Europeana Network Association
Members Council

Task force report

3D content in Europeana task force

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Date: 27th November 2019

Version 1.0 7 January 2020

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Acknowledgements

With thanks for their contributions to this task force's activities to:

Lovas Lajos and Etele Szüts, Forum Hungaricum Nonprofit Ltd, Hungary;
Matjaž Kragelj, National and University Library, Slovenia;
Zsófi Zombori, Hungarian National Museum, Hungary;
Haris Georgiadis, National Documentation Center of Greece, Greece;
Ingrida Kelps, Vilnius University, Lithuania;
Dulce Fontes, Registo Nacional de Objetos Digitais, Portugal;
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Walther Hasselo, Erfgoed Leiden en Omstreken, Netherlands;
Amy Smith, Ure Museum of Greek Archaeology, University of Reading, UK;
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Pranvera Kraja, University of Shkodra, Albania;
Matevz Domajnko, Fraunhofer IGD, Germany;
Kerstin Herlt, Deutsches Filminstitut & Filmmuseum, Germany;
Pieter Huybrechts, Meise Botanical Garden, Belgium;
Susanna Eklund, National Library of Finland, Finland;
Thomas Flynn, Sketchfab, France and USA;
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Barbara Fischer, Deutsche Nationalbibliothek, Germany.

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2 Introduction

3D digitization of the cultural heritage has become more common in recent years. New tools and services have made it much easier to capture, model and publish. The creation of highly accurate 3D models of monuments, buildings and museum objects has become more widespread in research, conservation, management and to provide access to heritage for education, tourism and through the creative sector. Yet this is still a developing field and organisations that are commissioning 3D media need to make a series of choices on the type of content that is created, how it will be visualised and rendered online, and for which users.

There has been work within the EuropeanaTech community on 3D digitization workflows and publishing pipelines (3D-ICONS.eu), on augmented and virtual reality (VI-MM.eu), on HBIM (INCEPTION-project.eu), on Sketchfab (Share3D.eu) and IIIF for 3D. But to date this work has not been reflected in either the Europeana Publishing framework or the guidance available to Europeana content providers.

Currently the content that is available under the 3D label in Europeana is very variable. 3D objects that can be directly manipulated by users are not distinguished from simple images or videos of 3D content. Offering better guidance to data providers and aggregators will help to ensure that 3D content is correctly labelled and promote the availability of more functional 3D content for Europeana's users to discover, explore and reuse.

2.1 Objectives of the task force

The task force has three main objectives:

1. Collect details of 3D data content, file formats, viewers and methods of publishing 3D online amongst the network of Europeana data providers. Identifying means of making 3D content more accessible on Europeana collections such as embeddable viewers and/or formats that can be played directly by modern browsers.
2. Review the Europeana Publishing Framework and Publishing Guide and the current recommendations for 3D files, making comparisons to the recommendations for audio and video files.
3. Develop guidance and recommendations for Europeana, CH institutions and 3D content creators on publishing 3D content and making it accessible via Europeana Collections.

Expected outcomes and communication results

- Development of guidance and FAQs for 3D creators and CH institutions on publishing 3D media online in the context of Europeana and its users.
- Identify viewers and 3D media formats recommended for support in Europeana Collections and means of linking and embedding 3D content for Europeana and Europeana Aggregators.
- Development of the Europeana Publishing Framework to provide guidelines for 3D objects at each tier.

2.2 Overview of accessing and sharing 3D content

For 3D content access and discoverability is not simply a matter of permissions and availability. To identify, locate, retrieve, and reuse 3D content involves:

- Considering the multiplicity of content types,
- Considering the needs of different audiences,
- Understanding technology requirements and limitations,
- Resolving challenges related to usability, interoperability and sustainability.

2.2.1 Types of 3D content

3D content can be categorised as follows:

1) 3D content that is generated from images and measurements of real-world cultural heritage (objects, buildings, archaeological monuments, etc.) captured using instruments. This type of content provides a faithful, often photorealistic, representation of real-world objects; the accuracy with which reality is depicted is linked to the instruments used for capture and the processing algorithms. Models are generally created in the form of point clouds or meshes. This category includes photogrammetry, scanned models, digital terrain models and volumetric models. Examples of this type are:
    a) Photorealistic representations of the exterior of an object in a museum collection in its current condition;
    b) Representations of the interior and exterior surfaces of an object;
    c) 3D surveys of historic buildings and archaeological sites describing the interior and exterior surfaces and components of the structures;
    d) 3D surveys of archaeological landscapes
    e) Volumetric representations of objects for 3D printing;
    f) 3D radiological imaging, magnetic resonance and CT scanning (e.g. tomography of mummies and other museum objects).

2) Visualisations and virtual representations that are generated from a range of sources. These may include virtual reconstructions based on real-world measurements (e.g. of the surviving ruins of historic buildings and archaeological monuments) as well as born-digital modelling projects (e.g. scenes, simulations, games). Models in this category may be either polygon/mesh based or NURBS-based. Examples of this type are:
    a) Virtual reconstructions of archaeological monuments and historic buildings, for example depicting the monument at a specific period in its life based on measurements and evidence from excavations and research.
    b) Visualisations of historic buildings or monuments that no longer exist based on documentary evidence and by comparison to known monuments of this type.
    c) Virtual reconstructions of an object in its original condition.
    d) 3D scenes visualising an object in its original setting.
    e) Simulations or animations of an object in its working condition, for example an animation showing how a watermill works.

f) Volumetric models for printing may be produced for virtual reconstructions and visualisations.

3) 3D models produced for buildings management and design purposes. This category includes Buildings Information Models (BIM) and Historic Buildings Information Models (HBIM) produced using CAD/CAM software as well as 3D GIS models of large landscapes. Models are generally NURBS based. Examples of this type include:

   a. HBIM models produced for buildings restoration and management, which allow historic buildings specialists to share information with architects, engineers and other specialists;
   b. BIM-to-GIS and/or 3D GIS models of archaeological landscapes and large-scale environments.

4) 3D models for games - these may include reality-based 3D content and/or virtual representations, but in addition have specific interactions related to gameplay – for example animation physics, goal objectives, activities, stages/levels, etc. Models of this type use procedural/algorithmic modelling techniques to generate scenes and other content based on rules or shape grammars, for example as a player moves through a historic building.

5) 3D works of art – this category includes 3D artworks (drawings, hyper-realistic 3D models and other forms) as well as 3D animations depicting dances and performances, intangible heritage, cultural habits, and so on. Works in this category may be entirely born-digital but may also be based on interpretations of documents, paintings and other archives.

All five of these categories of 3D content fall within the scope of Europeana's collecting policy.

Other 3D content types, which are outside the scope of Europeana's collecting policy, include:

- Procedural/algorithmic modelling techniques used to generate scenes and other content (e.g. in computer games or films) based on rules or shape grammars.
- Libraries of BIM objects used by architects in building design (these include generic and manufacturer objects such as building components with standard geometry and behaviours).
- Other libraries of generic object types used in product design (these include furniture, equipment amongst other types).

2.2.2 Audiences

A simple categorisation of the audiences for 3D content is as follows:

- Scholars and researchers who are creating and reusing 3D datasets in their research
- Educators and students using 3D content to meet learning objectives
- Museums creating virtual exhibitions and facilitating user engagement
- Professionals who are creating and using 3D datasets in their work

- General users

2.2.3 Technology requirements and challenges affecting access

It is important to consider how 3D content will be accessed. The different audiences for 3D have access to different kinds of technology. Modes of access vary according to hardware, Internet access and access permissions.

- Professionals/specialists who have access to high-powered workstations.
- Researchers who may have access to high-powered computers in the university but may have different modes of access in the field.
- General users who are accessing content via home computers and internet connections, mobile devices, and via public libraries and internet cafes.
- Educators and museum professionals who are accessing content via their organisation's network infrastructure, generally on standard computers rather than high-powered workstations.

The challenges affecting access include restrictions:

- on downloading and installing specialized software,
- on the resolution, complexity and size of file that can be downloaded,
- on the speed of access/download.

Other challenges include:

1) **Standardisation is low**. 3D content is being created in all types of workflow and a range of software is used for producing a wide range of formats. There are some common file formats (e.g. OBJ, PLY, DAE, STL, X3D, gLTF, DICOM) but many proprietary ones. Some 3D models are software specific, which makes it difficult to share, review and embed them. Some formats are industry specific (e.g. E57 for point-clouds or IFC for buildings.) which can also cause issues with data sharing. Another issue is that some popular software has multiple versions which are not backwards compatible.

2) **3D content is complex and data volumes are large**. 3D content often originates from multiple datasets with elements (such as the shape, surface appearance, lighting, sound, collisions, etc.) being held in separate files and rendered to visualise a model, scene or interactive virtual environment. High-resolution 3D content involves large volumes of data which require substantive storage. Rendering such content online requires highspeed connectivity.

3) **End users may have restrictions on software downloads**. Many organisations restrict users' ability to download and install software on computers and networks. Many users are reluctant to download and install software simply to assess a file.

4) **Many end users have low-bandwidth devices**, which make it difficult for them to access high-fidelity 3D content.

5) **Security/confidentiality** is a challenge in some sectors. For example, the medical sector may enable 3D content to be viewed but needs to restrict the ability to download any content (patient data) onto client machines to protect confidentiality.[1]

6) **Rights in 3D content may be layered**. In some cases, there are pre-existing rights in the original monument, building or object being digitised. Rights are generated during the capture, processing, model generation and visualisation stages of 3D projects. These rights may be owned by different individuals/organisations. Agreements need to be in place to licence access and re-use of the 3D content and metadata that is produced, which requires discussion between the various institutions and individuals involved in the different stages of the 3D workflow.

2.2.4 Means of access

1) **Viewers** that allow access to 3D content online offer a distinct advantage when considering access for the general public as they enable access to a wide range of 3D formats without requiring any software to be downloaded. There are different options available:

   a. **Service platforms** such as Sketchfab accept a wide range of 3D formats for upload and provide, host the content on robust cloud-based storage systems with highspeed connectivity, and provide access via web-based viewers that are accessible across a wide range of computers and devices. These viewers enable users to rotate, zoom, move through and manipulate the content in 3D and tend to standardise the user experience. There may be file size limits for upload to such services, but these platforms offer a popular way for institutions to make lighter-weight (versions of their high-resolution) 3D content accessible and provide valued forums for 3D content creators and users.

   b. **Self-hosting viewers** such as the Smithsonian's Voyager: Next Generation 3D Editing and Viewing Tool Suite or ISTI CNR's 3DHOP. Installing a viewer on an institution's repository still depends on substantive storage capacity and highspeed connectivity to provide a satisfying user experience. While self-hosting may remove constraints on the size of the model, there may still be a need to provide a lighter-weight or decimated version of a model to make loading times reasonable for users. Each viewer has different design features and varying controls, so although they offer similar functionality the user experience is different. When industry standard viewers emerge, this will tend to standardize the user experience.

2) **File downloads** may be an option where organisations are able to offer these. However, it is worth noting that:

[1] For example: https://www.postdicom.com/en/how-it-works

a. High resolution 3D content requires high-performance computers and specialist desktop applications are needed for re-use.

b. Much 3D content cannot be reused unless it is provided with the paradata needed to understand how the content has been created and its constraints. The content needs expert processing for re-use in research, heritage visualisation or gaming environments.

c. Lower resolution 3D content files can be viewed using online viewers (some allow files to be viewed without any content being stored on the company's servers.[2]

3) **Direct access**. A small number of file formats (X3D, X3DOM, glTF) can be streamed directly to a webpage (using WebGL, Javascript and the HTML5 canvas). Large data volumes are involved, and this technique requires robust storage and highspeed connectivity, and also the tools for users to engage with the 3D content need to be available within the browser. It is worth noting that tools are under development that allow for multi-resolution streaming of large 3D models (for example Nexus[3], which reduces the load times for users. Direct access to the file via streaming does not necessarily mean that the file is available for download.

It is worth noting that the 3D workflow for cultural heritage generates several datasets – from the captured data (from scanning or photogrammetry), to processed datasets rendered as 3D model(s), and versions that have been reprocessed for online publication or 3D printing. The final processing steps may involve decimation/simplification of the model and conversion into a new format (whether for 3D printing, online publication, publication as a multi-resolution model or conversion to a format such as X3D/X3DOM or glTF).

In the context of Europeana, users should have an equivalent experience whether content is rendered online in a viewer or directly in an HTML5 webpage. Both methods visualise the 3D content and should enable users to interact with it. Implementation in a viewer can offer additional benefits, such as the ability to view annotations or related content (such as still images and texts) side-by-side with the 3D content.

File downloads offer users less immediate access to 3D content. Users need to access software to visualise the content and review the metadata/paradata to assess whether the content is relevant to their needs. So, although file downloads do enable potential re-uses of the content in other materials the process is much more involved than reusing images or text.

Professionals/specialists/researchers are likely to have very specific requirements and may wish to access higher resolution data. The materials published online, together with good quality metadata and paradata should enable them to assess the 3D content, but they may need to contact the data provider to request access to raw data files and/or high-resolution models.

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[2] For example: https://www.viewstl.com/

[3] http://vcg.isti.cnr.it/nexus/

3 Task force approach

The approach of this task force has been to investigate how 3D content is being implemented for the cultural heritage in the Europeana Network and amongst cultural institutions, universities and other bodies. In the early stages, the task force was advertised to the EuropeanaTech community and others. 49 individuals expressed interest in the activities of the task force.

This section of the report summarizes the findings of a series of exercises to gather information. The task force began by compiling information about 3D formats and viewers to create an inventory. The initial analysis of the inventory informed a questionnaire that was circulated to the Europeana Aggregator Forum and EuropeanaTech, to gather information about content that is being created but which has not yet been delivered to Europeana. A separate analysis was carried out on the content that is currently tagged as 3D in Europeana. This study complements work by the previous 3D task force, which invited feedback from users on 3D content items published in Europeana. In addition, the findings of a survey carried out in spring 2019 by Sketchfab amongst its members from the cultural heritage sector have been reviewed.

3.1 Inventory of 3D formats and viewers

Following the initial discussions, a survey was launched amongst members of the task force and the EuropeanaTech community, to establish an inventory of 3D formats and viewers (see Appendix A). A parallel effort by the IIIF 3D community group[4] is currently gathering information about 3D viewers and their functionality; details of which have been added to the inventory.

The inventory was reviewed by the task force during a meeting in Brussels on the 22nd May. The task force identified a short list of display formats and viewers for further investigation (table 1 below).

[4] https://iiif.io/community/groups/3d/

Table 1: Display formats/viewers identified for further investigation

Name	**Description**	**Source and formats.**
Viewers		
3D Hop	3D-HOP is an online viewer developed by ISTI-CNR. It has a limited take-up in academic community to date. The format underneath is NEXUS (multi-resolution).	Open source, available on Github.
Hexalab	HexaLab is a WebGL application for real time visualization, exploration and assessment of hexahedral meshes. This is a new development from IST-CNR.	Source on Git hub under the MIT licence.
INCEPTION viewer	HBIM model rendering. Final stage of prototyping. The project is aiming to release a service.	Closed source
Plas.io	Lidar point cloud rendering viewer, including intensity, classification and RGB values. Requires .las or .laz file format.	Source available on Github under a MIT licence.
Potree	Potree is a free open-source WebGL based point cloud renderer for large point clouds utilising the “point splat” methodology. Requires conversion of point cloud data using the PotreeConverter.	Open source
Scan the World	Active service/repository. (Stereolitography (.stl) format inside). 3D printing	
Sketchfab	Viewer (40 formats can be converted to the format that sits under the service). Sketchfab’s internal format is a development of open source OSG.js format), industry standard. Good established user community in CH.	Closed source
Smithsonian open source viewer	Under development – alpha release now available. Can import 40+ formats and allow for the creation of Voyager Stories Supported by Smithsonian Cook which can simplify the processing 3D models.	Open source
Formats		
GL Transmission Format (.gltf, .glb)	New development for PBR (physically based rendering).	
USDZ (Apple AR)	Format announced by Apple in 2018 for augmented reality content, based on Pixar's Universal Scene Description specification.	Closed source.
X3D	Virtual reality visualisation (file format which sits under several web applications)	Open source

A series of follow up actions were planned by the task force to gather more information about these formats and viewers, their user community and 3D content in Europeana.

3.2 Survey of Europeana data partners

A survey of members of the Europeana Aggregator's Forum and EuropeanaTech community was carried out in June-July 2019 to gain insight into how 3D is being approached by members of the Europeana network. The results of this survey are summarised here.

38 individuals from 37 institutions responded. The institutions represented included:

- 8 Europeana Aggregators
- 3 Creative industry organisations
- 17 GLAMs
- 9 Research

76% of respondents were not currently providing 3D content to Europeana.

Do you currently provide metadata for 3D content to Europeana?

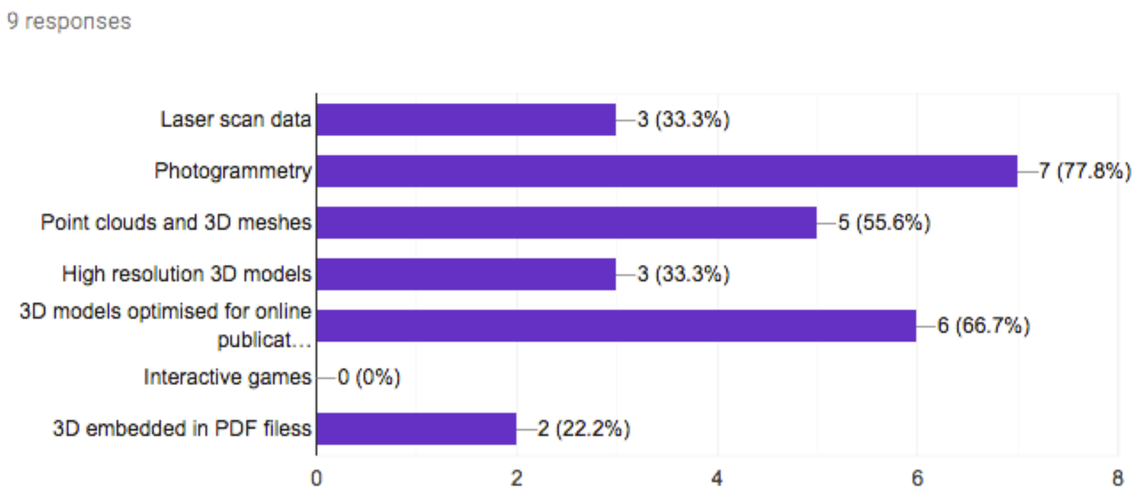
The 28 of respondents who reported currently providing metadata for 3D content to Europeana, are working with:

- Small and large museum objects (67%, 25 respondents)
- Buildings (56%, 21 respondents)
- Archaeological sites (44%, 16 respondents)
- Urban areas or landscapes (22%, 8 respondents)

55% of these respondents reported that the 3D content was created by their organisation, with 44% providing content created by their data partners.

What types of 3D object do you work with?

9 respondents reported working with the following types of 3D object:



6 respondents reported using the following methods to publish their content online:

- Sketchfab – 3 (50%)
- Scan the World – 1 (17%)
- Wikimedia commons[5] - 1 (17%)
- INCEPTION 1 (16.7%)
- Directly uploading 3D models - 1 (17%)
- 3D HOP - 1 (17%)
- STL viewer - 1 (17%)
- 3D SOM pro viewer - 1 (17%)
- Meshlab - 1 (17%)

Of the 9 of respondents who reported currently providing metadata for 3D content to Europeana:

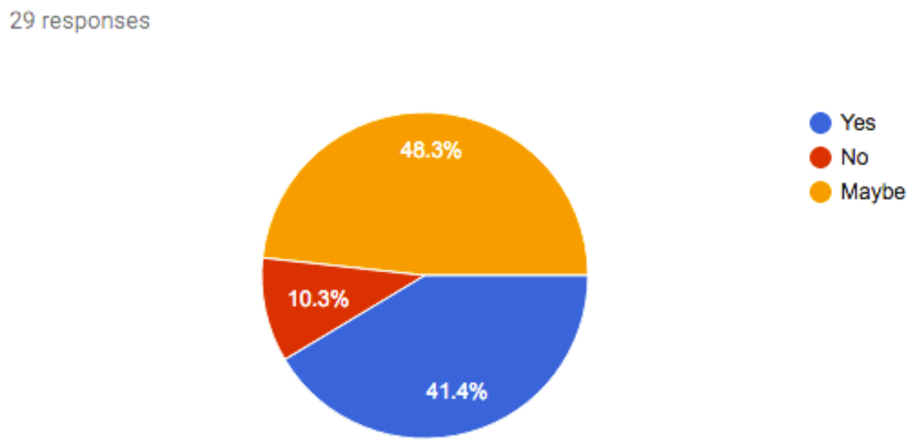
- 4 provide metadata directly to Europeana
- 4 provide metadata via a national or regional aggregator
- 1 provides metadata via a domain aggregator

Organisations not currently providing 3D content were asked:

Are you likely to begin providing 3D content in the near future?
76% of respondents represented organisations who are not currently providing 3D content to Europeana. Of these organisations, the majority reported that they may begin providing 3D

[5] A limited range of file type can be uploaded to Wikimedia Commons – JPEG, GIFF, SVG, GIF, LNG, MIDI, WebM, OGG, OGV, MP3 and WMA. No 3D file formats are included on: https://commons.wikimedia.org/wiki/Commons:First_steps/Quality_and_description#Filetypes_and_naming

content in the near future (41% indicated that they are likely to begin, with a further 48% indicating that they may begin providing 3D).



The subject scope of the content that may be provided includes:

- Archaeology – monuments, sites and artefacts
- Museum objects – Art, history, statues
- Rare books
- Historic documents in photos
- Natural history objects - insects, single bones, skeletons, skulls, seeds, plants etc.
- Architectural heritage
- Maritime Archaeology
- Historic film cameras, film set objects

Are you considering any particular platforms, viewers or formats for your 3D content?

66% of respondents (including both current 3D content providers and those considering providing in future) answered this question, reporting the following:

- A range of formats including:
  - pdf, rotation enabled;
  - mtl, obj, jpg;
  - obj or fbx under consideration
  - .e57, .pts, .pod and .xyz files
  - polygon file format
  - glb, gtf
- 8 respondents reported they were using or considering using Sketchfab
- Other viewers/platforms in use or under consideration included:
  - FreeWRL VRML/X3D browser
  - An open source HTML5 solution
  - Augmenter reality platform Salmi AR

    - 3dmusea
    - INCEPTION platform
    - pano2vr
    - X3DOM
    - A GLB/gltf viewer

- One respondent noted laser scan data is more difficult as the original datasets can be very large
- Several noted that no final decision had been made yet
- One respondent commented that they would appreciate some advice
- One respondent reported they were considering the Europeana Education[6] platform (for their content)

Metadata schemas

16% (6 respondents) reported that the metadata schemas in use for the 3D content being provided include:

- CARARE – 3
- LIDO – 2
- EDM – 1
- EpiDoc – 1
- "Our own formats" - 1

A further 68% (24 respondents) answered a question about which metadata schemas they are considering for 3D content, of these:

- EDM – 2
- LIDO – 1
- CARARE – 1
- Local metadata schema – 2
- Qualified Dublin Core – 1
- Smithsonian schema – 1 (possible)
- EFG metadata schema
- Undecided - 8

One respondent commented "we have no experience in this field".

Do you face any particular issues with providing 3D content?

68% (24 respondents) responded to this question, saying:

[6] https://pro.europeana.eu/what-we-do/education Europeana Education showcases cultural content for use in education but it does not host content or offer any viewers.

- No / not really (8 respondents)

Technical issues

- We don't yet have a possibility to add 3D content to local database
- Only that we currently have little prospect of being able to *display* them in our own aggregator interface.
- Apart from Sketchfab I have no idea how, to whom or where to provide the data to, and in some cases, size is an issue.
- No issues at Sketchfab, which I'm currently using. Haven't tried Europeana yet.
- Our (larger) pilot has just started and will get results at the end of 2019, but e.g. a common metadata schema and file size (quality) to be used on platforms would be very useful already now.
- Mainly regarding texture / visualization issues and semantics
- Yes, appropriate platforms & standards, not to mention storage.
- Compatibility, download speed, interface issues
- We don't have the tools and devices to provide 3D content
- Data storage, rights clearing, metadata mobilisation

Resources

- Budgetary limitations, in terms of licences of software and hiring highly skilled staff
- Costs for scanners and resulting files

Experience/Knowledge

- 3D digitisation campaigns are not very common in cultural institutions
- We don´t have enough information regarding supported formats. All the models are not totally complete due photogrammetry method.
- Understanding all of the different formats and finding tools to convert from various formats to something that is compatible with the viewers available.

General experience of 3D content in Europeana

The survey asked respondents to comment on their experience of the existing 3D content in Europeana.

What works well in your opinion?

The 24 respondents who answered this question gave a broad range of responses.

- 5 respondents had not viewed any 3D data in Europeana
- 2 commented that the embedded Sketchfab records work well
- 2 commented on the ability to limit the search to 3D content
- 1 commented on Indexing and Data curation in Europeana

- 2 commented that they were not sure if there was anything to mention
- 1 commented on the ability to rotate 3D models
- 1 commented "everything"

Is there anything that could be done better in your opinion?

The 21 respondents who answered this question gave a broad range of responses:

- No, in my opinion

Access

- We have noticed that many of the 3D items in European have broken links.
- Much of the 3D content seems only available via the data provider - more embeddability on Europeana would be good.
- Make it easy to find view and share
- Filtering for 3D - if not yet implemented
- Hard to find 3D materials, even with the Type facet. There are a lot of objects where the link to view the 3D object does not resolve and some of the materials tagged as 3D don't really seem to be 3D.
- It would also be great if data providers / aggregators could include original source files for download where licencing permits. This would enhance reuse opportunities e.g. in the creative industries.
- More unity in appearance

Technical issues

- It might be nice if the 3D viewers could be embedded in the Europeana page so that you can see the object right there rather than only a thumbnail image.
- 3D Visualisation in galleries which currently does not work
- Showing and using the 3D content (driver for 3D?)
- Yes, you can't manipulate, rotate the models
- Maybe integrate a 3D viewer?
- The 3D content should be available for end users in a browser compatible 3D viewer. Currently only PDF encoding with limited interaction is available in Europeana Collections (accordingly to my level of knowledge)

Metadata issues

- There is also a confusion with EDM Type 3D in EDM specs since many providers assumed that 3D items that are digitized as 2D (as photographs) should be tagged with 3D as the value for EDM type. There aren't clear guidelines on what edm:isShownBy should contain in case of 3D and what are the accepted formats. Some of our providers for instance included a zip file that packages the required files used by their custom viewer. Some others provide in edm:isShownBy a good image (2D) view of their 3D model.

Other issues

- Extensive innovation schemes with open source utilities free to download with the community of the citizen scientists, from the Europeana Website
- Looking ahead. A feature where museums can store geometrically correct 3D objects (not Sketchfab) for preservation of our cultural heritage. But also decimated 3D models (Sketchfab) optimised for AR and VR. And possible sharing those among museums, for exhibitions and other museum related events.
- International standards asap

3.3 Review of 3D material currently in Europeana

Common Culture survey

A review of the content tagged as 3D that is currently published in Europeana was carried out by a member of the Task Force as part of the Common Culture Project.

The review identified the following formats and viewers currently in use for existing 3D content in Europeana:

- 3D PDF - 4,535 items provided by 14 organisations
- 3D SOM - 1,652 items provided by 6 organisations
- Sketchfab - 899 items provided by 3 organisations
- SCENE WebShare - 17 items provided by 1 organisation
- CNRS-MAP meta-viewer - 238 items provided by 1 organisation
- 3D-HOP – 166 items provided by 1 organisation
- Local implementations of X3DOM - 4 institutions have implemented X3DOM on their servers – 494 items from 4 organisations
- OBJ, X3D and FBX files for download - 264 items from 2 organisations

The content was reviewed, and a number of issues were identified with content that is tagged as 3D in Europeana including:

- 2D content that has been incorrectly labelled as 3D. One of the respondents to the task force survey (see 2.2 above) noted that "many providers assumed that 3D items that are digitized as 2D (as photographs) should be tagged with EDM type = 3D".
- Panoramic images, which give the impression of 3D but are not true 3D objects are also tagged as 3D
- A relatively large percentage of the 3D content published in Europeana has broken links – 15,078 items from 16 organisations, with more than 13,000 of these items having been provided by the Probado project.

A separate issue with the Probado[7] collection is that the content comprised of a 3D model library (examples of general object types) and not models of real cultural heritage objects. As

[7] The Probado collection was de-published from Europeana in November 2019 as a result of this report.

such the content did not conform to Europeana's Content Strategy, which focuses on cultural heritage content. It was uploaded to Europeana as part of a project trial and the content has now been withdrawn.

Advanced documentation of 3D digital assets task force

In 2017 the "Advanced documentation of 3D digital assets" task force ran an online survey inviting feedback from users on 3D content published in Europeana. The survey found:

- Respondents would like to be able to interact with 3D content in Europeana and/or be able to download the model for reuse
- Respondents would like more detailed information to be provided in the metadata for the model including:
    - Metadata for the digitisation process
    - Technical information about the model (metrics, structural information)
    - Details of the original cultural heritage object (typology, date, materials, geolocation, environment, archaeological analysis/study)

3.4 Sketchfab review of cultural heritage and cultural content

In spring 2019, Sketchfab carried out a survey of its members who are categorized as Museums and others from scientific, education, archaeological projects, libraries and archives with an interest in Cultural Heritage[8]. 142 individual Sketchfab members responded to this survey by Sketchfab, whose results were shared with this task force by Thomas Flynn (Sketchfab). The main findings of relevance for Europeana are summarised below.

A majority of respondents are creating their 3D content themselves or in-house (136), a small number reported working with partner institutions (21) or commercial companies (14).

The digitisation/creation method for the 3D content made available through Sketchfab includes:

- Photogrammetry scans (127)
- Meshes (41)
- Structured Light Scans (34)
- 3D reconstructions or illustrations (31)
- Laser scans (25)
- Point clouds (24)
- CT scans (17)

The most common 3D file formats uploaded to Sketchfab in the Cultural heritage and History category are:

8 https://docs.google.com/presentation/d/1avExQtbfl6vDCFyo5VgSyBy638BjdDTAIhw79ClHT5A/edit?usp=sharing

- Wavefront OBJ – 61,054 files
- Filmbox .FBX – 16,284 files
- Polygon File format .PLY - 5,154 files
- Blender .blend – 4,370 files
- Collada digital asset exchange .DAE – 3,572 files
- Stereolithography .STL – 3,387 files
- 3D Studio Max .3DS – 1,427 files
- Virtual Reality Modeling language .WRL – 442 files
- Graphics Library Transformation Format - .GLTF
- Keyhole Markup Language .KMZ – 265 files

The survey included a set of questions asking how respondents create their 3D models. The most commonly used editing software were reported to be:

- Blender (62)
- ZBrush (38)
- Max (29)
- Maya (15)
- Meshlab (12)
- Meshmixer (11)
- Cinema 4D (10)
- 3D-Coat (9)
- Geomagic (6)
- Mudbox (4)
- Rhino (4)
- CloudCompare (3)

The main barriers to 3D content creation were reported as:

- Lack of time
- Lack of funding
- Lack of trained staff
- Lack of equipment
- Lack of support from colleagues / institution
- Copyright issues

When asked "do you collect metadata related to your 3D objects?", 67% of respondents said Yes. 33% reported that they do not collect metadata.

The type of metadata that is collected includes:

- Raw data files
- Capture or creation details (e.g. data of creation, author, location, etc.)
- Software project files
- Processing, editing and conversion workflows

The metadata that is captured is stored in:

- Online databases – 17 (16%)
- Spreadsheet – 32 (30%)
- Offline database – 60 (55%)

3.5 Analysis

The survey of the Europeana content community and by Sketchfab confirm that there are a large number of different formats in use amongst the 3D content creating community.

This variety is reflected in the number of formats that are supported for ingestion by platforms such as Sketchfab and the viewer under development by the Smithsonian.

The responses to the survey also note the range of applications of 3D, with the more specialised formats (e.g. for 3D printing, high resolution laser scan data etc.) being supported by specialised viewers and formats.

The survey results suggest that there are two platforms on which substantial amounts of 3D cultural heritage content is being deposited currently: Sketchfab and Scan the World/MyMiniFactory. Other services are available.

The survey also suggests that there is a desire amongst the Europeana aggregator community and some cultural institutions to support 3D content. There is interest in content hosting, online delivery and (open source) software and viewers. Several respondents highlighted their lack of experience in this area and their desire for more information.

The IIIF 3D community survey has collected information about the technical characteristics of viewers including, for example, whether the viewer/platform is embeddable. The information gathered by this 3D task force has narrowed down the list of viewers/platforms that are potentially relevant. The next step must be to collect the information about their technical characteristics needed to assess whether they are embeddable in Europeana collections.

4 Metadata for 3D content

The terms of reference for the task force on 3D content in Europeana did not include reviewing metadata schemas. However, metadata has been identified as an issue by the task force and respondents to the survey. This analysis was carried out in conjunction with the "Sharing New Perspectives" Europeana Generic services project.

4.1 Context

3D technologies are used in a range of different contexts in the cultural heritage, ranging from capturing archaeological monuments, historic buildings and landscape, to small objects for documentation, conservation, reconstruction, and to create virtual environments.

It is relevant to note that the 3D workflow has a number of stages and generally results in more than one digital object:

1. **Data capture** – photography, photogrammetry, structure-from-motion, laser scanning, structured light, time-of-flight, phase-shift, lidar; identification of archive sources, related objects, landscapes, scientific data
2. **Data processing** – cleaning, editing, noise filtering, registration, aligning, scaling, point cloud data processing, mesh data processing, texture mapping. This stage includes interpreting the data, for example when segmenting a mesh (of a building) to create a BIM model.
3. **Visualising** – modelling, shading, reconstruction, animation, annotations
4. **Delivery** – high resolution offline models, online models, interactives, 3D printable models, augmented and virtual reality models, publications, images, videos, panoramas

There are a range of factors that influence the techniques used at each stage of the workflow:

- the size and characteristics of the cultural object,
- the objectives of the project; is there a need to produce
    - Highly accurate representations of the heritage objects e.g. for conservation or research.
    - Realistic visualisations of the heritage e.g. for an education application.
- logistics, budget available, timing and environmental conditions

All these factors drive technical choices that are made, the type of visualisation and the models and datasets that are produced. For example, the workflow needed to support the conservation of a historic building and its management, will produce a high-resolution model for use in buildings information management systems. This high-resolution model may later form part of a second data processing and modelling workflow to produce a version for online viewing and other reuses. The workflow to create an animated working model of a clock for a museum installation requires a different workflow again. Table 1 below summarises the workflow for a museum object.

<table>
<tr><th colspan="2">Table 1: Museum object workflow</th></tr>
<tr><td>Name of the object: “Salmon” baton, Goyet</td><td rowspan="6">Online delivery:
Sketchfab iframe embedded on a webpage of the virtual museum of Belgian prehistoric mobile art (http://paleo- art.naturalsciences.be /EN/objets/poissons.html) and in the online database of RBINS. Sketchfab automatically converts the model to its online format.


Snapshot of a webpage of the virtual museum of the palaeolithic mobile art with the embedded 3D model

Model use/purpose: The model was originally created as a part of a virtual museum (created in Unity3D) on a touch screen in the human evolution exhibition at RBINS. The online virtual museum was made to complement to this.

Snapshot of the Unity 3D palaeolithic mobile art virtual museum displaying the 3D model</td></tr>
<tr><td>Location: RBINS collections</td></tr>
<tr><td>Institute: RBINS</td></tr>
<tr><td>Description: Perforated baton, also known as “bâton percé” or “baton de commandement”, have at least one perforation and an elongated part. Many hypotheses on their function have been proposed; the real function is still unknown. One of the most common is that perforated batons were hunting tools, used either to straighten spears or as spear-throwers. They are found in European sites during the Upper Palaeolithic from Aurignacian to Magdalenian. This perforated baton is known as the “salmon” baton because of the representation on the elongated part of what looks like a fish with a speckle pattern (characteristic of salmon). It also has a wavy edge that could have been used as a rasp, a rhythmic instrument.</td></tr>
<tr><td>Capture: Structured light scanning


Snapshot of the 3D model</td></tr>
<tr><td>Equipment: Mechscan</td></tr>
<tr><td>Modelling/processing software: Flexscan, ZBrush, Blender, Unity3D</td><td></td></tr>
</table>

Processing pipeline: Object scanned with a Mechscan structured light scanner, using an automated turntable (2 rotations of 8 scans). The object was cleaned, meshed and textured in Flexscan. Zbrush was used to decimate the model and create a new texture overlay to enhance the engravings. The final output is a triangular mesh stored as an .obj with a .jpg (colour information) and .png (lines enhancing the engravings) texture.	The model is also included in the online database and used for 3D printing in place of the traditional plaster casts.

4.2 Key concepts

The metadata for 3D projects should support:

- Discovery and access to the model
- Understanding about how the model was produced (its provenance) and its technical characteristics
- Understanding of the cultural heritage object(s) which the model represents.

The metadata should include:

- **Project information** – the project scope, goals, date, including:
    - The questions that the data was collected to address ranging from research to conservation objectives
    - Any relevant conditions that affected the data collection and processing
    - The methods, techniques and instruments used to collect or process the data, including their specifications and calibration details
    - The actors involved

- **Cultural heritage object** –the object that has been captured in 3D
    - The type of asset and its characteristics
    - Cultural, geographic and temporal information,
    - References.

- **Digital data** (there may be multiple digital objects created):
    - 3D model - Name, subject, type, description, rights and access licences; Where the model can be found; how it was produced technically - acquisition, processing, provenance; from which sources it was elaborated – datasets, research sources, references
    - Model information – geometry, triangles, vertices, PBR, Textures, Materials, UV layers, Colours, Animations, Annotations, other.
    - Provenance – if the model is a version of a higher accuracy/resolution model

- **Archive package** – inventory of 3D objects, data files, source files

Other information may be included, such as uses of the model in online/virtual exhibitions and learning environments.

4.3 Metadata schemas

Several existing metadata schemas are in use amongst the Europeana Network and 3D community. Each of these schemas has been developed in a specific context, and understanding the differences is key to defining the best strategy for metadata.

The schemas that have been investigated are:

- Smithsonian 3D metadata model
- LIDO (Lightweight Information Describing Objects)
- CARARE
- STARC metadata model
- CRM dig
- EDM (Europeana Data Model)

Smithsonian 3D metadata model[9]

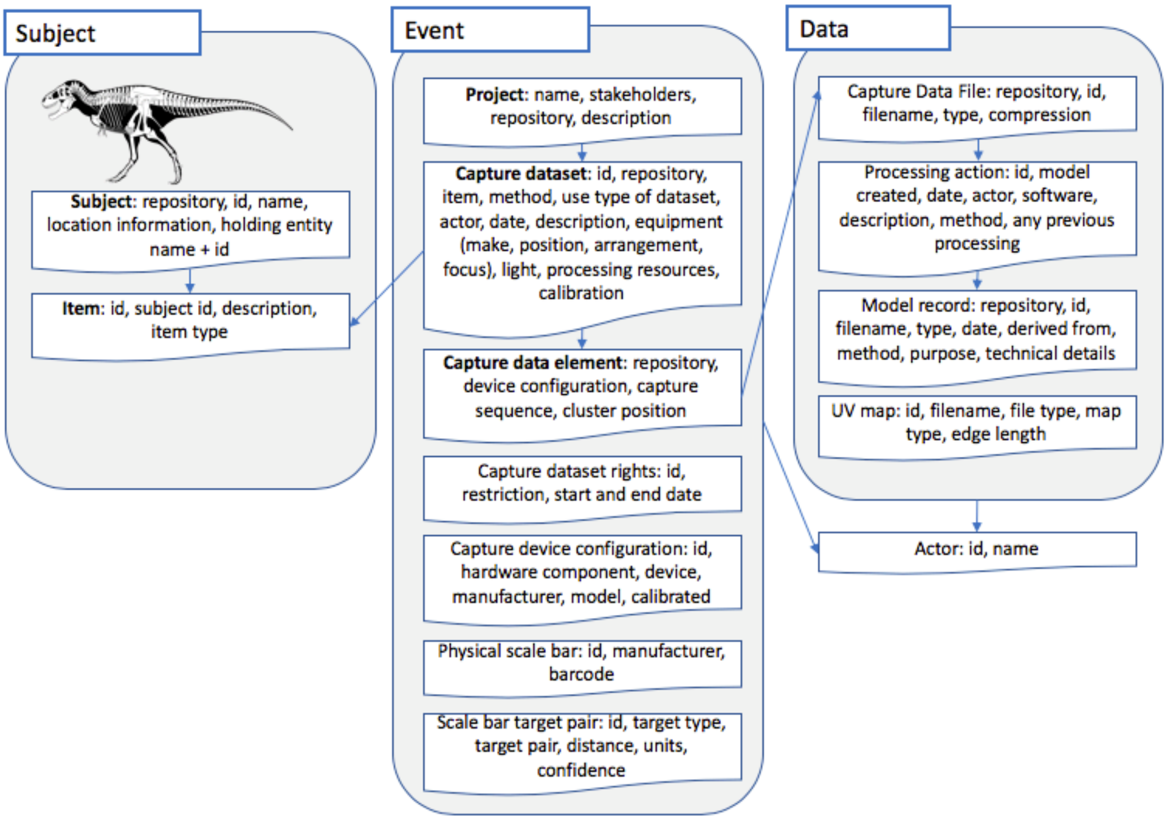
A product of the Smithonian's digitisation advisory committee's 3D sub-committee metadata working group, this metadata model was developed to address the needs of stewardship of the Smithsonian's 3D data. Developed by a working group of practitioners, the model

- Documents a 3D capture event (with a specific focus on photogrammetry) and the technical processes going into data collection and model creation.
- Describes both the digital surrogates produced as a result of the capture, and
- the 'raw' source data from which 3D models are derived

The key elements of the model are:

- **Project** – a digitization effort
- **Subject** – the conceptual thing that is held in the museum collection
  - **Item** – the physical thing that was digitised, which may be a whole object or a component of the object
- **Capture dataset** – event information about a logical collection of capture data
  - **Capture data element** – event information for a specific data capture
  - **Data file** – the individual files

[9] https://dpo.si.edu/blog/smithsonian-3d-metadata-model



Overview of the Smithsonian metadata model

The main focus of the Smithsonian model is on the data capture and the data that is produced. There is a clear identification of which component of an object (e.g. the particular bone in a skeleton) that was digitised in a specific data capture event, the equipment used and the files produced in that event.

The model does not include metadata describing the museum object itself, but the inclusion of the repository id provides a link to related information systems.

The metadata model does seem to support virtual reconstructions, virtual or augmented reality models and it does not currently capture related information. Such information includes the research, analysis or interpretation involved and sources consulted in creating a reconstruction.

LIDO metadata model[10]

LIDO is a harvesting schema and is designed to deliver metadata from an organisation's collection database to online services. It is not intended to be used for cataloguing or as the basis for developing databases.

LIDO is designed with museums in mind and supports the full range of descriptive information about museum objects (art, architecture, natural history, etc.). Developed by an international working group of museum professionals, the model:

- Documents the object (with a specific focus on physical museum objects)
- Captures events that an object has taken part in (acquisition, creation, finding, modification, use)
- Provides information about digital resources that are surrogates for an object provided to the service environment
- Is compatible with the CIDOC Conceptual Reference Model (CRM) and EDM

The key elements of the model are:

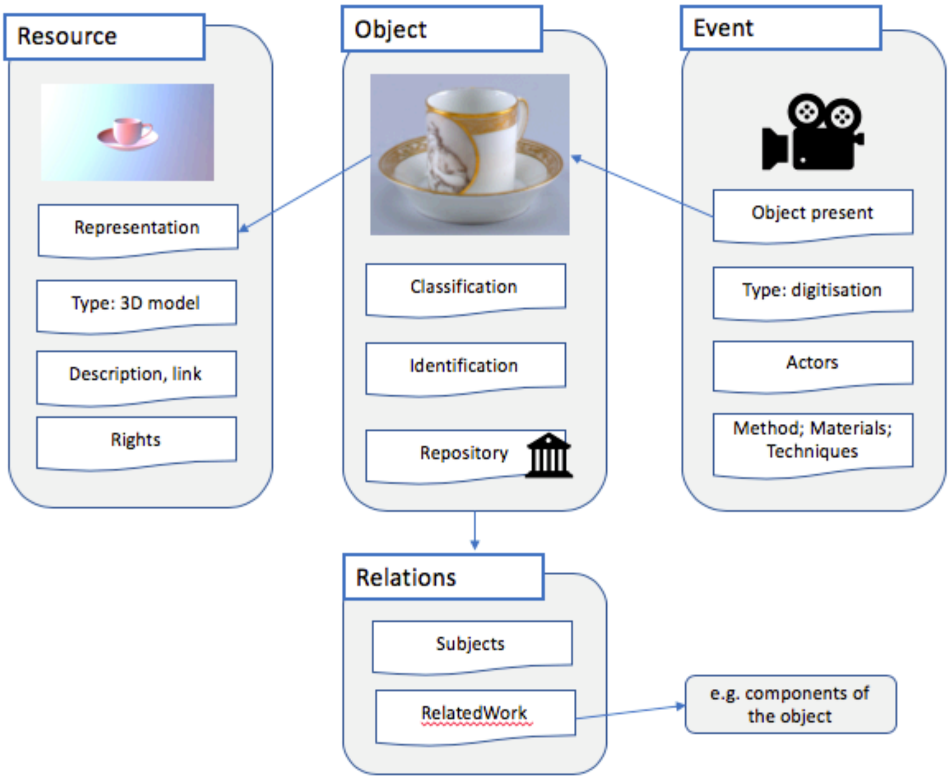
- **Object** – the type of object or work, its title, name, description, location and measurements
- **Event** – this may include a digitisation event in which the object has taken part
- **Resource** – the id, link, type, perspective, description, date, source, rights

The main focus of the LIDO model is on providing an exchange format for the information held in museum collection management systems (CMS). These CMS are primarily concerned with physical objects held in the collections and events relating to those objects. Although some museums hold born digital objects and many are digitising their collections, the LIDO model makes limited provision for digital projects.

In the LIDO model a museum object may be present in a digitisation event, but the schema does not provide for the same level of detail about components, capture devices and processing actions seen in the Smithsonian model. There is no direct connection between the digital resource and the event(s) which created it.

The description of the digital resource is primarily concerned with the information needed when making it available in an online service (link, rights, general type). There is limited information about the technical characteristics of the resource, its creation or digital provenance.

[10] http://network.icom.museum/cidoc/arbetsgrupper/lido/L/11/



Overview of the LIDO model

LIDO supports digital representations of museum objects. The current schema does not seem to support other types of digital object. For example, a project may begin with a museum object that has eroded or been damaged over time and, following research, create a 3D reconstruction, virtual or augmented reality models showing the object in its working/original condition. Other projects involve digitising complex objects with multiple parts creating complex models with multiple components.

There is limited scope within the LIDO model to capture information about the process of creating a 3D model (the research, analysis, interpretation and techniques used) - the digital provenance or paradata defined in the London charter (data about the processes by which the data were collected). LIDO does currently allows for the creation of relations from a digital resource, but these are intended to be used for relations to Linked Data concepts. There is no direct relation from the digital resource to an Event, which would allow for the 3D workflow (digitisation, processing, modelling, etc.) to be described.

CARARE metadata model[11]

The CARARE metadata schema was initially designed as a harvesting schema but is now also being used in data capture. Developed by international working groups under the CARARE and (version 2) the 3D ICONS project, the model

- Documents heritage assets (which may be physical or born digital assets)
- Captures information about events in which both heritage assets and digital resources have taken part (excavation, data capture, data processing)
- Provides information about digital resources that are representations (or versions) of a heritage asset
- Is compatible with the CIDOC CRM, CRM_{dig} and EDM

The key elements of the model are:

- **Heritage asset** – the type of physical or born digital asset, its title, description, characterisation, provenance, location and measurements
- **Event** – This may include a project with several stages and the methods, techniques and materials used in each stage, and both the heritage assets involved and the resulting digital resources
- **Digital resource** – the id, type, format, format details, extent, description, link, rights, etc.

The main focus of the CARARE metadata schema is on the archaeological and architectural heritage, and their representations in 2D and 3D. As with LIDO, the CARARE schema builds on work in CIDOC on the CRM. Its strength for the 3D heritage lies in the rapid take-up of 3D digitisation techniques amongst archaeologists and architectural historians and the development of the schema to reflect this.

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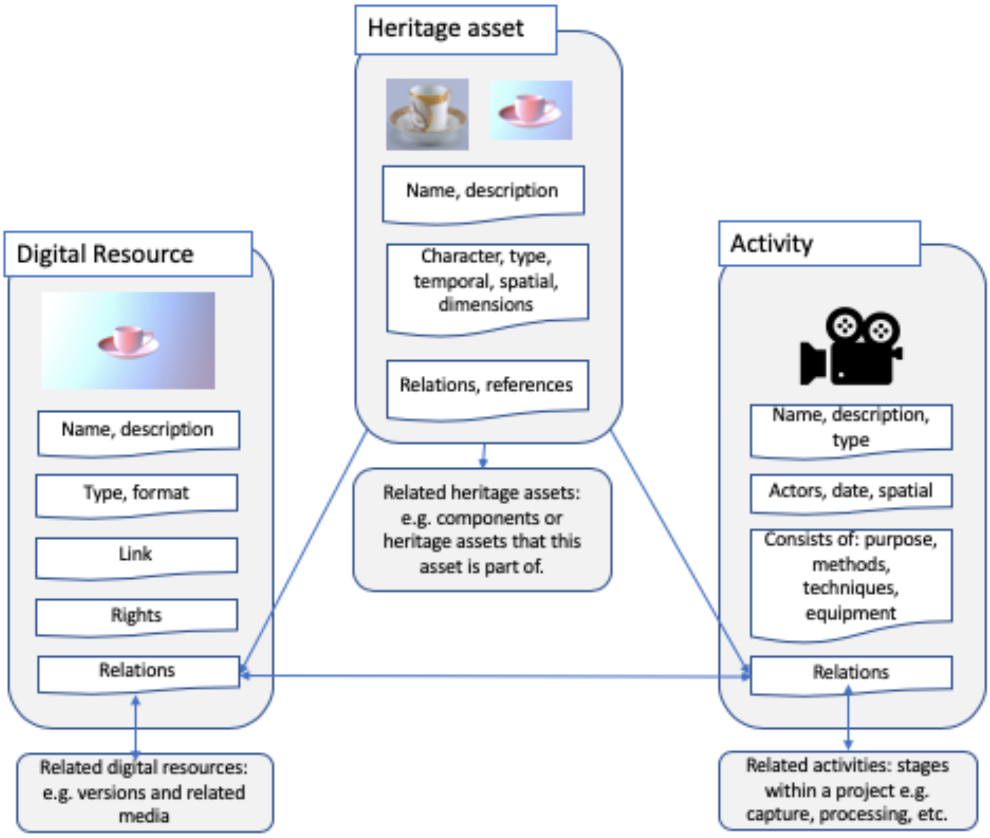
[11] https://pro.carare.eu/doku.php?id=support:metadata-schema



Overview of the CARARE model

Version 2.0 of the CARARE metadata schema was produced during the 3D ICONS project and was specifically designed to enable the description of born-digital heritage assets (3D models, movies, etc) including their digital provenance and paradata (data about the processes by which the data were collected). The model allows for a more detailed description of 3D workflow, and allows for the description of virtual reconstructions, virtual and augmented reality models, and for relations between digital resources.

The CARARE model does not currently support the same level of detail about the capture dataset and data files as defined in the Smithsonian model.

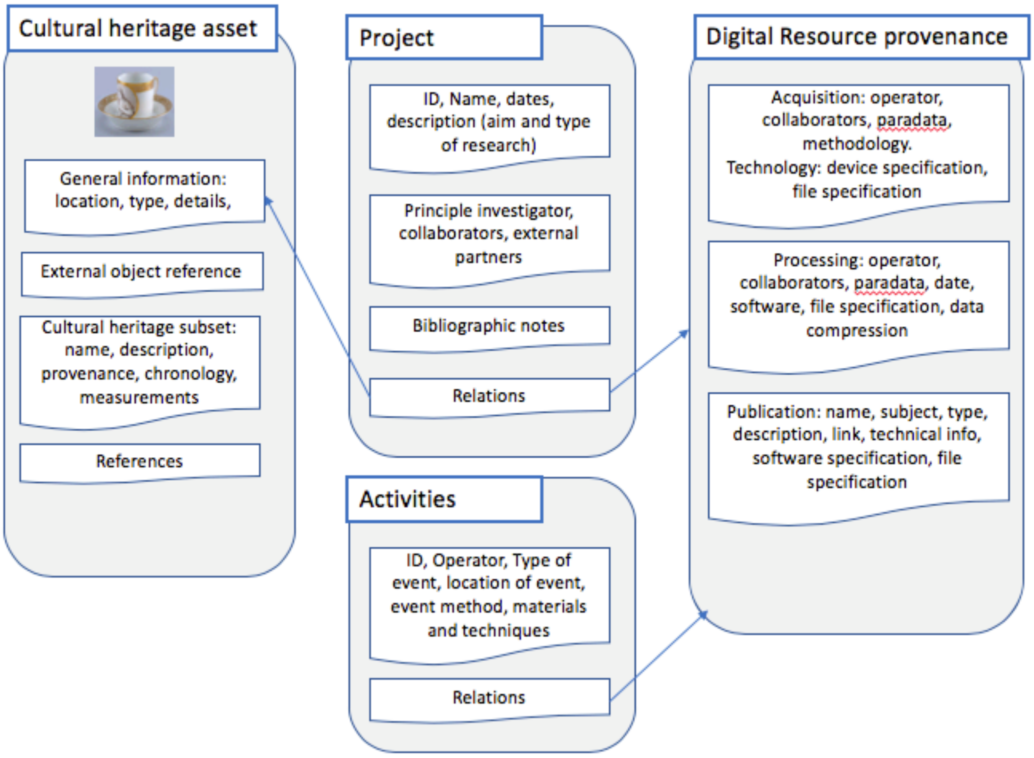
STARC metadata model[12]

A product of the Science and Technology in Archaeology Research Centre (STARC) team at the Cyprus institute, this metadata model was developed to address the needs of stewardship of STARC's 2D and 3D data and its digital repository. The model:

- Documents the heritage assets (with a specific focus on physical archaeological monuments or sites)

12 https://www.researchgate.net/publication/259786414_A_METADATA_SCHEMA_FOR_CULTURAL_HERITAGE_DOCUMENTATION

- Captures information about the project – name, date, description, research objectives, the principle investigators and collaborator, and
- Activities within the project – the location of an event, event method, materials and techniques used
- Captures the provenance of the digital resource in 3 main phases: acquisition, processing and publication
- Is compatible with CARARE, the CIDOC CRM and CRM_{dig}



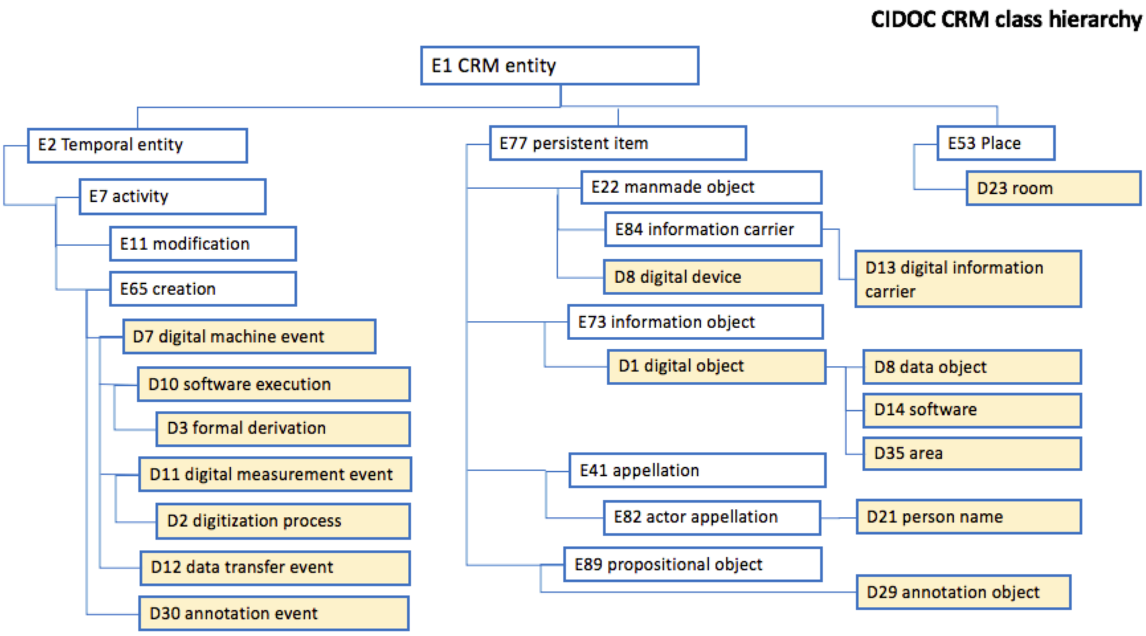
Overview of the STARC model

The STARC model inherits some aspects of the CARARE model but has more focus on the technical aspects of acquiring and processing the data, and its paradata. The model does not support the same level of detail about the data files as defined in the Smithsonian model. There is no direct link between the cultural heritage asset being digitised and the digital resource, and the cultural aspects of the resource are less well described than in the CARARE model.

CRM$_{dig}$[13]

CRM$_{dig}$ is an extension to the CIDOC CRM model designed to provide a model for the provenance of digital projects. Developed by an international team under the CASPAR and 3D-COFORM projects, the CRM$_{dig}$ model.

- Provides a framework for encoding the steps and methods of production of digitisation projects, and the creation of 3D models by various technologies,
- Is compatible with the CIDOC CRM



Overview of the CRM$_{dig}$ model

The main focus of the CRM$_{dig}$ is on the data capture and the processes, techniques and equipment used in creating digital objects. As with the Smithsonian model, CRM$_{dig}$ supports capture of information about the (raw) data files produced in addition to the published objects.

The CRM$_{dig}$ dig classes are highlighted in yellow in the overview above. The model does not include information about the heritage asset or the activity in general, but as the diagram shows these aspects are covered in the CIDOC CRM itself.

Europeana Data Model (EDM)[14]

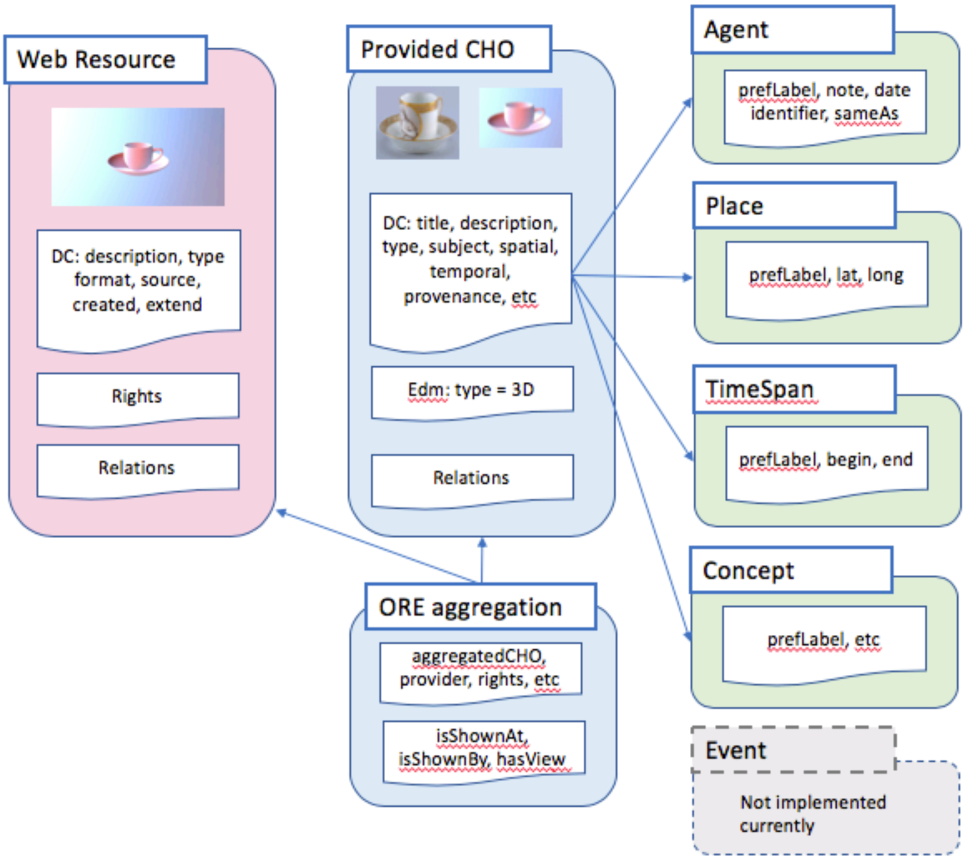
The Europeana Data Model is a product of an international working group and was developed to define the metadata used in Europeana. EDM aims to be an open, cross-domain semantic web framework that can accommodate metadata from a museums, libraries, archives and galleries. The model:

[13] https://www.ics.forth.gr/isl/index_main.php?l=e&c=656
[14] https://pro.europeana.eu/resources/standardization-tools/edm-documentation

- Describes the Cultural Heritage Object, which may be a physical object, book, artwork, film, sound or a born digital object
- Aggregates together the description of the CHO with details of where it can be found online and information about its rights, source and provider

The key elements of the model are:

- **Provided Cultural Heritage Object** (PCHO) – a description of the conceptual thing that is being provided to the Europeana service environment contextualised by information about its typology/subject, place, time span and agents
- **ORE aggregation** –binds together the PCHO with links to its representations online
- **Web resource** – a description of the digital object that is made available



Overview of the Europeana Data Model

The main focus of the Europeana Data Model is on the "provided cultural heritage object" and its online representations. There is a clear description and contextualisation of the contextual thing that is being provided, which may be either a physical or a born-digital object.

Although an event class exists in theory in EDM, this class has not yet been implemented by Europeana in its version of EDM. This means that Europeana provides limited opportunity to describe the digitisation process. The provenance element within the PCHO may be used to hold some information describing the digital provenance of the object.

The Web Resource class of EDM allows for the description of the digital object that is actually being made available online. But there is limited scope to describe the format, technical characteristics of the object. The class includes neither a provenance element nor any relations (to an event or to related digital resources).

4.4 Analysis

Each of the six models has a slightly different focus and differing strengths. Their characteristics are discussed below and summarised in Appendix 2.

The Smithsonian model provides a full description of the 3D capture process and the files that are produced. Designed to address the museum's internal stewardship needs, the model covers the stages 1 and 2 of the 3D workflow (see 3.1 above). The scope of the model does not currently seem to include the delivery stage (4) and the information needed to discover a 3D model in an online environment.

The LIDO model provides a full description of the museum object and events in which the object has taken part, which may include digitisation (stage 1 of the workflow). The model provides information about digital surrogates of museum objects but currently provides limited scope to describe their technical characteristics or digital provenance. As LIDO is a harvesting format, the information available depends in museum Content Management Systems. It would be useful to know how/whether museum CMS are developing to accommodate born-digital objects and the 3D workflow.

The CARARE model provides a full description of monuments, buildings, artefacts and born digital objects. Version 2 of the CARARE model covers the 3D workflow (stages 1-3) in the activity class and (stage 4) in the digital resource. It allows for the inclusion of digital provenance data and is compatible with CRM_{dig}. The model does not currently allow for the same level of detail about the capture dataset and raw data files as the Smithsonian model but there is scope for extension.

The STARC model is an interesting development of the CARARE model. It provides for both a full description of the heritage asset being digitised, with a more detailed description of the 3D workflow (stages 1-4) but the link between the digital resource and the cultural heritage asset that was digitised is indirect. This schema was developed for implementation on STARC's repository and is not intended for wider deployment.

The CRM_{dig} articulates the metadata needed to describe the digital provenance of 3D models in an extension to the established CIDOC CRM standard. As an extension, any implementation would need to include relevant elements from the main standard to provide full documentation of the cultural heritage asset, the digitisation process and the resultant digital objects. Taken together CIDOC CRM with the CRM_{dig} provides a good basis for recording metadata and provenance data for 3D. However, both the CIDOC CRM and

CRM_{dig} are RDF schemas. RDF is not supported in Europeana[15], which raises some issues for organisations wishing to provide metadata records to Europeana starting from implementations of CIDOC CRM and CRM_{dig}.

EDM's strength lies in its ability to integrate information from a wide range of different cultural institutions. It provides for a full description of the conceptual thing that is being provided and binds this together with information about where digital representations may be found online. However, the model does not currently readily allow for the digital provenance of a representation or the technical characteristics of a digital file to be included.

Conclusion

Of the six metadata schemas analysed three are actively used in the Europeana network – CARARE, LIDO and EDM.

Of these three, the CARARE metadata schema currently offers the best balance between support for the 3D workflow and compatibility with EDM. The schema provides for relations between digital resources enabling 3D models to be related to images, text documents, videos and different versions of the 3D model. There is scope for extension of the schema to include more information about raw data files and technical characteristics of the 3D models.

Although the LIDO schema is widely used among the museum community and is compatible with EDM, its focus is on objects registered in museum collection management systems. It currently offers limited support for the 3D workflow and there is limited ability to describe rich 3D objects. For these reasons, it is not recommended for use with 3D in its current form.

EDM requires extensions to the Web Resource class to enable the characteristics of 3D models to be captured, and users to assess their quality. Implementation of the EDM event class would enable the 3D workflow and the digital provenance of 3D models to be captured.

The CIDOC CRM and CRM_{dig} provide a good framework for describing 3D content and their paradata. However, the RDF implementation of these schemas currently presents some issues in terms of data supply to Europeana.

[15] Europeana can process only RDF/XML records that adheres to a specific XML implementation of the EDM Schema

5 Recommendations

The objectives of this task force were to review the status of 3D content publication amongst Europeana's network with the specific objective of making recommendations to help make 3D content more accessible to users of Europeana Collections. These recommendations concern Europeana's Publishing Framework and a call for action for future work.

5.1 Europeana Publishing Framework

The *Europeana Publishing Framework* and *Publishing Guide*[16] are intended for organisations who wish to share their material in Europeana Collections. Together they provide guidance on the technical criteria for the content formats available in Europeana Collections with detailed criterion for four quality tiers. Currently images, texts, audio and video media formats are covered in these guides. 3D is not currently covered in the Publishing Guide.

The recommendations for extending these documents to include 3D content are summarised below:

Digital objects

Europeana defines a digital object as a representation of an object that is part of Europe's cultural and/or scientific heritage, this may include a born digital object. A 300-page book is expected to be represented in Europeana as one single object. If the object is a photograph of a painting, the metadata should make it clear that the object being described is not the painting itself.

In the case of 3D, it is recommended that a **digital object** may include:

- Photorealistic representations of the exterior of a museum object in its current condition
- Photorealistic representations of the interior and exterior surfaces of an object in its current condition.
- Representations of very large objects, monuments and buildings.
- 3D scenes depicting objects within their landscape or setting, for example furnishings within a house.
- Animations representing an object in its working condition, for example the movement of a clock or a watermill
- Reconstruction of an object in their original condition (or at a moment in time) based on scientific research
- Works of art
- Volumetric representations of an object for 3D printing

In general, it is recommended that for 3D content fall within Europeana's collecting scope it should:

- Have a connection with Europe and Europeans,

[16] Europeana Publishing Guide: https://pro.europeana.eu/post/publication-policy

- Be related to cultural heritage including the material culture held in European museums and other institutions, and
- To be classified as being 3D, a digital object should have 3D geometry. 2D representations (images) of three-dimensional real-world objects (e.g. sculptures) should not be given the type 3D in Europeana records.

Preview
Europeana requests previews of digital objects for display within its platform to help users to assess the actual content. For 3D content it is recommended that a 2D image of a scene within a model may be offered as a preview to display with the metadata record.

Metadata
Europeana does not host content. New content is signposted in Europeana by the inclusion of a metadata record. The metadata record provided should point to 3D content where it can be accessed online (see below for discussion about the means of providing access). It is recommended that the metadata provided to Europeana should:

- Conform to the mandatory requirements for EDM.
- Include a clear description of what is represented in the 3D content so users can distinguish between a representation of an object in its current condition, a virtual reconstruction and other types of 3D.
- Provide an account of the digital provenance of the 3D content so that users can understand the context in which the content was created, the methods and processes used, and the research/interpretation that has been carried out in creating the content.
- Conform to recommendations for good metadata quality including the use of controlled vocabularies, Linked Open Data resources and authority files, and language labelling of the metadata to improve retrieval.

The recommendations for the EPF tier specification for 3D content are summarised below:

Minimum requirements for 3D files (tier 1)

It is recommended that the specification notes that:

- 3D objects are visual resources for users to look at, rotate and interact with.
- The quality of 3D content depends on a number of factors, such as the number of points and vertices, the underlying research and production methods, and the choices made in processing the data. For users the quality of their experience of 3D also depends on highspeed connectivity, load times and their ability to interact with the content (to pan, rotate, zoom, move through). The ability to reuse 3D content depends on the availability of metadata that describes how the content has been created
- In publishing 3D content on-line, there has been a balance to be struck between preserving the original quality of the underlying data and the size of file. Streaming

technology is developing but it is important to remember that if the file is too large it will be slow to load and rotate in a standard user's computer. Another important consideration is providing access to 3D content in industry standard formats (e.g. glTF, X3D, OBJ, PLY, STL, DAE, PLY, WRL, DICOM, IFC) that users can view without requiring them to install additional software.

- Organisations and individuals who are contributing 3D content to enable discovery via Europeana Collections need, as a minimum to provide either a link to the 3D file on a website in which the file can be viewed online or is made available as a download, or provide a direct link to a 3D file for download. You are also recommended to provide a link to a still image file to provide a preview of the 3D content for use in Europeana search results.
- Embedding 3D content into PDF documents is not a recommended format for new content.

Criterion for 3D files (tiers 2-4)

Content tier 2 (Europeana as a showcase)

It is recommended that the specification notes that:

- Content that is classed as being at tier 2 is of higher quality, is more accessible to users and is showcased by Europeana in its thematic collections. Organisations and individuals who wish to make their 3D content more accessible on Europeana Collections should publish the content in a viewer that is embeddable[17] in Europeana collections.

The task force recommends that:

- Europeana investigates the embed options for 3D viewers used for a body of content and/or data providers, or which have potential for adoption by Europeana aggregators and data providers (e.g. Scan the World, 3D HOP, the Smithsonian explorer), and to investigate the integration of 3D file formats that can be played directly in HTML5 browsers.
- Europeana takes steps to ensure that 3D content that is embedded in a viewer on Europeana can be showcased in Europeana's thematic collections and galleries.
- Europeana collaborates with the 3D community to investigate whether the provision of model information (numbers of triangles, vertices, textures, animations etc) could be used to provide quality measures for 3D content. In the case of video files, the vertical height (in pixels) is used as a quality measure at tier 2 (it is worth noting that there is no increase (in height) for video to achieve tiers 3 and 4 of the Europeana Publishing Framework).

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[17] Europeana supports the Sketchfab viewer, any oEmbed compliant viewers and, for IIIF images, the Leaflet viewer.

Content tier 3 (Europeana as a distribution platform for non-commercial reuse):

There is no specific recommendation for 3D content at tier 3.

It is worth noting that content that is classed as being at tier 3 in the Europeana Publishing Framework is made available under licences that permit reuse for non-commercial purposes (by private individuals, educators and researchers. In line with other media formats, Organisations and individuals who wish to make 3D content available at tier 3 should, in addition to the criteria described for Tier 2, should make sure the content is released under one of seven rights statements that allow reuse (four Creative Commons licences: CC BY-NC, CC BY-NC-ND, CC BY-NC-SA, CC BY-NC-ND; three RightsStatements.org's[18] statements: NoC-NC, NoC-OKLR, InC-EDU).

Content tier 4 (Europeana as a free reuse platform):

There is no specific recommendation for 3D content at tier 3.

It is worth noting that content that is classed as being at tier 4 is made available under fully open licences that permit reuse for commercial and non-commercial purposes. Organisations and individuals who wish to make 3D content available at tier 4 should, in addition to the criterion for Tier 2, make sure that the 3D content is released under one of the rights statements that allow free reuse (CC BY, CC BY-SA, CC0 or PDM).

5.2 Call for action

The recommendations in this section represent a call for actions to help improve standardization, description, content labelling, accessibility, interoperability and to collaborate in further work.

Common file formats

Adopting a limited set of common file formats (and updating the list regularly) will help to increase standardisation amongst Europeana data providers and aggregators, and in this way increase interoperability with Europeana. Encouraging the use of formats that are considered suitable for long-term preservation will increase the reusability of 3D content in the longer term.

Europeana, Europeana data providers and aggregators are recommended to adopt the formats

- glTF
- X3D
- STL
- OBJ
- DAE

[18] https://rightsstatements.org/en/

- PLY
- WRL

Two formats are recommended for industry specific 3D content:

- DICOM (a standard for medical images including radiography and computed tomography)
- IFC (a standard for the Building Information Modeling)

Embedding 3D content into PDF documents is not a recommended format for new content as 3D PDF is no longer supported by Adobe.

Viewers/platforms for delivery

Agreeing on a limited set of viewers/platforms for delivery will help to facilitate the process of ensuring these can be embedded in the Europeana collections platform. The choice of viewers/platforms for inclusion on this list should be guided by the list of recommended file formats.

The viewers/platforms that are currently supported in Europeana include:

- The Sketchfab viewer
- oEmbed compliant viewers
- the Leaflet viewer (for IIIF images)

Europeana is recommended to collaborate with the developers to test the embed options for:

- Scan the World's viewer
- 3D HOP
- Smithsonian explorer
- INCEPTION viewer

The EuropeanaTech 3D community is recommended to collaborate with the IIIF 3D community in:

- Designing and developing a viewer/platform aimed at universal delivery of 3D content

Metadata schemas

3D content should be described with rich metadata which supports discovery and access to the content, and also understanding about how the content was produced, its technical characteristics, and also understanding of the cultural heritage represented in the content.

Using an existing metadata schema designed with 3D content in mind helps ensure interoperability with international standards and Europeana's data model. Support and guidance for content providers is more readily available, which helps improve the consistency with which metadata is captured and its completeness. It is important to communicate the need to include enough information to allow 3D content to be accessed and understood later on.

Europeana data providers and aggregators are recommended:

- Implementing the CARARE metadata schema currently offers the best balance between support for the 3D workflow and compatibility with EDM.
- CIDOC CRM with the CRM_{dig} extension offers good support for the 3D workflow, however work would be required to establish compatibility with EDM.

The guardians of the LIDO schema and EDM are recommended:

- To collaborate with the 3D community to develop the extensions needed to support the 3D workflow and the rich description of 3D content.

Europeana data providers and 3D content creators are recommended:

- To improve metadata quality and in this way to improve the discovery/findability of 3D content
- To establish processes to clean up and enrich existing metadata
- To implement persistent identifiers for 3D content wherever possible. A persistent identifier (PID) works even if the web address of a resource changes and improves the findability of content over time.
- To capture the provenance (paradata) of 3D content systematically to make clear what can and what cannot be expected in the dataset.

Content labelling

There has been confusion amongst some Europeana data providers about when to label content as 3D in the EDM Type element. To be classified as being EDM Type = 3D, a digital object should have 3D geometry. 2D representations (images) of three-dimensional real-world objects (e.g. sculptures) should not be given the type 3D in Europeana records.

Europeana is recommended to:

- Update the Europeana Publishing Guidelines and Publishing framework in line with the outline provided in section 5 above;
- Update training materials to help inform aggregators and data providers about the recommendations for 3D content (including which type of content to label as 3D);
- Roll out a programme of work to clean contents that were mis-labelled as 3D in Europeana collections in past projects.

Broken links

A lack of persistence in the links to cultural heritage content is a general issue and has a negative impact on users' experience in Europeana. Broken links in Europeana records are caused, for example when changes in an underlying database structure alters the URL pointing to a content item. In such cases, the content providing organisation needs to send an updated metadata record to Europeana to provide the new link. Implementing a persistent identifier (PI or PID) avoids this requirement as the PI maintains a link to the current location of the content online.

Europeana is recommended to:

- Roll out a programme of work to address broken links to 3D content in Europeana collections
- Continue communicating the issue of broken links and the benefits of persistent identifiers to its data partners.

Collaboration

Working collaboratively with institutions, Europeana aggregators, projects and developers to increase standardisation will help to improve the findability, accessibility, interoperability and reusability of 3D content.

Our experience suggests that areas for collaboration include:

- Contributing towards developing standards for 3D content and metadata
- Contributing towards standards for interoperability between 3D and text, still images and other media content
- Providing well documented APIs to enable integration of viewers and platforms for delivery
- Supporting common file formats to increase standardisation and interoperability with Europeana and other platforms
- Support standard metadata schemas that improve the rich description of 3D content
- Clearly documenting any extensions to metadata schemas to increase interoperability

Europeana and the 3D community are recommended to support work on international standards for 3D content, metadata and delivery systems.

5.3 Training

The results of the survey of Europeana data partners highlighted variations in experience and a desire for support and guidance on 3D digitisation, visualisation, tools, formats, storage, rights and metadata.

Europeana is recommended to collaborate with specialists to support work to develop and deliver training for cultural heritage institutions and aggregators on 3D content, metadata and delivery systems.

5.4 Conclusions

Improving on the means of delivery for 3D and increasing standardization is currently very topical. A survey carried out in June this year by the Friedrich-Schiller-Universität Jena amongst scholars in the field of Digital Cultural Heritage Studies in Germany found that 3D was the area of highest demand concerning standardisation and policies. This finding was echoed in the survey carried out by this task force and others. The IIIF 3D community group highlights the interest from commercial, non-profit and academic sectors in advancing and developing 3D technologies. There is much potential and still work to be done before 3D content achieves the level of standardization and interoperability as still images.

This task force has focused on improving the availability of 3D content in Europeana Collections. Our approach has been to identify bodies of content, formats and viewers that are currently the most readily implementable by Europeana and its network.

6 References

Europeana Network Association, 2018, Final report on Advanced Documentation of 3D Digital Assets Task Force,

Europeana Publishing Guide: https://pro.europeana.eu/post/publication-policy

Parthenos, 2017, White paper, Digital 3D Objects in Art and Humanities: challenges of creation, interoperability and preservation.

Standards

CS3DP Community Standards for 3D Data Preservation (https://osf.io/ewt2h/)

DICOM Standard: https://www.dicomstandard.org

The Khronos Group Inc, glTF Overview: https://www.khronos.org/gltf

Web3D Consortium, What is X3D?: https://www.web3d.org/x3d/what-x3d

Wavefront, OBJ overview: https://en.wikipedia.org/wiki/Wavefront_.obj_file

PLY overview: https://en.wikipedia.org/wiki/PLY_%28file_format%29

COLLADA/DAE overview: https://en.wikipedia.org/wiki/COLLADA

STL overview: https://en.wikipedia.org/wiki/STL_%28file_format%29

Nexus: http://vcg.isti.cnr.it/nexus/

IFC: https://www.buildingsmart.org/standards/bsi-standards/industry-foundation-classes/

Platforms/Viewers

Scan the World: https://www.myminifactory.com/scantheworld/

Sketchfab: https://sketchfab.com/

3D HOP: http://www.3dhop.net/howto.php

INCEPTION: https://www.inception-project.eu/

Appendix 1: Inventory of 3D formats and viewers

1.1 Formats

Wikidata-Entry	Name	Description	Representation	Type	Developers
Q28135989	GL Transmission Format (.gltf, .glb)	File format for 3D scenes and models using the JSON standard. The intention is that glTF be an efficient, interoperable asset delivery format that compresses the size of 3D scenes and minimizes runtime processing by applications using WebGL and other APIs. glTF also defines a common publishing format for 3D content tools and services.		Display, exchange	Khronos group
Q54809843	USDZ (Apple AR)	Format announced by Apple in 2018 for augmented reality content, based on Pixar's Universal Scene Description specification.		exchange	Pixar
Q930428	X3D .x3d	Successor of VRML. Royalty free ISO standard (ISO/IEC 19775). Free and open.		Display, preservattion	Web 3D consortium
Q176061	Virtual Reality Modeling Language (VRML) .wrl	designed with the web in mind, it has been superseded by X3D (ISO/IEC 14772-1:1997) (Not much used any more)		Display, preservattion	Web 3D consortium
	3D PDF	Embedded 3D objects in PDFs (Going out of use, no longer supported by Adobe)		Display	Adobe
Q1238229	Stereolitography (.stl)	STL describes geometry surface of a 3D object without colour (in most cases) or texture information. It exist in ASCII and binary. Mostly use for rapid prototyping, CT/µCT 3D models and 3D printing.	meshes	Printing, exchange	3D Systems
Q2119595	Alias Wavefront (.obj)	OBJ (or .OBJ) is a geometry definition file format first developed by Wavefront Technologies. The format is open and has been developed by other 3D graphics application vendors.	meshes	Exchange	
Q3063041	Autodesk Filmbox, FBX (.fbx)			Preservation	Autodesk

Q603967	Collada, digital asset exchange (.dae)	Created as an interchangeable format between different applications. Recognize as ISO standard	meshes	Preservation	Khronos group
Q3077345	Polygon File Format/Stanford Triangle Format (.ply)	Enable to store surfaces, point clouds, colour, texture coordinates, surfaces normals. Exist in ASCII and binary		Exchange	Greg Turk, stanford University
Q27441566	.las	3D Point cloud format (Lidar Data exchange file)	point clouds	Exchange	ASPRS
Q616714	Initial Graphics Exchange Specification (IGES)	CAD format most used in the Industry	meshes	Exchange	National Bureau of Standards
Q979630	Industry Foundation Classes (.ifc)	3D BIM platform neutral, open file format specification to facilitate interoperability in the architecture, engineering and construction (AEC) industry	BIM models	Preservation	
	Point cloud format .fls (ptc)	3D Point cloud format, Faro Point Cloud format	point clouds		Faro
	Point cloud format .imp (+) ptx	3D Point cloud format, Leica Point Clous Format	point clouds	exchange	Leica
Q33517407	Point Cloud format .e57	This specification describes a data file exchange format for three-dimensional (3D) imaging data, known as the ASTM E57 3D file format, Version 1.0. The E57 file format is a compact, vendor-neutral format for storing point clouds, images, and metadata produced by 3D imaging systems, such as laser scanners. The file format is specified by the ASTM, an international standards organization, and it is documented in the ASTM E2807 standard. The E57 format was developed by the Data Interoperability sub-committee of the ASTM E57 Committee on 3D Imaging Systems.	point clouds	exchange	IEEE
Q49620191	Revit native format .rvt	Autodesk Revit Architecture project files			Autodesk
Q735441	Autodesk Inventor Drawing File (.idw)	Inventor has a number of separate file formats used in conjunction to create complex designs. Part fields and assembly files can be described in a schematic drawing file .idw.			Autodesk
	Autodesk Assembly part file (.iam)	Inventor has a number of separate file formats used in conjunction to create complex designs. Part files are combined to create			Autodesk

		complex designs in assembly files .iam.			
Q28771225	3DS MAX	3DS is one of the file formats used by the Autodesk 3ds Max 3D modeling, animation and rendering software.			Autodesk
Q28975796	Drawing exchange format (.dxf)	AutoCAD DXF (Drawing Interchange Format, or Drawing Exchange Format) is a CAD data file format developed by Autodesk[2] for enabling data interoperability between AutoCAD and other programs.	meshes	exchange	Autodesk
Q15029253	3D Manufacturing Format 3MF	3D Manufacturing Format or 3MF is a file format standard developed and published by the 3MF Consortium.3MF is an XML-based data format designed for using additive manufacturing, including information about materials, colors, and other information that cannot be represented in the STL format.			3MF Consortium

1.2 Viewers

Wikidata-Entry	Name	Description	Supported file formats	Embed options	Developers
	3D Hop	Online viewer	PLY, OBJ, STL, PTM, RTI		ISTI-CNR
	CNRS-MAP meta-viewer	HTML5 meta-viewer based on Web GL and Javascript, able to visualise 3D models and videos. The viewer uses the Potree visualisation tool	Collada, OBJ, PLY, JPG, BMP, AVI, MOV		CNRS-MAP
Q5499685	FreeWRL	An X3D/VRML open source viewer	X3D, VRML		John Stewart and others
	Hexalab	HexaLab is a WebGL application for real time visualization, exploration and assessment of hexahedral meshes.	.MESH,		ISTI-CNR
	INCEPTION viewer	INCEPTION developed a RESTful web platform for Cultural Heritage Buildings this platform allows at converting IFC models into semantic triples, keeping the semantics of BIM models. At the same time, the project developed also a 3D			INCEPTION consortium

		viewer in order to access those converted models and querying them through SPQRL.			
	Interspectral Viewer	Visualisation software for 3D data from CT and micro-CT.			Interspectral
	Plas.io	Plas.io is a project that implements point cloud rendering capability in a browser. Specifically, it provides a functional implementation of the ASPRS LAS format, and it can consume LASzip-compressed data using LASzip NaCl module.	LAS		by U. Verma and H. Butler
	Potree	Potree is a free open-source WebGL based point cloud renderer for large point clouds. Includes PotreeConverter software for LAS/LAZ and PLY. Using Three.js, the WebGL 3D rendering library on which potree is built as well as plas.io point cloud viewer. LAS and LAZ support have been taken from the laslaz.js implementation of plas.io.	LAS, LAZ, PLY		Institute of Computer Graphics and Algorithms, TU Wien.
	Scan the World	Archive of open 3D printable artefacts, built using crowd-sourced collection or through collaborations with cultural institutions. The 3D viewer implemented is an open source javascript tool, https://threejs.org/, Scan the World currently hosts STL but are preparing for other methods in case the file-type becomes obsolete. Open API with models uploaded to Wikipedia	STL		MyMiniFactory
Q7534755	Sketchfab	The Sketchfab Viewer uses WebGL and allows users to inspect 3D models that have been uploaded to the Sketchfab platform.	50 formats	iframe, bbcode, oEmbed	Sketchfab
	Smithsonian viewer (legacy)		custom	iframe	Smithsonian
	Smithsonian Voyager Explorer and Authoring	open source, available to everyone, initial alpha release planned early 2019	imports 40+ formats, directly reads glTF, GLB, OBJ, PLY, (X3D)	iframe, oembed	Smithsonian

	UMORF	University of Michigan online repository of fossils	OpenCTM, OBJ, PLY	iframe	University of Michigan
	Universal Viewer	IIIF universal viewer. Threejs 3D library.	glTF, OBJ, PLY, threejs json, DRACO (experimental), Corto	iframe, oembed	Digirati?
	X_ITE	X_ITE is a 3D JavaScript library entirely written in JavaScript and uses WebGL for 3D rendering. Authors can publish X3D and VRML source online within an HTML5 page with X_ITE	X3D, GlTF		Create 3000
	X3DOM	X3DOM (pronounced X-Freedom) is an open-source framework and runtime for 3D graphics on the Web. WebGL 3D library	X3D, GlTF		Fraunhofer

1.3 Software

This is a short list of some of the software that is available for processing 3D.

Wikidata-Entry	Name	Description	Supported file formats	Licence	Developers
Q173136	Blender	Blender is the free and open source 3D creation suite. It supports the entirety of the 3D pipeline—modeling, rigging, animation, simulation, rendering, compositing and motion tracking, even video editing and game creation.	.blend (internal); Alembic, Collada, 3DS, FBX, DXF, SVG, STL, VRML, X3D, OBJ, PLY	GNU General Public Licence (GPL)	Blender Foundation
Q3306840	MeshLab	3D processing software (editing, cleaning, rendering, etc.)	PLY, 3DS, ASC, OBJ, OFF, STL, SVG, TTRI, V3D, VRML, X3D	GNU General Public Licence version 3 (GPL)	ISTI-CNR
Q2979718	CloudCompare	3D view, edit and process	PLY, OBJ, VTK, STL, E57, LAS, LAZ, PCD, FBX, SHP. OFF, FLS/FWS, DP, RDB, RDBX, RDS, PSZ	GNU General Public Licence (GPL)	
Q857341	LightWave 3D	LightWave 3D is a 3D computer graphics software developed by NewTek. It has been used in film, television, motion graphics, digital matte painting, visual effects, video games development, product design, architectural visualizations, virtual production, music videos, pre-visualizations and advertising.	LWS, LS, LWO, MD5A, MD5M, MDD, MOT, OBJ, RPF, SRF	Trialware	NewTek
	3DSom	Photogrammetry service: 3D content from photos - capture, process and sharing service			3DSOM

Appendix 2: Metadata schemas – support for 3D workflow

Schema name	Describes CHO (conceptual thing)	Describes item digitised	Describes born digital CHO	Describes digital resource being provided	Describes project (event)	Describes capture dataset	Relates project to capture dataset/ digital resource	Relates CHO to provided digital resource	Supports London charter	Compatible with EDM
Smithsonian 3D metadata model	√	√			√	√	√			
LIDO	√	*		*	*			√		√
CARARE	√	*	√	√	√		√	√	√	√
STARC metadata model	√		*	*	√		√	*	√	*
CRM dig				?	√	?	√		√	*
EDM	√		√	*	No			√		

√ = supported
* = supported with some limitation
? = not known