-centred quality criteria for metadata on 3D objects, especially identifying mandatory or recommended metadata elements. These could be included in the Europeana Publishing Framework[14]. For instance we can include information about 3D objects such as file format, number of vertices, etc., in the calculation of EPF Metadata tiers. The type/motivation for 3D models as discussed in Sec. 4 could also be relevant with regards to setting up quality requirements on the provenance metadata. For this effort it will be useful to re-use works that seek to define completeness of 3D information, such as the 4CH report mentioned above and the VIGIE 2020/654 Study on quality in 3D digitisation of tangible cultural heritage [1].

Supporting Work. In line with the directions raised in the previous section, we will discuss with the designers of the europeana.eu website, how the new metadata and content could be accessed and displayed. This includes how to download and display different versions of a 3D model, embeddable viewers ([6] includes a list of viewers in Sec. 5.2 and Appendix 1) as well as provenance information represented via the corresponding `WebResources`. We shall also review documentation and guidelines to properly reflect adherence to the one-to-one principle and avoid problematic mappings mentioned in Sec. 4. We will also seek feedback from other experts. This would allow more interested stakeholders to be involved, for example from the EuropeanaTech community.

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10 We could use IDOVIR [21] as case study. The portal presents some structured data on 3D digitization projects and the software they use, but it seems that it also has a free-form description of paradata and a link to a fuller representation.

11 We could draw an inventory of types of 3D content relevant for Europeana and a first analysis of digital provenance information from the report of the EuropeanaTech task force on 3D content [4] (e.g., Sec. 2.2.1, 5.1, 5.2 and Appendix 1).

12 It will be interesting to present cases where different versions of a 3D model are available and hierarchical objects where an object is embedded in another object.

13 Note that the current dcterms:provenance is focused on "ownership and custody" while we need to represent paradata.

14 Europeana Publishing Framework. https://pro.europeana.eu/post/publishing-framework. Accessed 31 July 2024.

7 Conclusion

In this paper we report on an analysis of EDM and its support for 3D in Europeana and the common data space for cultural heritage. Such analysis follows the need of maximising the impact of heritage digitisation as highlighted in the EC Recommendation 2021/1970 which, among others, poses the focus on 3D to innovate workflows in digitization, reuse and digital preservation of heritage across the EU. Europeana, as the coordinator of the data space, leads the digital transformation process that the sector is undergoing by adapting the existing tools to the new requirements and needs connected to sharing 3D models and fostering their use and reuse. In this light, we have identified several areas in which EDM may be adapted or extended in future to offer better support for 3D models, Digital Twins and paradata. This analysis is a first step that will support further actions: reflecting on existing metadata and paradata practices, identifying strategies to provide the datasets published in Europeana with enriched information, and understanding current constraints and desired developments. Supporting work is needed to advance our recommendations both by Europeana Foundation and organisations which are creating and delivering 3D to the data space. Our roadmap for the future includes specific work on EDM, on Europeana's Publishing Framework and website, but also with the content creators and cultural heritage institutions building capacity to help ensure that high quality metadata and paradata are produced to support and enable re-use of high quality 3D content.

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