3D Digitisation of Icons of European Architectural and Archaeological Heritage

3D ICONS

D4.1: Interim Report on Post-processing

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3D ICONS is funded by the European Commission's ICT Policy Support Programme

cip competitiveness and innovation framework programme

Revision History

Rev.	Date	Author	Org.	Description
0.1	08/09/13	L. De Luca	CNRS	Draft
0,2	10/1013	L. De Luca	CNRS	Draft
0.3	14/10/13	L. De Luca	CNRS	Version after first review
0,4	22/10/13	S. Bassett	MDR	Review and editing
0.5	23/10/13	S. Bassett	MDR	Addition of QC Form

Revision: [Final]

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Statement of originality:

This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both.

3D-ICONS is a project funded under the European Commission's ICT Policy Support Programme, project no. 297194.

Contents

Executive Summary

Deliverable 4.1 (Interim report on post-processing) is a first overview of all the aspects concerning the post-processing of the 3D digitisation that will be supplied to Europeana as viewable 3D models by content providers. The report concerns the progress of the post-processing work, the problems encountered and the actions undertaken. Starting from an analysis of the work in progress carried out by the content providers, an internal discussion concerning the main technical issues is used as starting point for the identification of a set of common approaches (elementary processing steps) aiming to harmonize the elaboration and the refinement of 3D models.

There are seven partners who have started the post-processing of their data sets (CNRS-MAP, POLIMI, UJA-CAAI, CMC, ARCHEOTRANSFERT, CETI and DISC) and it is mainly their experiences that are reflected in this report.

There is a strong overlap of the activities in WP3 and WP4 (as shown below) with complex relationships between digitisation and post-processing. Consequently, there has been in-depth discussion about the methodological approaches and the structure of the pipelines.

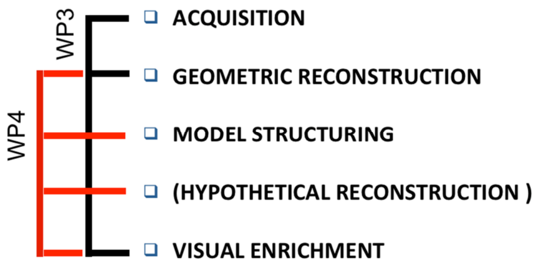


Figure 1. Overlapping of activities between WP3 and WP4

Five general post-processing aspects are identified: geometric reconstruction, visual enrichment, model structuring, hypothetical reconstruction and complementary 3D media (derived from the 3D model). Examples of approaches, issues raised and solutions encountered by partners are provided in the context of the identified post-processing activities. Some case studies are also presented which illustrate the different approaches.

The report concludes with a discussion about the link between the post-processing activities and the metadata creation, as well as the link between post-processing and publication. Finally, an updated version of this report (D4.3 Final Report on Post-Processing) will be published in M36 which will cover all the partner experiences, lessons learned and provide a complete and global overview of the post-processing part of the 3D-ICONS pipeline.

D4.1 Interim report on post-processing

1. Introduction

The 3D-ICONS project will provide to Europeana an important collection of reality-based 3D models (detailed and accurate geometric representations) for the purpose of cultural dissemination. In addition, the 3D models and their metadata will provide further uses such as documentation, digital inventories, etc. This report concerns the activities carried out within the framework of the task 4.1:

- The refinement of the 3D digitization produced in WP3 (Digitization), including geometric reconstruction, visual enrichment and model structuring;
- The making of all necessary graphical and content refinement improvements of the model and the other data provided;
- The creation of some complementary 2D media (derived from the 3D model) such as video tours, panoramic images, etc. for enriching the documentation of the monument and its details.

Activities concerning WP 4 started at month 12 of the project. This interim report (month 21) begins with a snapshot of the progress of the post-processing activities (see section 2), directly extracted from the monitoring tool developed within the framework of the project. Section 3 introduces an internal discussion about technical issues encountered, while section 4 presents the results of the classification of a set of elementary post-processing steps aiming to make emerge a common basis for the definition of post-processing methodologies. The issues about the relationship between post-processing activities and metadata creation and between model optimization and final publication are discussed respectively in section 5 and 6.

2. Progress on post-processing activities

2.1 Current Work in Progress

At this moment in time (October 2013), **444** models have been post-processed (**WP4**) starting from the **2,941** 3D digitations (WP3) identified and in progress by the project partners. One can consider these figures fairly normal, because the post-processing activities concern the complex phase of the elaboration of final 3D representations starting from the gathered data. In fact, according to the morphological complexity of the artifact, different geometric reconstruction and visual enrichment techniques are often integrated. In the case of complex architectural buildings, even if the digitization phase is often carried out in an automatic way (e.g. 3D laser scanning) an important activity of interactive modeling and structuring (which is very time consuming) is required. The following table shows the number of 3D models for which each partner has already achieved the post-processing (3D reconstruction, visual enrichment and model structuring).

	No. of 3D Models	WP3 Completion of Digitisation	WP4 Completion of Modeling
ARCHEOTRANSFERT	151	65	6
CETI	36	4	3
CISA	90	0	0
CMC	21	12	0*
CNR-ISTI	176	76	0
CNR-ITABC	153	134	0
CYI-STARC	83	2	0
DISC	109	65	27
FBK	57	11	0
KMKG	450	0	0
CNRS-MAP	323	283	261
MNIR	95	15	0
POLIMI	527	154	98
UJA-CAAI	619	150	49
VisDim	50	50	0
Total	**2941**	**1009**	**444**

* in progress

There are seven partners who have started the post-processing of their data sets (CNRS-MAP, POLIMI, UJA-CAAI, CMC, ARCHEOTRANSFERT, CETI and DISC) and it is mainly their experiences that are reflected in this report.

3. Problems encountered and actions undertaken

Internal discussion has focused on finding a good way for articulating the post-processing activities within the entire pipeline. This revealed an important overlap between the two work packages concerning the digitization implementation: WP3 (data acquisition) and WP4 (post-processing). In the Figure 1, representing the main steps of a typical 3D digitization process, several processing activities can be considered to be part of the data acquisition (WP3) as well as part of the post-processing (WP4).

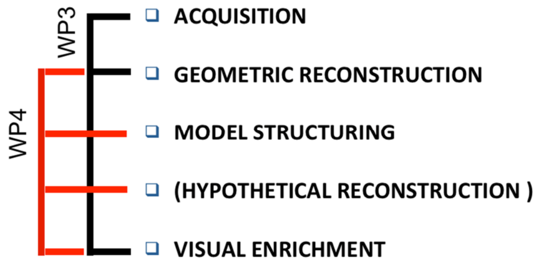


Figure 1. Overlapping of activities between WP3 and WP4

In some cases, the 3D digitization solutions (integrating hardware and software) merge the data acquisition (WP3), the geometric reconstruction (WP3/4) and the visual enrichment (WP4) into a unique automatic process; in other cases, the data acquisition (WP3) is strongly independent from the 3D modeling and structuring strategy (WP3/WP4), and so on.

For example, the post-processing is affected by factors hindering 3D data collection such as:

- Transparency
- Reflectance
- Poor light conditions
- Accessibility of the object and its position
- Geometric complexity of the object.

Software tools such as MeshLab, Blender, Geomagic and 3D Studio are used for Post-processing functions such as:

- Filling holes and gaps

- Correction of corrupted or duplicated sides and vertices
- Refinement and cleaning anomalies caused by defects of light conditions
- Texturing.

All these ambiguities make it difficult to really segment some of the more complex pipelines into well-identified processing steps. In fact, the overall pipeline generally depends on the main purpose of the 3D digitization, the specific strategy to produce the general model, as well as the final visual and geometric result to be achieved.

In addition, some content providers in the project have significant experience with 3D digitization and representation of heritage artifacts, sometime coupled with an in-depth knowledge of tools, methods and approaches, which constitute the results of their scientific activity. Furthermore, beyond the use of common and commercial solutions for handling 3D representations in various formats, within the context of this project, and in order to obtain excellent results in terms of geometric and visual accuracy, some project partners are experimenting with the integration of several tools and emerging technologies into more complex 3D reconstruction approaches.

Due to the WP3/4 overlap problem as well as to the high heterogeneity of the developed approaches (sometime resulting from a strong integration of technical and methodological aspects), we carried out the definition of a common basis to be used for classifying our different operating modes, as well the data structures and the file formats used for handling geometrical and visual content (see next section). This classification has a twofold objective: on one hand the aim of harmonizing the production of 3D models within the framework of the project (as well as the description of the processing steps during the metadata creation phase); on the other hand, the need to identify common refinement pipelines according to the final publication formats.

4. Internal discussion about methodological approaches

From a purely technological standpoint, during the generation of the 3D representation of an artifact, the geometrical precision, the detailed representation of visual aspects and the 3D real-time visualization are fundamental aspects. But beyond the simple application of a technical process, whether simple or integrated, the methodological dimensions plays an important role in identifying the objectives of 3D representation that can be achieved starting from a 3D digitization. Indeed, in several cases, the type of representation desired for the communication purpose (or required for the analysis needs) determines the data processing and post-processing strategy. In fact, the elaboration of 3D models of complex heritage buildings in their current state, as well as the reconstruction of their hypothetical past states, requires the definition of specific pipelines integrating surveying tools, geometric modeling techniques and (in some cases) an overall model structuring strategy.

Four main approaches are representative of the diffuse practices among the 3D-ICONS partners working on the digital documentation and visualization of heritage artifacts. Firstly, some approaches are inclined to **represent the geometric accuracy of 3D models**: these are mainly based on methods of automatic meshing starting from a 3D laser scanning acquisition. Secondly, other approaches are based on **morphological descriptions** that are specific to particular kinds of analysis (e.g. temporal transformations, architectural composition, etc.): they are characterized by data acquisition and data processing strategies consistent with specific representation goals. Thirdly, other techniques focus on **reproducing the visual appearance** of the surfaces forming the object, by taking into account photographic information. Finally, other approaches concentrate on the **simultaneous representation of multiple factors at multiple scales**: for this goal, they use different technical procedures in a complementary way.

In order to define a set of common elements of an overall methodology (taking into account the heterogeneity of the 3D reconstruction approaches used by the project content providers), we firstly analyzed several 3D reconstruction projects carried by content provides in order to produce a classification of the main procedures. This first analysis, carried out by studying and comparing a range of technical solutions, allowed the structure of a set of typical 3D reconstruction pipelines (from the 3D surveying on-site to the final 3D model used for various application contexts) to be identified.

In the following section, post-processing issues and solutions provided by partners are used as examples for each of the post-processing steps where applicable.

4.1 Classification of elementary "processing steps"

With the aim of identifying a set of elementary "processing steps" which can be combined in several ways in order to compose 3D reconstruction pipelines, this analysis takes into account the:

- Deployed digitization tools (3D scanners, digital cameras, etc.);
- Employed acquisition, geometric modeling and visual enrichment techniques;
- Source and final data formats.

Five general post-processing aspects (detailed in the following sections) have been identified: geometric reconstruction, visual enrichment, model structuring, hypothetical reconstruction and complementary 3D media (derived from the 3D model). This work is mainly based on the experiences of CNRS-MAP, CMC and UJA-CAAI as well as on several inputs coming from the WP2 (CNR-ISTI) and WP3 (POLIMI, FBK) leaders.

4.1.1 Geometric reconstruction

The geometric reconstruction is the essential processing step for the elaboration of a 3D representation of an artifact (starting from the results of a digitization campaign). The choice of the relevant technique (see Figure 2) for this step is generally based on the evaluation of the morphological complexity of the object, its scale, as well as the purpose of the final 3D representation (e.g. graphic documentation, metric analysis, dissemination, etc.).

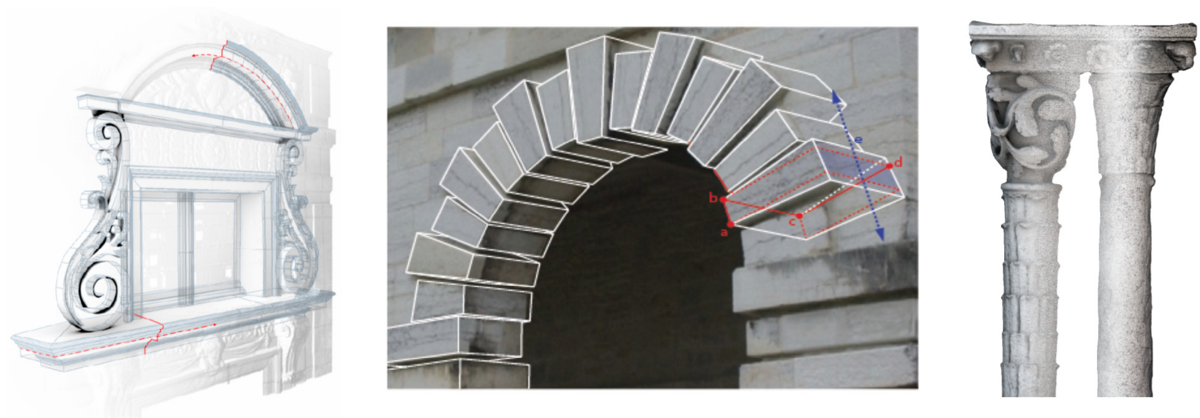


Figure 2. Examples of geometric reconstruction techniques (CNRS-MAP)

A simple criterion for choosing (and evaluating) a relevant 3D reconstruction technique is the degree of consistency of the 3D model with the real object. The list of techniques below is ordered from those which ensure high geometric consistency with the real object to the techniques that introduce increasing levels of approximations :

- Automatic meshing from a dense 3D point cloud;
- Interactive or semi-automatic reconstruction based on relevant profiles;
- Interactive or semi-automatic reconstruction based on primitives adjustment;
- Interactive reconstruction based on technical iconography (plans, cross-sections and elevations);
- Interactive reconstruction based on artistic iconography (sketches, paintings, etc.)

Regarding the archiving of the obtained 3D representations the following formats are generally used:

- **.ply** _ Polygon File Format - Stanford University – ASCII;
- **.obj** _ Wavefront Technologies – ASCII;
- **.dae** _ Collada (Khronos Group) – ASCII;
- **.3ds** _ Autodesk 3Ds Max; (proprietary).
- **.ma** _ Autodesk Maya - ASCII ;
- **.blend** _ Blender (proprietary).

CMC have used Quantum GIS, Gimp & Blender to process Ordnance survey digital height maps of Skara Brae and its environs which were included in a set of GIS data provided by Historic Scotland. Using Quantum GIS, these point clouds were rendered as a greyscale image with the terrain height displayed as a grey value, black being sea level and white being the highest terrain feature (in this case as the highest point was a hill top 95 meters above sea level, white was set to represent 100 meters). The greyscale images was exported as a 300dpi tiff file.

The tiff was then imported to Blender and applied to a UV mapped plane. The plane was subdivided to very dense mesh and the image applied as a Displacement map, the distortion was scaled with reference to the x and y dimension of the plane to produce a 3d model of the landscape. The model was then used to form the basis for a series of investigations for rising sea levels and the creation of interpretations of the sites possible appearance when in use. This process is reported to have very well.

However, the Leica scan data of Skara Brae was very dense, approximately 200 scans each ranging from 5 million to 30 million points each. To reduce the overhead to a manageable level, it was decided to take each individual 'house' and process these as separate entities. The files were first exported as E57 files which recorded the clouds global position and intensity values. These were opened in CloudCompare where the intensity was converted to an RGB value and the point density reduced by a spatial subsampling to approx. 5 million points. These were exported as a PLY file to retain RGB colour values. The PLY file was then opened in pointstream to manually remove noise before being exported to Geomagic from wrapping. This part was facilitated by the Discovery Programme team. The next stage is to use the wrapped mesh to create retopologised low poly models of each house. The issues raised by this process is the storage of the scan data as a proprietary Leica format limits access to those with costly specialised software and that converting such dense clouds and subsequent mesh geometry to an easily accessible format is a long process requiring several complex steps.

4.1.2 Visual enrichment

With regard to the visual enhancement of the geometric 3D reconstructions, several computer graphics techniques were systematically examined in order to assess their degree of relevance in the specific context of the digitization of heritage artifacts. As this project aims to provide detailed and geometrically accurate 3D digitizations of heritage artifacts, our analysis primarily focuses on techniques which provide the simulation of visual characteristics in geometric consistency with the real object (see Figure 3). Other techniques, mainly used for cultural disseminations purposes, are taken into account.

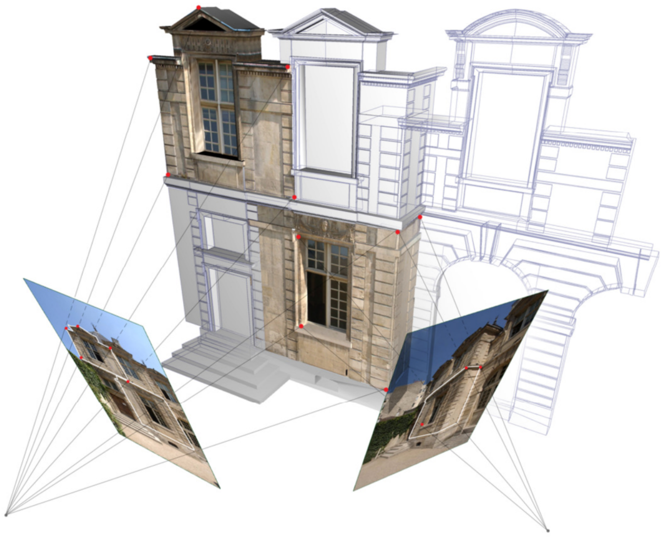


Figure 3. Example of visual enrichment based on the projection of textures starting from photographs finely oriented on the 3D model (CNRS-MAP)

The list of visual enrichment techniques below are ordered from those that ensure a strong geometric consistency with the real object to the techniques that introduce increasing approximations:

- Texture extraction and projection starting from photographs finely oriented on the 3D model (e.g. image-based modeling, photogrammetry);
- Texturing by photographic samples of the real materials of the artifact;
- Texturing by generic shaders.

Concerning the archiving of the results of the visual enrichment processes (textures, shaders, colors, etc.), it's very difficult to identify some general approaches because, in most cases, these aspects are directly related to the 3D modeling and rendering software used, and often directly embedded (in proprietary format) into the general 3D scene. Nevertheless, the technical solutions presented below are currently used for preservation purposes:

- Storing textures at different levels of resolution;
- Storing the source images used to generate textures;
- Using standard formats for image-based textures (.jpg, .png, .tif, .tga, .bmp, etc.);
- Using standard ColladaFX shaders.

UJA-CAAI compared two software packages for generating models from photography as follows:

- Free Software: Autodesk 123D Catch
- Commercial software Agisoft PhotoScan Professional Edition

After experimenting with both programmes, CAAI concluded that Autodesk 123D Catch gives the best results when making 3D models of sculptures and small objects (I.e. 'details'). Considering all the software available for Photogrammetry, Autodesk 123D Catch is especially useful due to its capacity to recognize areas of shade and irregular contours. However, Agisoft PhotoScan Professional Edition is considered to be the best tool for 3D models of architectural and archaeological excavations, particularly for its correction placing of each of the shots generated by the model.

CMC also used Agisoft Photoscan in combination with Blender, and Photoshop/Gimp. Artefacts were placed on an even background and uniformly lit to minimise highlights and shadows. The subject was photographed in several radial patterns, each image at approx. 15 degree intervals. 3-6 such rotations were recoded. The images were all colour balanced using the Auto levels function in Photoshop/ Gimp.

The images were imported into Photoscan and the backgrounds masked. An initial alignment and low density mesh was generated first to asses coverage, then a higher quality mesh produced with high resolution texture maps (4096*4096).

The triangular mesh was imported in to Blender for retopology to a UV mapped light weight mesh, suitable for export as a DAE, FBX or OBJ model.

CMC noted the following concerns: the Photoscan software can be challenged with simple objects when insufficient areas of unique reference points fail to generate registration. Positioning of highlights or shadows can often confuse the registration algorithms. This issue was resolved by moving around the object, keeping a constant relation between the objects and light sources even though this resulted in shadows and highlight being 'baked' on to the texture map (but which can be rectified by further processing).

Mesh retopology can be a time consuming process, however, it produces better quality light weight topology than automatic decimation. It also facilitated the creation of human recognizable texture maps.

4.1.3 Model structuring

Depending on the scale and on the morphological complexity, a geometric 3D reconstruction of an architectural object or an archaeological site generally leads to the representation of a single (and complex) geometric mesh or a collection of geometric entities organized according to several criteria. The model structuring strategy (see Figure 4) is generally carried out with the aim of harmonizing the hierarchical relations, which can express the architectural composition of a building (e.g. relations between entities and layouts) and can also be used as a guideline for structuring the related metadata. In some cases, it could be important to identify a scientific advisor ensuring the consistency of the chosen segmentation (e.g. temporal layers) and nomenclature (e.g. specialized vocabulary).

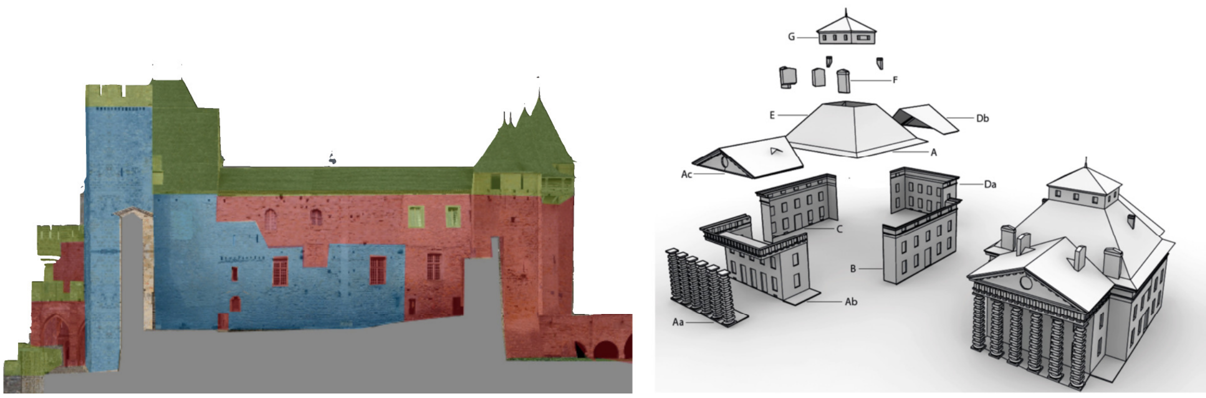


Figure 4. Example of 3D model structuring (CNRS-MAP)

According to the technique used and to the general purpose of the 3D representation, the results of a geometric reconstruction can be structured in four ways:

- Single unstructured entity (e.g. dense point clouds, or detailed mesh);
- Decomposed in elementary entities (e.g. 3D models composed by few parts);
- Decomposed in elementary entities hierarchically organized (e.g. 3D models decomposed in several parts for expressing the architectural layouts);
- Decomposed in entities organized in classes (e.g. 3D models decomposed in several parts for expressing the classification of materials, temporal states, etc.).

According to the chosen model structuring strategy, the final dataset structure (including geometry and visual enrichment) can be composed in several ways.

3D geometry:

- Single structured 3D file (with one level of detail);
- Multiple independent 3D files (with one level of detail);
- Multiple independent 3D files (with multiple level of detail).

Textures:

- Embedded into the 3D geometry file;
- Stored as external 2D files.

4.1.4 Hypothetical reconstruction

The hypothetical reconstruction of the past state of an architectural object or archaeological site is an issue primarily related to field of historical studies. Nevertheless, some specific technical and methodological issues with 3D graphical representation of disappeared (or partially disappeared) heritage buildings are often integrated in 3D reconstruction approaches. While primarily related to the analysis of iconographic sources and historical knowledge, the methodological approaches for the elaboration of hypothetical reconstructions (see Figure 5) can be based on the integration of metric representations (2D or 3D) of existing parts of the object, as well as on the reconstruction of the objects shapes starting from non-metric graphic descriptions of the artifact.

According to the informative degree of the iconography available as a source, the elaboration of the 3D representation of the hypothetical state of an artifact, may mainly be carryiedout based on:

- the 3D acquisition of existing (or existed) parts;
- previous 2D surveys of existing (or existed) parts;
- non-metric iconographic sources of the studied artifact;
- iconographic sources (metric and / or non-metric) related to similar artifacts;

These methods (which can also be used in a complementary way) do not necessarily determine the procedures, but emphasize the importance of the scientific dimension, the intellectual rigor and transparency in the development of a hypothetical reconstruction. In this sense, in order to include the 3D reconstruction of hypothetical states of an artifact into an effective context of production of historical knowledge, the following recommendations should be taken into account:

- Identify the scientific advisor(s) who can guide and validate the 3D model during its elaboration;
- Save information about iconographic sources and bibliographical references and used in the elaboration of the 3D model;
- Identify and save information indicating the degree of uncertainty (information gaps, doubts, etc.).

Figure 5. Example of 3D hypothetical reconstruction of a past state (CNRS-MAP)

4.1.5 Complementary 2D media (derived from the 3D model)

During the elaboration of the 3D representation of an artifact object, complementary 2D media are produced starting from the 3D model. These 2D media can be produced in different ways, depending on the type of 3D source (point cloud, geometric model, visually-enriched 3D model), as well as on the final visualization type (static, dynamic, interactive). As those 2D documentary media are directly derived from the 3D model, with the aim of anticipating the metadata creation, it is important to underline the relationships which can be established between images, videos, etc. and the 3D model.

2D complementary media can be produced starting from (and still remain linked to) the 3D general model of the entire architectural or archaeological artifact or to entities or sub-entities of the 3D general model. These issues will be discussed within the framework of the upcoming (October 30 and 31, 2013) workshop on metadata.

Concerning the archiving of complementary 2D media, the following formats are generally used:

Static image (e.g. renderings):

- Source file format: .tif, .tga, .bmp, etc.
- Final output file format: .jpg, .png, etc.

Animated images (e.g. videotours):

- Source file format: .mov, .avi, etc.
- Final output file format: .mpg, .mkv, etc.

Interactive Image (e.g. panoramic imaging, VR objects):

- Source file format: .tif, .tga, .bmp, etc.
- Final output file format : .mov (quickTime), .swf (Flash), etc.

4.2 Case studies

Starting from the results of the aforementioned classification, a set of typical 3D post-processing pipelines has been identified based on several aspects. First, the common articulation of several elementary processing steps into a relevant process. Second, the evaluation of the relevance of each elementary processing steps (as well as the combination of some processing sequences) according to the object scale, its morphological complexity and its final representation format. The following sections illustrate some examples showing the relationship between the characters of the artifact (morphological complexity, scale, typology, etc.) and the chosen post-processing pipeline (composed by several elementary processing steps).

4.2.1 Cerveteri and Tarquinia Tombs (FBK)

Based on the methodological approaches presented in Section 4.1, the technical aspects concerning the post-processing of this case study can be described as follows.

A - GEOMETRIC RECONSTRUCTION

- Automatic meshing from a dense 3D point cloud

B - MODEL STRUCTURING

- Unstructured, single mesh

C - VISUAL ENRICHMENT

- Texture extraction and projection starting from photographs finely oriented on the 3D model (photogrammetry)

D - DATASET STRUCTURE (Geometry)

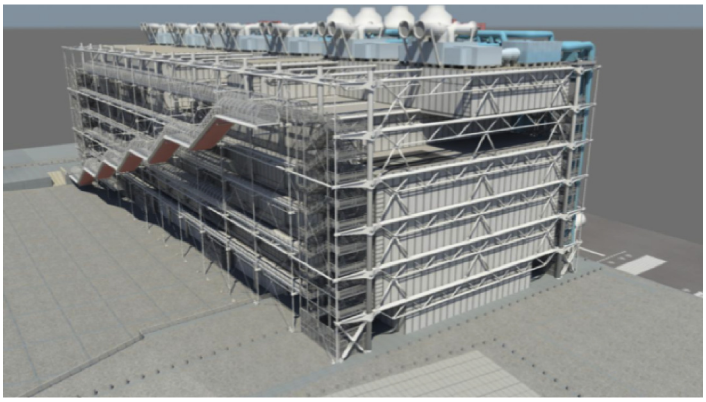
- Single 3D file with 1 level of detail

E - DATASET STRUCTURE (Textures)

- Stored as external 2D files

4.2.2 Centre Pompidou in Paris (CNRS)

Based on the methodological approaches presented in Section 4.1, the technical aspects concerning the post-processing of this case study can be described as follows.



A - GEOMETRIC RECONSTRUCTION

- Interactive and semi-automatic reconstruction based on relevant profiles
- Interactive reconstruction based on technical iconography (plans, cross-sections and elevations)

B - MODEL STRUCTURING

- Decomposed in elementary entities hierarchically organized (by following the architectural layout)
- Decomposed in entities organized in classes (materials)

C - VISUAL ENRICHMENT

- Texturing by photographic samples of the real materials of the artifact
- Texturing by generic shaders

D - DATASET STRUCTURE (Geometry)

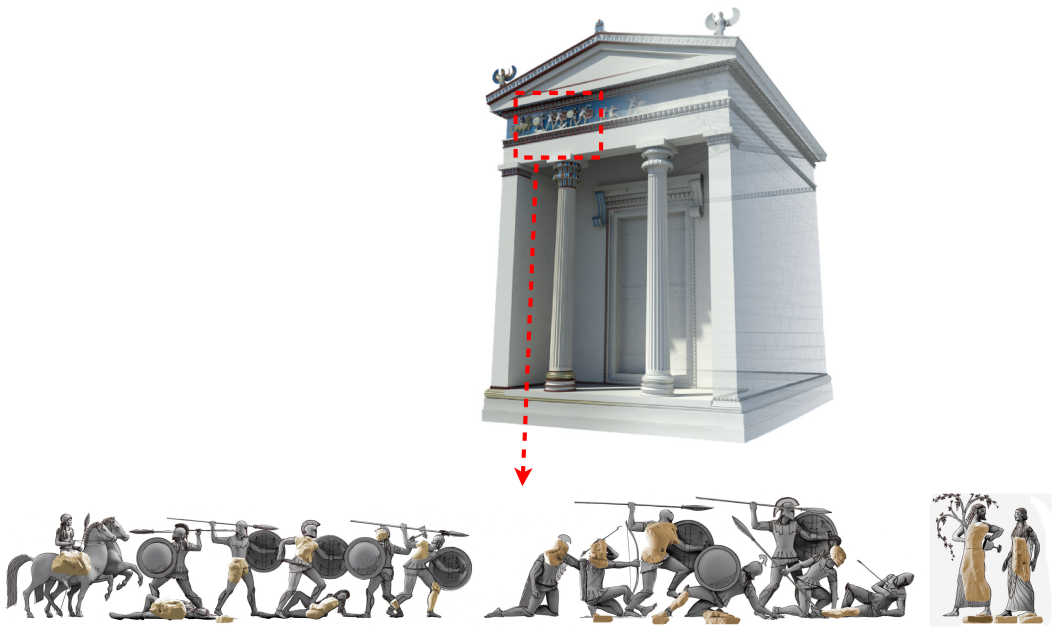
- Multiple independent 3D files with multiple levels of details

E - DATASET STRUCTURE (Textures)

- Embedded into the 3D geometry file (generic shaders)
- External 2D images (external textures).

4.2.3 Treasury of Marseille in Delphi (CNRS)

Based on the methodological approaches presented in Section 4.1, the technical aspects concerning the post-processing of this case study can be described as follows.



A - GEOMETRIC RECONSTRUCTION

- Automatic meshing from a dense 3D point cloud *(sculpted elements)*
- Interactive *and* semi-automatic reconstruction based on relevant profiles *(existing architectural elements)*
    - Interactive reconstruction based on *ancient* iconography (*hypothetical architectural elements*)

B - MODEL STRUCTURING

- Decomposed in elementary entities, partially hierarchically organized

C - VISUAL ENRICHMENT

- Texture extraction and projection starting from photographs finely oriented on the 3D model (Image-based-modeling)
- Texturing by generic shaders.

D - DATASET STRUCTURE (Geometry)

- Single 3D file structured with 1 level of detail

E - DATASET STRUCTURE (Textures)

- Embedded into the 3D geometry file
- Stored as external 2D files

F - HYPOTHETICAL RECONSTRUCTION

- Based on the 3D acquisition of existing (or existed) parts;
- Based on non-metric iconographic sources of the studied artifact;
- Based on iconographic sources (metric and / or non-metric) related to similar artifacts;

G - SCIENTIFIC (Historic) ADVISING

- Scientific Committee (nomenclature, temporal states and hypothetical reconstruction)
- Bibliographic references (nomenclature and hypothetical reconstruction)

4.2.4 Roman archaeological finds (POLIMI)

Based on the methodological approaches presented in Section 4.1, the technical aspects concerning the post-processing of this case study can be described as follows.

A - GEOMETRIC RECONSTRUCTION

- Automatic meshing from a dense 3D point cloud

B - MODEL STRUCTURING

- Unstructured, single mesh

C - VISUAL ENRICHMENT

- Texture extraction and projection starting from photographs finely oriented on the 3D model (photogrammetry)

D - DATASET STRUCTURE (Geometry)

- Single 3D file structured with 1 level of detail

E - DATASET STRUCTURE (Textures)

- Stored as external 2D images

G - SCIENTIFIC (Historic) ADVISING

- Scientific Committee

5. Metadata on post-processing

Within the framework of WP4, post-processing activities run in parallel with the metadata creation. Besides the metadata for Europeana, essentially oriented through resource discovery, the CARARE2 metadata schema encompasses a larger vision which includes digital preservation. This project is an important opportunity to create documentation on processing pipelines (including technical and methodological aspects).

In this sense, the work presented in the previous sections could also be used as a framework for capturing metadata during the post-processing pipeline. These aspects, accompanied by more general issues on the metadata creation, will be covered by the deliverable D4.2.

6. Quality Control

In conjunction with WP2, Task 2.2, a quality control process has been defined by CISA and FBK in consultation with the other partners for the production and processing of the digitized content. This process involves recording the information about the processes and equipment used to capture the data through to the post-processing techniques used (in the final section which covers data registration, alignment and processing). The purpose of recording this information is to provide an audit of the complete sequence of activities and the equipment used (with settings etc.) so that if any issues arise with the output, from the original dataset through to the final processed model, then once the cause of the problem has been identified, it can be traced and modifications made to rectify the problem. The complete form is to be found in Appendix A.

7. From post-processing (WP4) to publication (WP5)

The analysis of the overall production of 3D models within the framework of the project, as well as the conclusions of the first deliverable (D5.1) concerning the publications issues, allowed identification of two general pipelines which can be considered as a reference for pre-orienting the post-processing activities according to specific final outputs.

PIPELINE _ TYPE 1

3D digitization and reconstruction: dense point cloud + regular mesh + texture mapping (or vertex colouring)

Processing: automatic processing + optimization

Model structuring: unstructured

Final 3D representation: the final model is generally managed in Meshlab, RapidForm, ...

This kind of 3D representation can be converted in WebGL-based 3D viewers, such us NEXUS (for dense meshes and point clouds) or Potree (only for dense point clouds).

PIPELINE _ TYPE 2

3D digitization and reconstruction: Sparse point cloud (e.g. topographical surveying, technical drawings)+ structured geometry + texture mapping

Processing: semi-automatic and manual processing

Model structuring: generally structured (architectural layout, temporal states, etc.)

Final 3D representation: the final model is generally managed in 3Ds Max, Maya, Blender,…

This kind of 3D representation can be converted in Collada (.dae) format in order to be interactively visualized by several 3D real-time engines (such as Unity, 3Dvia, etc..).

The post-processing phase concerns essentially the elaboration of the 3D representation, at the maximum level of geometric and visual accuracy, ready to be converted in the final publication format. The production of the final publication representation, including the geometry and texture optimization issues, will be presented in the deliverable D5.2 (WP5).

8. Conclusions

This interim report presents a first overview of the post-processing activities concerning the digitization implementation of the project. Starting from the presentation of the progress status of each partner in this task, we presented the main problems encountered as well as the main action undertaken concerning the definition of a common basis for :

- Classifying the elementary processing steps composing the post-processing pipelines;
- Identifying two main overall pipelines with the aim to pre-orient the processing of the data through a specific final output (for the publication);
- Give to content providers an initial (and common) grid for describing their post-processing activities when creating metadata.

Beside the presented methodological and technical issues (also including the solutions undertaken), the management and the long term preservation of high quantities of data (raw data, visually-enriched 3D geometric representations, complementary 2D media, metadata, etc.) forms an important issue within the framework of the project. Some solutions for setting-up several shared data repositories are currently under discussion.

Finally, an updated version of this report (D4.3 Final Report on Post-Processing) will be published in M36 which will cover all the partner experiences, lessons learned and provide a complete and global overview of the post-processing part of the 3D-ICONS pipeline.

Appendix A – Quality Control Form

Type of survey / Data acquisition				
	Image-based (passive sensors)			
	Range-based (active sensors)			
	Topographic / Geodetic			
	CAD / maps / sections / Sketch-up			
Employed sensor(s)/instrument(s)				
	Compact/Amateur digital camera			
	SLR/Reflex digital camera			
	Panoramic digital camera			
	TOF-CW terrestrial laser scanner			
		Brand / Model / Type		
		Ranging noise (datasheet)		
		Digital camera		
			calibrated? [yes/no]	
	TOF-PW terrestrial laser scanner			
		Brand / Model / Type		
		Ranging noise (datasheet)		
		Digital camera		
			calibrated? [yes/no]	
	Airborne laser scanner			
		Full wave-form [yes/no]		

	Triangulation-based laser scanner		
		Brand / Model / Type	
		Ranging noise (datasheet)	
		RGB camera [yes/no]	
	Stripe projection system		
		Brand / Model / Type	
		Ranging noise (datasheet)	
		RGB camera	
	Total station		
		angular resolution	
		Ranging noise with reflector (datasheet)	
		Ranging noise no reflector (datasheet)	
	GNSS receiver		
		Brand / Model / Type	
		Receiver class [navigation/geodetic]	
		Antenna class [internal/ geodetic external]	
		Used signal [code, single frequency phase, double frequencies phase]	
Scene / Object info			
	Location (city, museum, site, etc)		
	dimensions (W x L x H)		
	Units		
	Indoor		
	Outdoor		

	Material (marble, glass, stone, wood, iron, etc.)	
	Surface characteristics (translucent, opaque, porous, etc.)	
	Date of survey - beginning	
	Date of survey - end	
	Operator	
Data acquisition		
	CAMERAS / IMAGES	
	Geometrically calibrated? [yes/no]	
	Radiometrically calibrated / color profiled? [yes/no]	
	Color checkboard? [yes/no]	
	Focus [auto/manual]	
	Quality / format	
	Flash [on/off]	
	Extra artificial light (lamps)	
	Controlled environmental light? [yes/no]	
	Average baseline [value]	
	Average distance camera / object	
	Optical image stabilization [on/off]	
	Digital image stabilization [on/off]	
	Number of images [value]	

	HDR images? [yes/no]		
	Avg number of overlapping images [value]		
	Use of coded targets? [yes/no]		
	Ground Control Points (GCPs)? [yes/no]		
		number	
	Reference / known distances? [yes/no]		
		numbers [value]	
		avg length [value]	
	ACTIVE / SCANNER		
	Calibrated sensor? [yes/no]		
		Date of calibration	
	Number of scans [value]		
	cloud [value]		
	cloud + intensity [value]		
	cloud + intensity + RGB [value]		
		Calibrated camera? [yes/no]	
		Image resolution? [value]	
		HDR images? [yes/no]	
	Leveled?		
	Dual axis compensator [on/off]		
	Targets? [yes/no]		
	Min sampling step [value]		

	Max sampling step [value]	
	Avg sampling step [value]	
	Min acquisition distance [value]	
	Max acquisition distance [value]	
	Avg acquisition distance [value]	
	TOPOGRAPHIC	
	number of stations [value]	
	targets [yes/no]	
	natural features [yes/no]	
	open/free traverse [yes/no]	
	polygonal/loop traverse [yes/no]	
	link traverse [yes/no]	
	Network [yes/no]	
	double-face observation [yes/no]	
	reflector/target on tripod with tribrach [yes/no]	
	reflector/target on tripod [yes/no]	
	reflector/target hold by an operator [yes/no]	
	min acquisition distance /length of legs[value]	
	max acquisition distance [value]	
	avg acquisition distance [value]	
	topographic nails? [yes/no]	
	sketches of observed points? [yes/no]	

	GNSS receiver			
	Differential			
		static		
			local reference station	
			permanent reference station	
			avg baseline length	
			avg duration of acquisition	
		kinematic		
			real-time	
			stop-and-go	
			avg baseline length	
	Non-differential			
		Low-end instrument positioning [yes/no]		
		Precise Point Positioning (PPP) [yes/no]		
		avg duration of acquisition [value]		
	number of stations			
	CAD-like			
	Data provider			
	Data type			
		Digitized maps / sections		
		Old pictures		
	Metric/Scaled? [yes/no]			

Data registration / alignment / processing		
	CAMERAS / IMAGES	
	automated image orientation / alignment with SfM? [yes/no]	
	Guided/manual alignment [yes/no]	
	accuracy of the image orientation/alignment [value in px]	
	scaling & geo-referencing with GCPs? [yes/no]	
	scaling with reference distance? [yes/no]	
	Employed software	
	Operator	
	ACTIVE / SCANNER	
	target- or sphere-based registration? [yes/no]	
	ICP-like registration?	
	standard deviation of the registration procedure [value in mm]	
	geo-referencing? [yes/no]	
	TOPOGRAPHIC / GEODETIC	
	adjustment accuracy/misclosure of traverse [value in mm]	
	sigmaXY [value in mm]	
	sigmaZ [value in mm]	

Geometric modeling					
	point spacing of mesh reconstruction [value in mm]				
		number of triangles [value in mm]			
	smoothing / filtering [yes/no]				
		Auto [yes/no]			
		Tolerance [value in mm]			
	mesh decimation / simplification [yes/no]				
		Triangle count [yes/no]			
		Tolerance [value in mm]			
	final number of triangles [value]				
Texture mapping					
	Real images [yes/no]				
	Synthetic images [yes/no]				
	Bump mapping [yes/no]				
	Image-based				
		External images (for multispectral texturing for example)			
			Known exterior orientation (GNSS/INS, bundle adjustment, etc.)		
			Image to mesh registration (DLT, Tsai, resection, etc.)		
				manual	
				automated	
			Texturing with CG software (3DS, Maya, etc.)		
	Range-based				

		Images from scanner? [yes/no]			
		External images			
			Known exterior orientation (GNSS/INS, bundle adjustment, etc.)		
			Image to mesh registration (DLT, Tsai, resection, etc.)		
				manual	
				automated	
			Texturing with CG software (3DS, Maya, etc.)		
	color-vertex [yes/no]				
	parameterized texture [yes/no]				