Starting with 3D Data. A University of Bristol Theatre Collection guidance document for developing its procedures and workflows for the archival management of 3D data

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Purpose of this document

The University of Bristol Theatre Collection is not a specialist 3D data archive service, but looks after mixed format collections, including paper, objects, digital files, photographs and audio-visual documentation. In 2019 the Theatre Collection received a donation of LiDAR scans of the artist Ian Smith's studio, presenting it with a new set of preservation challenges.

The purpose of this document is to act as guidance for the archivists at the University of Bristol Theatre Collection to refer to as they develop procedures and workflows for the archival management of 3D data. Although it was created for this purpose, the intention of the authors is to share it with the wider archive profession to assist others working with 3D material in their collections and to generate discussion in this area.

The document was created through a three-day event in July 2022 hosted by the University of Bristol Theatre Collection with funding from The National Archives Innovate and Collaborate Award scheme, which brought together individuals with expertise in different areas of 3D data, from creation and capture through to management and accessibility. The document was created collaboratively in a short space of time using the intensive 'booksprint' method.

Two 'worked' examples - LiDAR scans of Ian Smith's studio and photogrammetry pantomime set models - that informed our discussions are appended at the end, together with the Reading List of sources used by the group.

The guidance document focuses on the types of 3D data held by the Theatre Collection, and does not include structural scanning and stereoscopic video, for example.

We have not included a glossary of terms in this document, but please refer to the Community Standards for 3D Data Preservation glossary.

Definition of 3D data

'3D file formats contain data that represent three-dimensional space and embedded information needed to render this data. 3D formats encompass a wide range of potential applications spanning many fields of research and implementation.' (*DPC Technology Watch Guidance Note. Preserving 3D: Data Type Series*.).[1]

Section 1: Capture

Why capture in 3D?

- Enables the preservation of an at-risk object or location of cultural significance that may disappear if not recorded.
- Allows wider access for research and access for people far away.
- When material is fragile, scans can help to preserve original objects by reducing handling.
- 3D scans are well-suited to teaching and educational use.
- It allows the creation of 3D printed objects which in turn can be used to improve accessibility for example for visually impaired people.
- 3D models can be repurposed and reused in ways that originals cannot.
- 3D models can be used as a way of lending and sharing objects.

Advice for creators planning 3D data capture projects for long-term preservation.

- It is important to have a data management plan. Think about what you are making and what you plan to do with it.
- How important is accuracy to your project? Is an accurate digital representation needed for the intended use?
- What do your audience and users want or need? Are you fulfilling the required functions in terms of the data, format and metadata?
- Do other forms of documentation exist such as 2D or moving film documentation which are good enough for the intended purpose?

[1] Artefactual Systems and the Digital Preservation Coalition, July 2021, *DPC Technology Watch Guidance Note. Preserving 3D: Data Type Series*. [Online] Available from https://www.dpconline.org/docs/technology-watch-reports/2479-preserving-3d/file. [Accessed 30 September 2022].

- Are there any ethical or legal reasons not to create a 3D scan? Do you have copyright permission?
- Consider sustainability and avoid the duplication of digital data as there is an environmental cost to preservation actions.
- What is technical best practice for the capture method you are using? Are there acceptable tradeoffs between best-practice and achievability? Can you document these decisions?
- Consider your output formats carefully. What is best practice (for example recommended formats for potential users and repositories)?
- It may be necessary to carry out a cost-benefit analysis. This would include the costs of capture, the time to process, and the time and costs of preserving, and actively managing the content in the future. 3D preservation files are fragile and because of dependencies are not straightforward to look after in the way that photographic files such as jpegs and tiffs might be.
- Who will store the outputs and where? Are there costs involved? Are you able to estimate the costs going forward?
- Do you have any formal agreements with the holding institution? Who will own the constituent data and metadata? Is this documented? Will the data and metadata be licensed and what are the implications of the licenses that will be used?
- If authenticity is important, minimise and document any editorial interventions.
- Risk management is an important factor in the reuse of objects. If you are using a third-party site such as Sketchfab to provide access, does it have a takedown policy? What is the element of risk and what is your institution's appetite for risk?
- How important is the ongoing preservation of the scans? If the scanned object is not at risk it could be rescanned in future using an improved method. This may be cheaper than long-term preservation of the original scans.

Capture methods

Method	**Suitability**	**Pros**	**Cons**
Lidar (laser scanning)	Bigger spaces (anything larger than a room)	Quick, portable, lower quality available in newest phones	Expensive (50k+)
Structured light	Small to medium-sized items, high resolution	Portable. Accurate geometry.	Relatively expensive handsets (12k). Texture capabilities not as good as photogrammetry.
Photogrammetry	Smaller items or large sites (drone photogrammetry)	Cheap, no special hardware required, so more democratic. Software cheap	Can have heavy processing (computing) requirements.

		(Agisoft) or free. Apps for phones now available. Good for beginners. Good on drones. Good for recording the material, colour and texture.	
Structured light/photogrammetry hybrid, e.g. photo texturing in Artec Studio	Small to medium sized objects.	Accurate geometry and high resolution texture	Still developing. Relatively expensive handsets (12k).

Other methods of 3D capture to be aware of are spatial audio and motion capture. Spatial audio is used to capture multi-channel ambient sound works in location which can be reunited with a 3D visual scan (for example in virtual-reality). Motion capture can be used to record movement and apply it to 3D models and can capture points moving in space over a period of time.

Section 2: Files and Metadata (outputs)

Files for Preservation

The table below lists the files that the Theatre Collection will aim to preserve. (The source files in Lidar and Structured Light scanning are proprietary making them difficult to preserve and, unlike 2D tiff and dng files from photogrammetry, which could lend themselves to reuse in other contexts, are redundant once the registered dense cloud has been created and so are not included.)

Method	**Source**	**Raw**	**Mezzanine**	**Access copy**
Lidar (laser scanning)		Registered, dense cloud open format e.g. E57	3D model, processed.obj/.mtl./.jpg	Lightweight .glb or .obj/.mtl/.jpeg
Structured light		Registered, dense cloud open format e.g. E57	3D model, processed.obj/.mtl./.jpg	Lightweight .glb or .obj/.mtl/.jpeg
Photogrammetry	Images sequence .dng & .tiff	Registered, dense cloud open format e.g E57	3D model, processed.obj/.mtl./.jpg	Lightweight .glb or .obj/.mtl/.jpeg

Metadata

This section summarises the metadata chapter of *3D Data Creation to Curation: Community Standards for 3D Data Preservation*[2]. There is a more detailed discussion of metadata with recommendations for good, better and best practice in this report.

It is important to collect three types of metadata:

- Capture metadata
- Processing metadata
- Metadata to facilitate access

Capture metadata and processing metadata show how initial capture information has been manipulated and interpreted to create the final 3D model.

The Archaeology Data Service has created a comprehensive spreadsheet to collect metadata from donors. The Theatre Collection will aim to adapt this metadata spreadsheet for use when collecting metadata from 3D scanning projects.

It may be advisable to ask the donor to create a readme .txt file explaining the file and folder structure for the material being transferred or to request a particular folder structure. (The University of Bristol Research Data Service has similar guidelines on its webpage for preparing data for publication.[3])

Capture metadata

- Who, what, when and how (common metadata standards such as Dublin Core can be used for this metadata)
- Camera or scanner parameters and settings at time of capture
- Structure of point cloud data (e.g. XYZ, RGB)

It is relatively straightforward to collect the who, what, when and how metadata but it is more onerous for creators to record the more detailed technical metadata. In reality it may be more difficult for archives to obtain this information but it is essential if the models will be used in an academic or scientific setting or in published work.

Decisions are made at the point of scanning and it is important to collect as much information as possible about those decisions. File metadata is often embedded in the original scans. Some of

[2] *Community Standards for 3D data preservation.* [Online]. Available from https://cs3dp.org/. [Accessed 30 September 2022].
[3] University of Bristol, *Information for Researchers: Preparing your Data for Publication in data.bris*. [Online] Available from https://www.bristol.ac.uk/staff/researchers/data/publishing-research-data/data-preparation-rules/. [Accessed 14 October 2022].

this will be transferred into an E57 file but the metadata is only available by downloading the file and looking for the metadata. Metadata can usually be extracted from a file through a platform such as Cyclone. It is advisable to store metadata separately (such as in a spreadsheet) meaning it can be accessed without downloading the file. Holding the metadata separately also means that there is no need to worry about what happens to the metadata when migrating the files.

The University of Bristol Theatre Collection also has the potential to add additional metadata fields to CALM. The Archeology Data Service ingests their metadata spreadsheet with the files. They moved away from recording technical metadata into a database because researchers are unlikely to be searching for technical metadata and tend to be more interested in the ‘who’, ‘what’ and ‘where’. They store Dublin Core metadata in a searchable database.

Processing metadata

- For photogrammetry, software packages often allow reports which are worth asking creators for (e.g. Agisoft Metashape report). Be wary of relying on this though because a new iteration of the software may not have the capacity to do this.
- Documentation on large decisions and modifications is useful to collect.

Metadata to assist with providing access

- Copyright details. Who owns the copyright of the scans?
- Is there copyright within the scans (for example of other objects)?
- Descriptive metadata about the object being scanned.
- Issue of distinguishing between the digital object and the physical object.

Section 3: Access

Audiences and Uses

- How well do we know the audiences?
- Who might want to access 3D data, and what will they want to do with it?
- What data might be required for access to meet the needs of an audience?

Digitised 3D models of physical collection objects extend the accessibility of collection objects, especially when available remotely, but audiences may not want to be limited to viewing 3D digital objects on a screen. 3D data can also be re-used in augmented and virtual reality environments, as well as for physical printing.

One reason for capturing objects in 3D data may be to allow for the re-creation of a 'handling' experience. This may be particularly useful when the risks of handling a fragile original are great, such as group teaching or workshop settings. NB – considerations around how to recreate an authentic handling experience that replicates the weight, texture and colours of the original object remain.

Details presented by the data (for example, measurements) as well as contextual metadata, can be important for researchers.

Types of Access: Downloads, Viewers and Hosting Platforms

- Whilst we don't know what audiences might want to do with 3D data, consider what archived data and metadata to make available, and where.
- Maintaining relationships between the original objects and digital files, preservation and access copies will be crucial.
- But be wary of the burden of managing separate assets in different locations. It can be difficult to maintain links when collections data is held on separately hosted sites: consider limited, consistent access places.
- Manual management of collections across multiple platforms may be challenging to scale-up and risks introducing discrepancies in data and metadata.
- How FAIR (Findable, Accessible, Interoperable, and Reusable) is the data? (FAIR concepts are well established in the research data community but lack traction in the heritage sector - the Towards a National Collection project is encouraging a better awareness – see https://tanc-ahrc.github.io/HeritagePIDs/index.html)
- Consider whether access restrictions on various versions of the data are required. This may include making files only viewable on external platforms, restricting full access to low resolution derivatives only, restricting access to certain individuals or

organisations, or adding licenses such as Creative Commons to share content with certain conditions. Sketchfab – see below - allows account managers to restrict discoverability and downloads of models.
- Remember it may still be possible to use content inappropriately even if it has a CC license.

Downloads

- As a minimum 'base-line' for access, consider how the raw(est) preserved files can be made available for download. Subsequent derivatives will come from this source.
- Consider which file formats to use to make access copies available. It may be beneficial to be able to provide access in more than one format (e.g. .glb and .obj), to allow flexibility for rendering objects in different viewers.
- Downloads can be made available from third-party hosted platforms such as Sketchfab, but limits on file sizes may restrict use.
- Will file formats and sizes available for download be suitable for a range of uses (e.g. printing, AR/VR etc.)?
- Consider whether there will be a need to restrict discoverability and/or access to downloads.
- Consider which licenses you may need to apply to downloads

Viewers

Various 3D viewers are available with a range of complexity, features and compatibility. Some viewers are already integrated into existing systems (such as Preservica), others are 'stand-alone' software or third-party platforms. It is important to understand the functionality of viewers and how they relate to various aspects of models and their potential use. It is also important to understand the organisation's systems infrastructure and to consider how viewers will best integrate with these systems.

- Microsoft have a 3D viewer available from Windows 10 onwards. You can also insert 3D objects into Word applications including Word, Excel, PowerPoint, and Outlook
- The Archaeology Data Service uses the 3DHop viewer, which is open-source and geared towards the heritage sector. Requires Javascript files to be available on the web server.
- Some viewers built-in to third-party services may be basic, and only able to support a limited number of file types
- Museums of the University of St Andrew's are using the Universal Viewer, which utilises the IIIF manifest (see below). The IIIF manifest has the advantage of being able to be transferred to another viewer.
- Sketchfab could be used as a viewer only, without making files downloadable.

Third-Party Hosting Platforms

- Sketchfab is the most well-known hosting service. (NB Like other 'free' platforms such as Youtube, Sketchfab is not a preservation repository and should not be used as one.)
- Having data accessible on Sketchfab may make it more easily discoverable. As a commonly used external provider, it has the benefit of a large external audience.
- Audiences searching for 3D content may well start with third-party hosted platforms and never visit an institutional archive.
- Well-known cultural heritage institutions, including the Science Museum Group, English Heritage, National Portrait Gallery, and the Historic Environment Scotland, have made content available on Sketchfab.
- Content from Sketchfab can be embedded in other websites, like wordpress.
- Consider carefully the licensing agreements in place for third-party hosted platforms, particularly concerning data ownership and the reuse, and potential misuse, of data.

IIIF

- IIIF (International Image Interoperability Framework) is an emerging set of open standards for delivering high-quality, attributed digital objects online at scale. It is gaining some traction for use in delivering 3D objects online (see https://iiif.io/community/groups/3d/).
- Implementing IIIF will require using a DAMS (Digital Asset Management System) that supports IIIF, or a hosted service that provides a IIIF Image API, or setting up your own IIIF Image server.[4]
- With IIIF users can create or use third party tools for using objects e.g. for creating narratives or for tagging. Questions remain about how we would bring this data into the archival copy and if that is even desirable.

Analytics and Monitoring

We know our in-person, on-site audiences better than we know the audiences we don't see using our collections. It's important to try and bridge this gap to better understand audiences using collections remotely and to be able to report to funders/senior managers etc.

- What are the organisational and funding reporting requirements?

[4] For an introduction to IIIF see Roddis, Tristan, 10th November 2017, *Everything You Always Wanted to Know About IIIF* (*But Were Afraid to Ask).* [Online] Available from Everything You Always Wanted to Know About IIIF* (*But Were Afraid to Ask) | by Tristan Roddis | cogapp. [Accessed 19 October 2022].

- Most websites will use some analytics tools to track the number of hits or downloads for pages and objects (e.g. Google Analytics). Sketchfab offers more detailed information including specific named users.
- If PIDs (Persistent Identifiers) are assigned to digital objects, it should be possible to use tools to track the use of the assigned object across the web (e.g. bibliometric tools).
- The ADS measures page views and downloads separately, using piwik software to do this in part, with DOIs (Digital Object Identifier) to track external citation and reuse. DOIs offer sophisticated citation tracking and visualisation. It would be good to implement these for more heritage collections.
- Analytics could be used to calculate how many visitors came to a viewer page without downloading files, which may infer that they got everything they needed from the in-browser viewer.
- If possible it will be important to collect qualitative data, as well as quantitative, in order to create narrative accounts/assessments of impact.
- Where 3D digital objects are used in physical settings (e.g. on screens or using VR headsets in an exhibition, in teaching or engagement activities) it may be useful to record numbers of visitors/participants, in addition to qualitative data via visitor/student feedback forms.

Appendix

Worked example 1

Photogrammetry

The Making a Scene project at the University of Bristol Theatre Collection required set model pieces from Bristol Old Vic's production of Babes in the Wood (2000) to be captured in 3D for Zubr to use to make an AR app. The project was used to learn about 3D scanning and photogrammetry.

At the start of the project model pieces were photographed against a green screen in the photography studio. The green screen was used to help with creating masks to exclude the background from the 3D models. Another capture and masking approach was used later in the project to avoid using the green screen as this introduced some green tone to the models. The models were photographed in the photography studio on a lazy susan, the camera set up on a tripod, the model lit with the studio lights trying to avoid shadows on the item, the camera's ISO, shutter speed and aperture set manually. The lazy susan was gently rotated to photograph the different sides of the model. The camera and model were positioned at different angles during capturing to ensure all of the model was photographed. The x-rite colour patch was used to create a colour profile to apply to the images which were initially exported as jpegs, as suggested by Zubr. With this example of the haunted truck approximately 288 images were taken to make this half of the haunted truck.

Agisoft Metashape was used to make the 3D models. The stages for a new project are 'add photos', image quality checks are run on the photographs and masks imported. Then the images go through the different workflow stages starting with 'align photographs' the next stage is 'build dense cloud'. The mesh is then built, and texture created. An export is created as an .obj, mtl and jpg, the model is then reduced in size and retextured to create a smaller version to display on Sketchfab: UoBtheatre-collection - Sketchfab. Viewing settings are edited in Sketchfab.

The files that have been kept to date for photogrammetry carried out at the University of Bristol Theatre Collection are DNGs and TIFFs (to follow our 2D digitisation processes), a very large object file (obj) and another file where the mesh has been worked on which can be put on Sketchfab. The smallest access file that could be created is in glb format https://www.marxentlabs.com/glb-files/. The University of St Andrews uses glb files in its IIIF Universal Viewer.

Points about Photogrammetry raised through group discussion

- The better our photogrammetry techniques, the fewer photographs would need to be taken and stored.
- We agreed that it makes sense to follow our 2D digitisation standards for saving the images resulting from photogrammetry. Currently at the Theatre Collection capture is

done using a canon DSLR, the files are converted from cr2 files to dng, these are relabeled to have the correct reference number. TIFF files are created and some basic adjustments are made to them.

- Camera locations during the photogrammetry process should be recorded as metadata (which is one of the metadata fields on the ADS spreadsheet).
- An argument for keeping the RAW data would be that there might be unforeseen reuse of the data. The processed version is never going to be as accurate a rendition of the original as the RAW data.
- It is important to measure the item or object before beginning the scanning. Recommended to use a GretagMacbeth chart with colour and scale that can be included in the photograph (https://www.chromaxion.com/information/colorchecker.html). The colour chart needs to be replaced after a certain period of time due to light exposure.
- The image including the colour chart must be kept as it is used to build a colour profile when processing the images. One image with the colour chart should be included at the beginning and one at the end because the lighting conditions may change.
- In the ADS metadata spreadsheet there is a field for metadata collected from depositors about the colour chart that was used (it's recommended to record this information). This raises issues to do with file naming and fitting the image of the colour chart into a sequence.
- A photograph can be taken of the scanner in the room to document the setup. These are metadata photographs rather than images of the collection. These documentary photos should be kept in a separate folder to be distinct from the data. The use of file naming conventions linking the colour chart image back to the original object is important.
- Evenly lighting the green screen helps to produce good quality images. It's useful to move the model higher up to get information from the lower angles of the model or move the camera angle lower.
- Metadata in the RAW file includes metadata about the type of camera used, DNG supports EXIF.
- ADS treats images and point clouds as separate objects but uses PREMIS relationships to link them together.
- There are questions that would take some consideration regarding how to organise the source files so that we know that they are all connected and how this fits with Preservica's data model.
- A mezzanine format (the mesh) has more value than the average access copy. The mezzanine copy would be the first obj created.
- There are questions about when to create the mesh cloud for example whether to create it before processing has taken place or not. Other participants at the event create their mesh cloud earlier in their workflow than the Theatre Collection.

Worked example 2

LiDAR scans of Ian Smith's studio

When Angie Dight and Malcolm Brown began talking about documenting Ian Smith's studio LiDAR scans seemed like a good solution to recording the small space which contained lots of items on display. The scans were viewed as being able to support and extend the documentation from medium format photography and provide an alternative way of experiencing the studio. The LiDAR scanner would capture both colour information and photographic information. A Leica BLK 360 LiDAR scanner was used to create the scans. It was very portable and came with an ipad with proprietary software loaded onto it. The scans were sent directly from the ipad into Autodesk Recap Pro software.

When scanning Ian Smith's studio, Malcolm placed the scanner in five locations and used ambient lighting. The studio was a small space and it was important to capture as much detail as possible. LiDAR allowed for the capture of the structure of the space, including the ceiling. Once the scanning was complete, a project folder was created in Recap Pro on the iPad however a problem with the Recap Pro software led to the Leica software being used instead.

As well as the scans, the Leica takes 360 degree photographs at the same time, as this video shows, and saves the files on the scanner itself. Malcolm passed these RAW files to the Theatre Collection with the LiDAR scans. In addition, the scanner takes colour calibration photographs first. Once the scans have been meshed the colour can be corrected. The point cloud is RGB.

When the scans were received they were registered for each part of the studio (ten for one room and seven for the other). Sam worked on structuring all of the scans together to create one file or object covering the entire studio. Each point cloud for Ian Smith's studio is 2 to 3 GB. These were then aligned and duplicates removed. So far Meshlab and Cloud Compare (which is open source software) have been used to attempt to create a mesh, but with limited success. Sam has worked on getting these files into a mesh and making the files smaller so that they can be made more readily accessible. He used Autodesk software - Autodesk Recap is proprietary software used for LiDAR and needs to be used to view the original files in their current status - but thinks that the scans still require more cleaning up. There is an option for meshing in Autodesk but this feature is not free. Options for export in Autodesk are RCP, RCS, PTS and e57.

Points about Lidar Scans raised through group discussion

- The Archaeology Data Service asks for metadata containing the number of points in the original point cloud so that when changing file formats they are able to check that the output is the same as the original.

- ADS also takes the mesh but does not create any derivatives and uses 3D hop software for previewing. Original measurements are important. The mesh is derived from the point cloud.
- The size of files is more of an issue with LiDAR scans. Processing power may be an issue as well as the number of working hours required to complete the processing.
- The process with LiDAR scans tends to be that you have a RAW data set, a minimally processed data set (point cloud) and then you do the work needed for dissemination. The most minimal dataset would be the rawest files plus documentation. RAW files may be proprietary but you can normally get an export as ascii or e57.
- 360 degree photographs, taken by the scanner at the same time, would also be suitable for an archive to take when accessioning the LiDAR scans.
- Ideally we'd want a scan of the colour chart to be able to work with the scans in the future.
- Registering the scans means aligning everything with common coordinates.
- It would be useful for the archive to have a sketchmap (otherwise known as a planimetric sketch) showing the set-up of the scanner to be able to link every individual file to a particular position. Looking more closely at the Recap software it looks like this is possible.
- E57 is an export format, so could be the rawest scans or the processed point cloud. Pts is an ascii export format. PTS files are structured in rows containing: X Y Z I R G B (the X Y Z coordinates of the point, the intensity value and then the colour values).
- E57 files combined with plain ascii files seem to be the emerging standard (or the closest there currently is to a standard).
- We needed to know that Malcolm used a Leica scanner, opened the files in Recap and gave us the Recap files (it is important to understand the process that has taken place before receiving the scans).
- There are free viewers for point clouds but unfortunately these rely on proprietary formats. It is important to be careful about the point at which proprietary files are converted into an open format such as the E57, to make sure no important information that may have been included in the original is lost.
- In terms of previewing the files it may be possible to have a look for the Leica viewer for initial assessment. Cloudcompare is also good. It is possible to open the file in a text file just for info as there will be some info in the header of the file.
- Ask the depositor for the OBJ file as well for the final view as the depositor would want input into how the final model looks. (OBJ files can be opened in a text viewer.) This is the whole purpose of them creating the 3D scans.
- When loading the scans in Sketchfab it's important to set the point for the user inside the room.

Reading list

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