Specification Writing Guide : How To Manage a Project in 3D for Cultural Heritage

Jean-Baptiste Barreau, Eric Leroy Du Cardonnoy, Florent Laroche, Sophie Madeleine, Véronique Mathieu, Xavier Granier, Pascal Mora, Thomas Pouyet, Mehdi Chayani

RECOMMENDATIONS OF THE

"CONSORTIUM 3D FOR THE HUMANITIES"

SPECIFICATIONS WRITING GUIDE

How to manage a project in 3D for Cultural Heritage

2021 ENGLISH EDITION

English edition review by Dickinson Richard – Service Traduction INIST CNRS

VERSION 2019

Jean-Baptiste Barreau (CNRS, CReAAH - CNPAO)

Eric Leroy du Cardonnoy (Université de Caen-Normandie, CIREVE - UFR HSS)

Florent Laroche (Epotec-LS2N UMR 6004)

Sophie Madeleine (Université de Caen-Normandie, CIREVE - UFR HSS)

Veronique Mathieu (CNRS, ASM - UMR 5140)

Pascal Mora (ADERA, Archeovision production)

VERSION 2018

Thomas Pouyet (MSH Val de Loire- CNRS, CITERES USR 3501 UMR 7324)

TABLE OF CONTENTS

As part of the activities of Huma-Num's Consortium 3D for the Humanities, many meetings have taken place, bringing together scientists from various fields (historians, archaeologists, computer sciences, architects, 3D engineers, archivists, etc.) with the aim of providing effective solutions for the creation and usage of 3D digital models in the Humanities and Social Sciences (SSH). One of the tasks assigned to the Consortium 3D for the Humanities was to develop and write specifications on how to manage a 3D Cultural Heritage project.

This document follows up the release of the recommendation of the Consortium 3D for the Humanities available in open access on the HAL platform in 2018. These first recommendations were mostly included into the guide "Guide pour la rédaction d'un cahier des charges de numérisation en 3D" published by the French Ministry of Culture in the context of the National program to digitize and to valorize cultural content.

1. INTRODUCTION

The aim of this document is to ensure seamless potential exchanges between one ordering party who wants to study or valorize a heritage artifact or site using 3D technology and 3D expert service providers. This report is based on the analysis of the requirements to obtain a 3D digital model and defines the different possible purposes according to the recipients (e.g., expert, general public, education, etc.)

The organization of this document follows an "acquisition project or 3D restitution project of a heritage site or artifact" type approach. It is based on the document "3D vocabulary: a lexicon for the Human and Social Sciences" and "Long-term preservation of 3D digital models for the Human and Social Sciences" which have to be also consulted when drawing up the specifications to realize a project in 3D for Cultural Heritage.

Six subsections / steps appear:

1. Preparation and project monitoring
2. Data acquisition
3. 3D raw data preprocessing
4. Data production by acquisition / 3D survey production without interpretation
5. Restitution – Modeling – Virtual reconstruction of hypotheses – Virtual Reality
6. Prototyping / Physical mock-up

The following recommendations are intended for the ordering party and also for laboratories or companies which request services for acquisition or 3D restitution and their associated processing.

These sub-sections are correlated with different 3D products, corresponding to distinctive requirements and targeting specific audiences. An ordering party wishing to enhance or study a cultural heritage artifact or site through a specific 3D application does not necessarily need all of these steps and they do not necessarily have to be followed in a linear fashion.

Steps 1 and 2 may be sufficient for a study of a building or a pure 3D acquisition in order to preserve an existing state of the heritage site or artifact. Similarly, in the case of the restitution of lost or very damaged heritage objects or site, the direct acquisition of steps 2, 3 and 4 are to be removed. The final stage of prototyping of the object is finally a possibility, but not in any way an obligation.

The aim here is to present all possible deliverables, making a clear distinction between their uses and the audiences they are intended for. The purpose of this document is twofold:

1. To help the ordering party to make the right choice according on their specific problems.
2. Once the requirements are clearly defined, to provide a guide to best practices to ensure that the project is running well.

For each step, we clearly define:

- **The required deliverable;**
- **The conditions and contexts of intervention;**

2. PREPARATION AND PROJECT MONITORING

The ordering party should, as far as possible, define its present and future requirements. The type of expected deliverable and the target audiences will define the 3D requirements. Do not hesitate to approach experts in the 3D field (e.g., members of Consortium 3D for the Humanities) to support you in your choice of the most suitable solution. This step is essential since it conditions the production process. 3D data required for one kind of requirement are not necessarily compatible with the other development possibilities listed in this section. In case of doubt, at this stage, it may be advisable to ask for a support service, and possibly to add a project monitoring service. Indeed, it is important to have an expert opinion to correctly refine expectations in terms of accuracy, resolution and so forth within a reasonable volume of data.

The ordering party must keep in mind that a 3D production does not simply depend on tools, but also, and most importantly, on human skills and an efficient methodology in using such tools together with a recognized ethic. The key to success is found in the expertise of the service provider at every step, from the production of the raw data to the final deliverable. In this field, more than anywhere else, the service provider must demonstrate its expertise when answering the call for specifications (skills, references of project already carried out, presentation of results in a book, etc.).

When the ordering party examines the offers of service providers, s/he must already think about the archiving of their final product. This must be compliant with OpenScience and OpenData as stipulated by legislation in France and Europe. It is strongly recommended that the formats of the deliverable are compatible with perennial software solutions and also easily convertible in order to extract and convert data in others formats.

Finally, in order for service providers to be fully aware of their responsibilities, it is essential to get them to sign the call for specification in addition to their own proposal.

3. ACQUISITION OF RAW DATA

3.1. Introduction

This step consists of getting a 3D virtual footprint of a heritage artifact or site, most often by lasergrammetry or photogrammetry campaigns (direct acquisition). It can also go with (indirect acquisition) collected iconographic, textual or oral sources, etc.

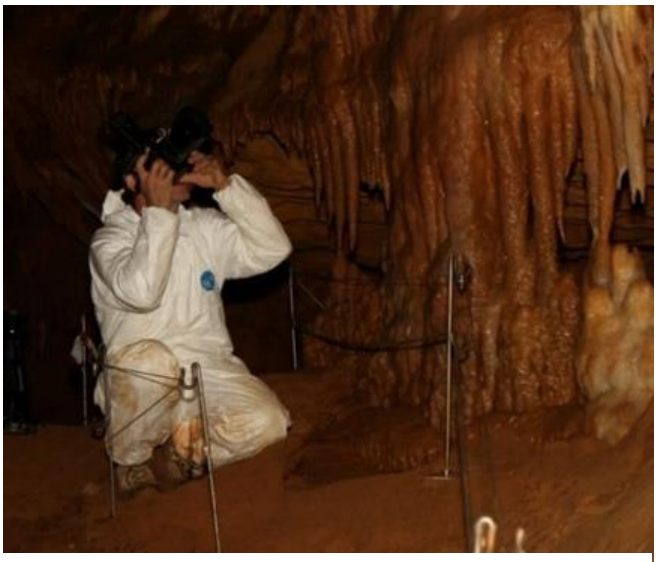

Figure 1: photogrammetry survey of Cussac Cave (France) – Archeovision Prod.

3.2. Deliverable

The raw acquisition files are required for future data processing required by new requirements and by the evolution of tools and software.

Images and videos:

- Photographs in RAW format with all the original metadata (EXIF of images). A copy of these photographs in TIFF, DNG, JPEG or any other format compatible with the long term data preservation (refer to the list of formats recommended by the CINES for data archiving[1]) as long as all the initial metadata (EXIF) is preserved, while adding those documenting the conversion from RAW format to the new format.
- Provide information of the shooting conditions (light sources positioned and calibrated).
- Add calibration chart images, and generally, the calibration process.
- If possible, save videos in RAW format. Promote a free file format (OGV, MP4, MKV, etc.) for perennial videos.

3D data:

- Output data of 3D scanners (e.g. E57, LAS, PTX, etc.) with all device data, its calibration and the location of the station.
- Raw and preprocessed point clouds (at least with cleaning, registration and georeferencing) if they have been obtained by lasergrammetry (ASCII format or other format readable by any text editor in an open data perspective, and in a format compatible with the archiving instructions of the CINES). The survey must therefore be requested in at least two formats, the first for use according to the requirements of the ordering party, and the second for archiving purposes. This version is called: *version V0* of the 3D model.
- The 3D models and manual surveys stating the scale, which will be used for photogrammetry campaigns.
- Topographic surveys, GPS, color calibration chart, scans and photographs (for data archiving purposes).

Unless specified redundancy in requested data should be avoided. For example, it is not necessary to request pictures in PNG and JPEG formats, but it is possible to request them in RAW and DNG formats, because one ensures access to the original data and the other allows long term preservation because it corresponds to a standardized format. It is often more relevant to request a single convertible and perennial format provided that it allows the storage of unprocessed raw data.

Paradata:

- Contextualization of the acquisition phase by photography images or video.
- Calibration data.
- Methodological report (field notes).
- Software versions and type of hardware.

[1] https://facile.cines.fr/

3.3. Condition and context to carry out a direct acquisition

The service provider has a duty to advise the ordering party on technical and legal aspects as follows:

Environmental conditions:

The meteorological conditions during the acquisition by photogrammetry, lasergrammetry, drone and so forth and the influence of brightness, wind, rain, temperature, etc. It may be a good idea to specify the capacity of the service provider to return on site if the conditions are not adequate.

- It may be necessary to inform the service provider of the obligation to prepare and clean the site to facilitate access to the remains (devegetation, absence of vehicles, etc.).

Physico-chemical conditions of the object:

- Non-destructive acquisition conditions for the object: heat, light, hygrometry, keeping it in position on a turntable without contact (calibration chart)
- Respect for the integrity of the heritage object.

Conditions for security and administrative intervention:

- Ensure the safety of the remains and people.
- Authorizations and insurance (management of the people present, UAV flight authorization, etc.).

Working conditions

The signature of the contract is equivalent to receipt of the deliverable (working conditions and inventory of fixtures to be taken) by the service provider.

Figure 2: positioning station of the Faro Focus scanner, positioning the spherical targets and the black and white plane target to ensure the 3D survey, the registration and georeferencing - St Honorat, Lerins Monastery (FRANCE) - S. Sorin/CEPAM

3.4. Particular points of attention that the ordering party and service provider must look at

During a lasergrammetry survey campaign

A sufficient number of stations must be set up to ensure sufficient resolution and avoid areas that are not accessible and therefore not covered.

For future registration

Beforehand, the number of stations required for a complete survey of the studied object must be defined, as well as the methods used for the registration.

The use of spheres (three-dimensional targets) and/or checkerboard targets allows automatic registration based on recognition of geometric entities. A sufficient number of these devices must be placed on the site to ensure three common spheres per pair of scans.

Checkerboard targets captured with a tacheometer along with consolidation will jointly enable the georeferencing of the 3D model in a global coordinate system. The topographic survey of the targets is preferably to be carried out alongside the lasergrammetry survey (also in the case of a photogrammetry survey) considering that the targets are not perennial.

Simultaneous use of spheres and checkerboard targets is recommended.

It is also possible to georeference characteristic points for which the homology between two stations is certain (not recommended apart from building archeology surveys).

During a photogrammetric survey

It is necessary to have reference points evidenced on the site and to survey with a tacheometer. The size of the reference points must be adapted to the desired resolution.

It is possible with these reference points to define the scale and spatial orientation of the 3D model and to spatially reposition all surveys carried out in the same coordinate system. This step is called registration.

The redundancy of points between the topographic points and points from the points cloud generated by photogrammetry enable quality control of the 3D model.

Other points of attention for acquisition campaign

- The accuracy and spatial resolutions required for acquisition and for all processing requirements to be defined according to purpose
- Simple object or complex system of objects
  - Define the extend area to be scanned
  - Object completeness (hole accepted or not)
  - Type of surface and materials (anticipate scanning difficulties).
- In order to justify the fidelity of the rendering:
  - Precision and calibration for colorimetric accuracy (including a document for traceability)
  - Accuracy of resolution at the level of geometric and/or texture rendering (specify the required scale; including a document for traceability).

In the case of an indirect acquisition, the scientific file completion (texts, inscriptions, iconography, archaeological sources) is the responsibility of the ordering party. The service provider must ensure that the scientific file is complete before drawing up the quotation

Scale	Scanning Interval (mm)	Precision (mm)	Max. Object Size (M)
1:10	2	2	5x5
1:20	4	4	10x10
1:50	15	15	20x30
1:100	25	25	40x60

Tableau 1: Example of accuracy for lasergrammetry Source: GIM – Terrestrial Laser Scanning – https://www.gim-international.com/content/article/terrestrial-laser-scanning-2?output=pdf

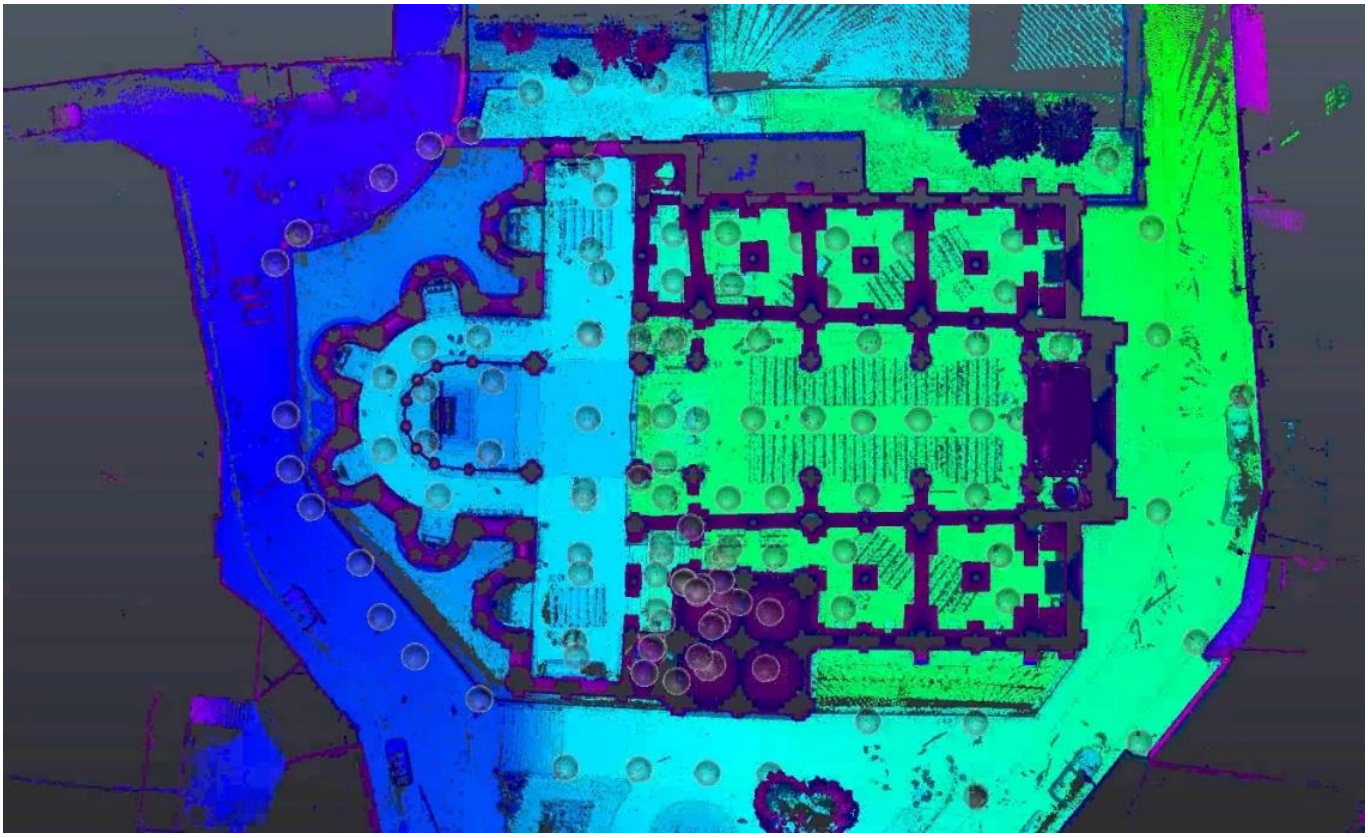

Figure 3: Map view – Lasergrammetry campain with 98 laser stations – Saint Hilaire/Poitier (France) – Archeovision

Figure 4: Perspective view of the Basilica Sainte Eutrope – Points cloud from a photogrammetric survey – Saintes (France) – Archeovision

4. DATA PREPROCESSING

Definition

The aim of this step is to define the skills and prerequisites required by the service provider. It provides information on how the data will be processed to be exploited in later steps of analysis and modeling phases.

Typical steps for preprocessing 3D data

The steps below are given for informational purposes only and the order and choice of these steps are to be selected according to the subject of study and the desired aim. Indeed, the choice of algorithms may influence the accuracy, the resolution and thus the final result. As a reminder, all the terms used are defined in the manual "3D vocabulary: a lexicon for the Human and Social Sciences".

- Registration for the scan alignment and for their possible merging; automatic or manual mode
- Cleaning outliers
- Point cloud noise removal
- Coloring and/ or mesh texturing of the points.
- Point cloud meshing
- Point cloud hole filling
- Decimation.

Deliverable

It is strongly advised to ask for a deliverable on the treatment methodology followed in order to be able to trace and validate the process. In addition, it should be drawn up prior to this co-construction process with the service provider to ensure that the provider has the required skills.

Recommendations

In the event that modifications are made to the model (hole filling, decimation, etc.), the service provider needs to provide all the intermediate models in order to trace the modifications and possibly be able to judge the loss/gain of information at each step. For example, hole filling or decimation may prove to be contraindicated in the case of archaeological remains or objects for which traces of wear and tear and tool marks contribute to research hypotheses.

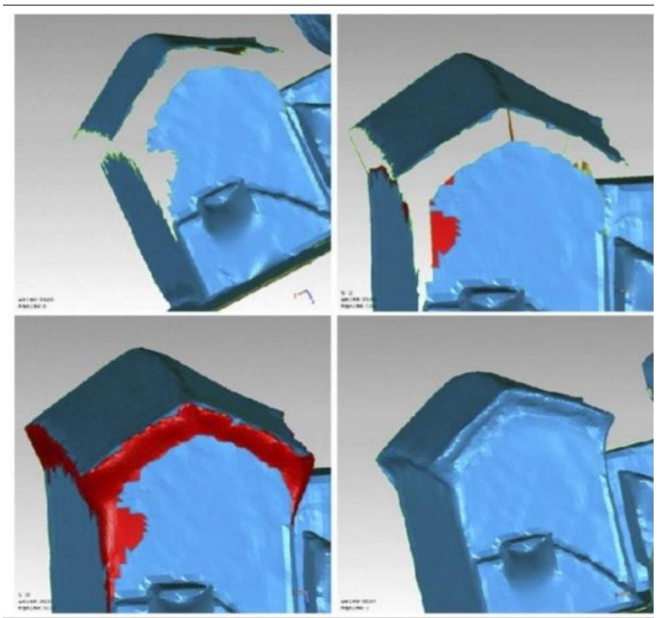

Figure 5: Point cloud hole filling- Nantes project F.Laroche/Epotec LS2N

Figure 6: 3D models of the Forum of Augustus and texturing – Map of Rome – Cireve, University of Caen

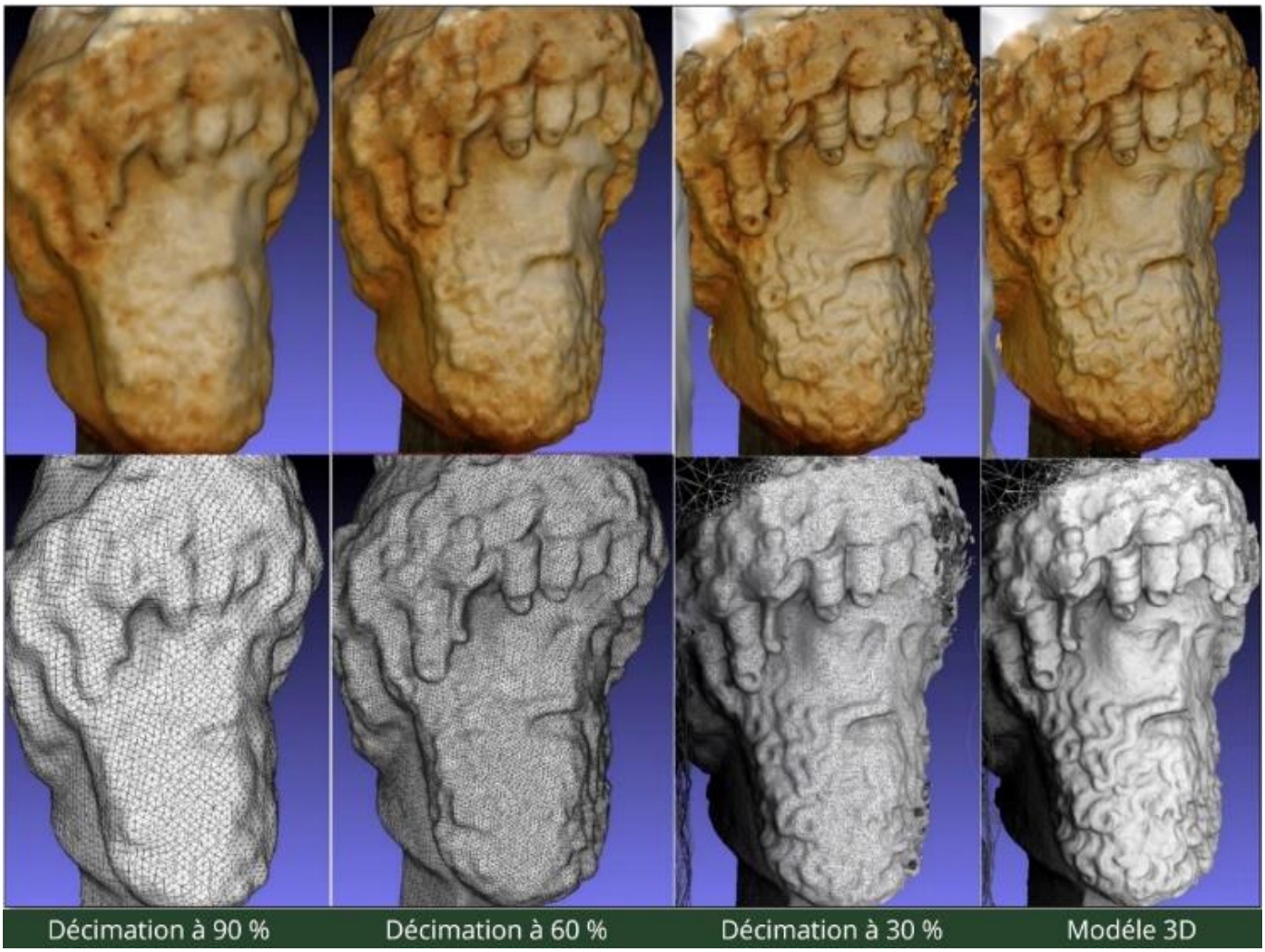

Figure 7: Various level of decimation (Jupiter 's head) – Tipasa museum (Algeria) – Archeovision

5. DATA PRODUCTION BY ACQUISITION / 3D SURVEY PRODUCTION WITHOUT INTERPRETATION

5.1. Definition

This step will produce technical data that can be used by the ordering party. This is based on facts and findings from the surveys. An interpretation is given in the next section (Section 6).

5.2 Deliverables

- Orthoimages (graphic scale and spatial resolution of the images (GSD[2]), georeferencing with clearly identified geographical coordinate system [Lambert 93, WGS 84, etc.], topographic surveys provided with layout , measurement uncertainty - quantified residuals).
- Elevations, longitudinal and transverse sections, general and detailed plans with indications of the graphical scale, orientation and legend for building studies (vectorial format, AI, DWG or raster as needed). It also needs to be compatible with the recommendations for archiving at the CINES. Two formats at least can be requested.
- Measurement report (spreadsheet table, etc.).
- 3D Model with a format compatible with the import/exports of the ordering party's software and potentially with the archiving recommendations of the CINES.
- Data can be provided with perennial software allowing the visualization, manipulation, measurements, 2D cut, and possible export plans (interoperability).

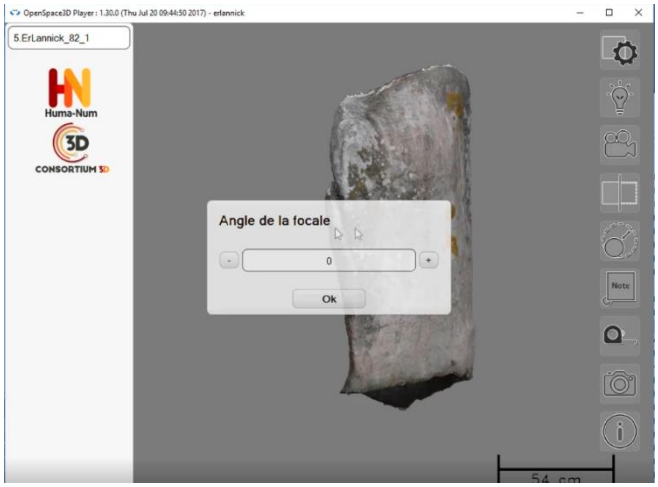

Figure 8: 3D visualizations of a Cromlech on Île Er Lannic (France) using open source software developed by the consortium 3D – V. Grimaud/LARA

[2] GSD for Ground Sampling Distance - see the «Software and Hardware book from the recommendation of the consortium

Figure 9: Orthoimage developed from the 'chevet' of the Chapelle de la Trinité – Iles Saint-Honorat, Cannes (France) – S. Sorin/CEPAM

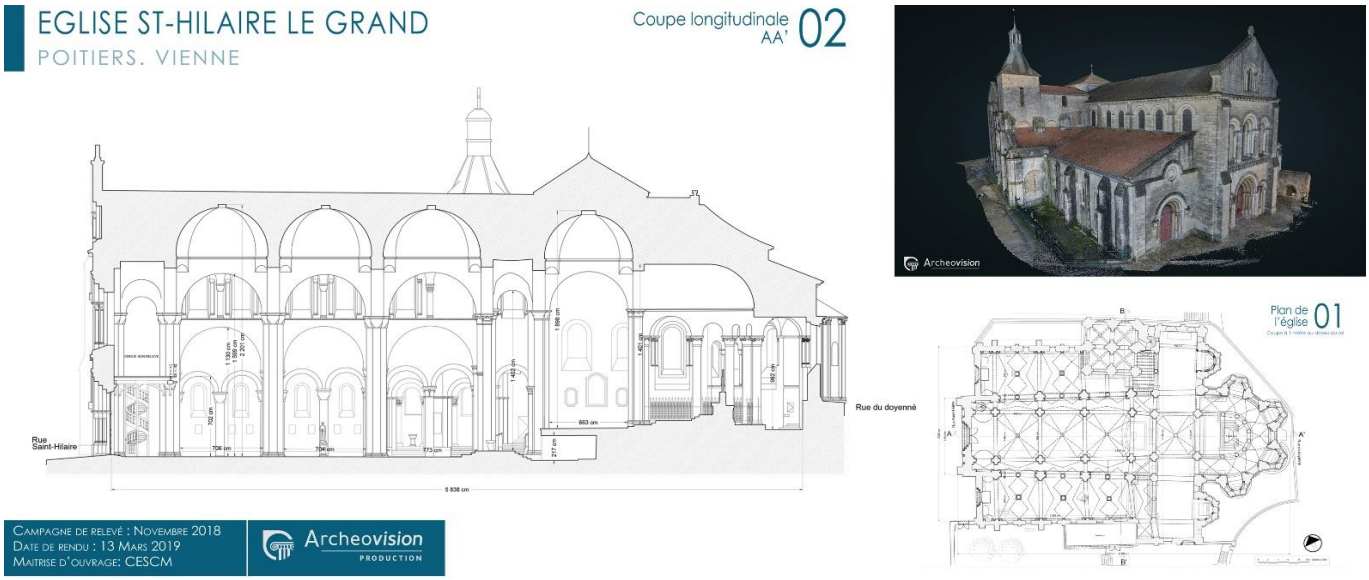

Figure 10: Longitudinal section extracted from a 3D mesh – The church "Saint Hilaire le Grand" church , Poitiers (France) – Archeovision Prod

6. RESTITUTION – 3D MODELING – VIRTUAL RECONSTRUCTION HYPOTHESIS

Definition

The aim of this step is to enable the interpretation of the digital data acquired in the previous steps or to create a 3D restitution of an environment or an object from a pre-established scientific file (ground plans, elevation plans, archaeological sources, textual sources, iconographic sources, etc.). These are *versions V1n to V2* of the 3D model. For these purposes, it is possible to validate restitution hypotheses by creating partial or complete virtual environments in order to, for example:

- compute digital simulations for research and for validation of scientific hypotheses
- valorize and disseminate works in museology or pedagogy.

It is essential for an interdisciplinary team to be set up to assist the ordering party. Experts in heritage, the analysis of ancient sources, 3D and virtual/augmented/mixed reality should participate in the restitution in order to ensure objectivity about the hypotheses according to their respective fields of expertise.

In the case of the restitution of a lost environment or artifact, a lead scientist who is recognized in the corresponding field (for example an academic or a researcher specializing in the corresponding period) will have to validate the choices of the scientific committee and ensure of the conformity of the 3D model at each step according to the specifications provided by the scientific committee.

Deliverable

- Images
- Movie / Video
- Photos or 360° panoramas
- Immersive and interactive navigation with Virtual Reality
- Augmented reality application/model
- Website

Figure 11: Visit of ancient Rome by night in an interactive software – Map of Rome / University of Caen Normandy, CIREVE

In addition to the final deliverable, the ordering party is strongly advised to request and store the working data in order to enable the virtual restitution provided to be enriched or changed later.

- Mesh in ASCII format in order to be able to complete the model later.
- Sources of the application defining the digital model of the scene: the complete project must be provided (example: 3DS files, Unity, textures, kinematic models, etc.) on the condition that the exploitation rights have been assigned.
- In addition, a written report is strongly required to define the delivered 3D model. The evolution choices between the different versions have to be justified. The virtual model only makes sense for a given historical date/period and this date/period must be decided before the restitution.
- In the case of the creation of a 3D model corresponding to a lost or heavily damaged environment or artifact, in addition to the deliverable related to the 3D model the service provider will give a complete report on the scientific file used for creating the 3D model. All the discussions of the scientific committee and the final choices made by the lead scientist must be clearly shown and justified. The discussions during the creation of the 3D model constitute data to be archived in the same way as the deliverable.

The data concerning the final version V2 must also be provided in a format compatible with the archiving recommendations of the CINES.

Supports of deliverable:

- Examples of media: CD, USB keys, external hard disk, *cloud storage* (preferably institutional: Huma-Num), etc.
- If the service provider proposes to make the data available via a proprietary system on the Internet, the ordering party must ask that this solution is not only-dependent on the service provider. This is because data would be lost if the service provider is no longer able to monitor the platform.
- In addition, any 3D model developed with public funding must be subject to a transfer of rights assignment and a deposit at the CINES.

Recommendations

Obligations for stakeholders:

- Establish a bibliography to justify the hypotheses and to follow the traceability of the studies.
- Provide a list of experts defining, among other things, the scientific support that will ensure the final validation (list co-constructed by the stakeholders).
- Establish a monitoring schedule.
- Define the person who will be in charge of the day-to-day scientific monitoring and who can be called upon on a daily basis by the 3D team during production.
- Define the periodicity of the scientific validations during the steps of creation of the restitution.

Points of attention for the virtual model for restitution:

- Specify the date of restitution production (the model is the result of a given state-of-the-art of the research) and the historical period modeled (time T of the history of the concerned object or site).
- Choice of graphical restitution: level of detail (simple volumes, scenery, statuary, tool marks, textures, etc.), environment (topography, vegetation, lighting, etc.), dynamic aspects (kinematics, etc.).

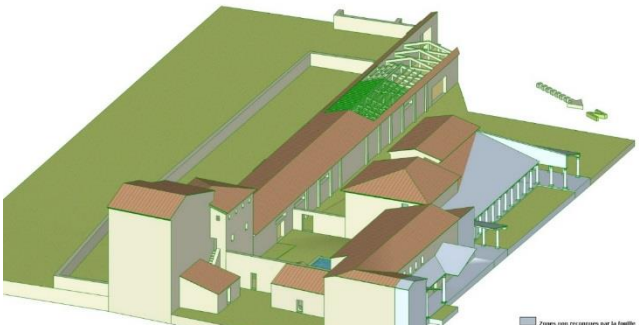

Figure 12: Restitution of the villa of La Garanne (Bouches-du-Rhône, France) – Study of the definition of volumes, without added textures – V. Mathieu / CNRS, ASM UMR 5140

Figure 13: an virtual character serving wine in a Roman domus – Map of Rome – University of Caen Normandy, CIREVE

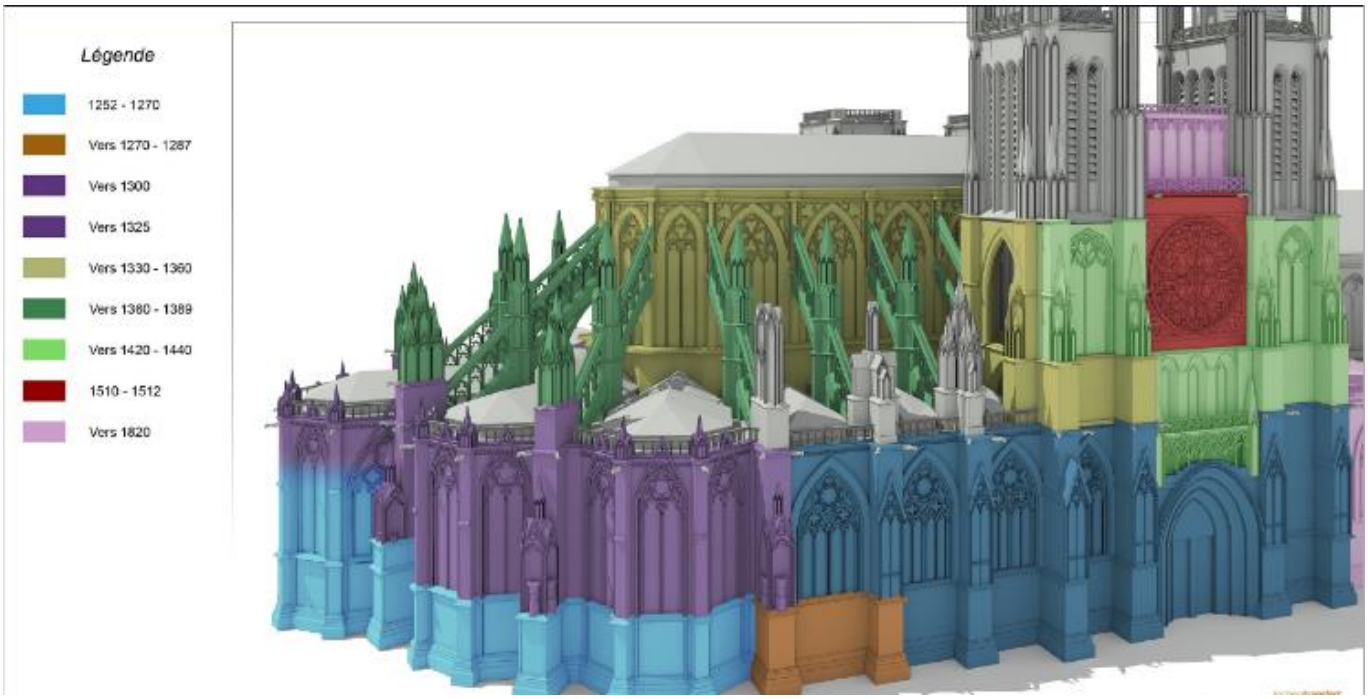

Figure 14: Construction phase of the Cathedral St André, Bordeaux (France) – Archeovision Prod

7. PROTOTYPING / PHYSICAL MOCK-UP

Definition

The prototyping of the object on a 1:1 scale or on a reduced scale is carried out by professionals in the field concerned (model maker, carpenter, etc.). It will allow the validation of hypotheses that the virtual model can hardly account for (weight of materials, etc.).

This final step is made possible thanks to current technological developments, in particular 3D printing.

Examples:

- Direct cutting on solid materials (stone, metal, moss, etc.).
- 3D printing.
- Validation or physical simulation of operating modes
- Condition state for restoration
- Printing of base elements.

Figure 15: Virtual reconstruction and 3D printing of Nero's dining room, Rome (Italy) – F. Laroche / LS2N

Recommendations

- Define the accuracy and the materials used to make the physical object (example: ABS or PLA for 3D printing, machined to the required dimensions, choice of wood species, etc.).
- Define the patina which must be in accordance with the original color (identification of the pigments and finishes used).
- Conduct interviews with or obtain testimonials from craftsmen / manufacturers to document the prototyping of the object.

Figure 16: Copy of the Naxian Sphinx from the Museum of Castings in Lyon – Archeovision Production & SNBR, 2005

8. GENERAL RECOMMENDATIONS

Project monitoring

All the best practices defined above for the study of heritage sites or artifact must be part of scientific projects. The use of 3D virtual objects or 3D scenes is a way of validating hypotheses.

It is necessary to define:

- A provisional timetable, which will be discussed and finalized with the service provider, in particular by setting the delivery date.
- Some reverse scheduling steps as the project the progress (to control possible delays and setbacks).

Duty of the service provider:

- The provider has to advise the ordering party on requirements (verification of the appropriateness of the requirements with the purpose of the scientific study and the condition of the object of study).

Duty of the ordering party:

- It is strongly recommended that the ordering party relies on a scientific team to carry out the mission that will provide assistance to the project manager. Indeed, a scientist, a team or a research laboratory will be able to help both the ordering party and the service provider in their choices and decisions. This team will assist with the specifications in order to choose the most suitable solution independently of the future service provider. It will also provide assistance in the translation of the digital data which sometimes is described in an abstruse language for the ordering party. Thus, as the scientific support team is not linked to economic profitability concerns, it will guarantee real ethics of use of the 3D digital documentation tools thanks to its expertise.
- The ordering party specifies in the contract clauses that, since the service provider agrees to carry out the mission, s/he fulfills the conditions of execution of the contract considering the state of the site, deadlines, weather conditions and so forth.
- The ordering party should give the service provider access to all documents required for the mission.
- The ordering party defines the confidentiality obligations of the project and for data protection.
- The ordering party checks the authorizations and insurance of the service provider: management of the presence of people in public spaces, required authorizations for the UAV flight (pilot certificate, flight authorization over the site, condition of move in a civil- or defense-controlled space, ground security perimeter, etc.).

Digitized object / 3D digital model

- The expected end-product must be clearly defined and the associated process well known. If necessary, expertise or advice may be asked.
- Particular attention should be paid to the format of the deliverable
    - Request non-proprietary formats: OBJ, RTF, DAE (XML), etc.
    - For a public ordering party, ensure the compatibility of methodologies with the archiving platform of the CINES and / or with standard interoperable formats.
    - Verify the adequacy between the requested model (deliverable) and the possibilities of use by the ordering party.
    - Define the rights of use, reproduction, and modification of 3D content by contract or agreement.

Please note:

Restitution is the result of scientific research and a creation process that may have taken a long time, whereas 3D acquisition is the result of technical know-how. Providing and transferring a 3D scene for restitution therefore requires more attention to be paid.

At each step of the process, the service provider has to be able to provide an intermediate version (V1n). During the intermediate validations and in particular at the final delivery (V2), a waiting period must be planned to allow the ordering party to evaluate the provided model according on past services, for the purpose to request possible

additional work before any closure / payment of the contract.

To ensure traceability, it is essential to name the people who have participated to the project and, to specify the versions of the software and the type of hardware that have been used.

9. BIBLIOGRAPHY

X. Granier, Violette Abergel, Pascal Benistant, Laurent Bergerot, et al.. Les recommandations du Consortium 3D SHS. [Rapport Technique] CNRS; SHS. 2019, 204 p. ⟨hal-01683842v4⟩

F. Laroche, M. Servières, D. Lefevre, J.-L. Kerouanton. Where Virtual Enhances Physical Mock-Up: A Way to Understand our Heritage. ISMAR - research, technology and application in Mixed and Augmented Reality, Oct 2011, Basel, Switzerland. 6 pp. ⟨ hal-00671976⟩

Historic England "3D Laser Scanning for Heritage: Advice and Guidance on the Use of Laser Scanning in Archaeology and Architecture". Swindon. Historic England, 2018

Historic England "Photogrammetric Applications for Cultural Heritage. Guidance for Good Practice" Swindon. Historic England.2017

Andrews, D, Bedford, J and Bryan, P 2015 Metric Survey Specifications for Cultural Heritage, 3rd edn. Swindon:

Historic England.

Calarco, A, Dam, A and Stewart Walker, A 2004 'Geometric precision of scanned imagery for production

photogrammetry'. ISPRS Archives XXXV (B1), 59–62 Heritage, G and Large, A (eds) 2009 Laser Scanning for the Environmental Sciences. Chichester: Wiley-Blackwell.

Luhmann, T, Robson, S, Kyle, S and Harley, I 2006 Close Range Photogrammetry: Principles, Methods and

Applications. Caithness: Whittles Publishing

Schuhmacher, S. and Böhm, J. (2005): Georeferencing of terrestrial laserscanner data for applications in architectural modeling. to appear in 3D Arch, Venice Italy

Wang, X., Totaro, S., Taillandier, F., Hanson, A. and Teller, S. (2002): Recovering facade texture and

microstructure from real world images. In: Proc. 2nd International Workshop on Texture Analysis and Synthesis,

pp. 145–149.

Chiabrando, F. et al. "SfM for Orthophoto to Generation: A Winning Approach for Cultural Heritage Knowledge."

ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences (2015): 91-98.

Krajníková, Katarína et al. "Different Approaches in Building Digitization Through the Use of 3D Laser Scanning." (2020).

Pulcrano, M. et al. "3D CAMERAS ACQUISITIONS FOR THE DOCUMENTATION OF CULTURAL HERITAGE." ISPRS – International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences (2019): 639-646.

Kersten, T. et al. "Virtual Reality for Cultural Heritage Monuments - from 3D Data Recording to Immersive Visualisation." EuroMed (2018).

Jo, Y. H. and Seonghyuk Hong. "Three-Dimensional Digital Documentation of Cultural Heritage Site Based on the Convergence of Terrestrial Laser Scanning and Unmanned Aerial Vehicle Photogrammetry." ISPRS Int. J. Geo Inf. 8 (2019): 53.

Fabio Remondino, David Lo Buglio, Nicolas Nony, Livio De Luca. Detailed primitive-based 3d modeling of architectural elements. Proceedings of The XXII Congress of the International Society for Photogrammetry and Remote Sensing. Melbourne, Australia, 25 august - 1 september 2012.

Benjamin Hervy, Florent Laroche, Jean-Louis Kerouanton, Alain Bernard, Christophe Courtin, et al.. Museum augmented interface for historical scale models: towards a new way for cultural heritage promotion. International Journal of Virtual Reality, IPI Press, 2015, 15 (1), pp.3-9. ⟨hal-01236995⟩

Zhou, Y. et al. "Detail Preserved Surface Reconstruction from Point Cloud." Sensors (Basel, Switzerland) 19 (2019): n. pag.

Skarlatos, Dimitrios et al. "DIRECT ORTHOPHOTO GENERATION FROM COLOR POINT CLOUDS OF COMPLEX SCENES." ISPRS - International Archives of the Photogrammetry, Remote Sensing and Spatial Information Sciences (2013): 367-371.

Agosto, Eros and L. Bornaz. "3D Models in Cultural Heritage: Approaches for Their Creation and Use." (2017).