

Share - Publish - Store - Preserve. Methodologies, Tools and Challenges for 3D Use in Social Sciences and Humanities

Anas Alaoui M'Darhri, Vincent Baillet, Bastien Bourineau, Alessio Calantropio, Gabriella Carpentiero, Medhi Chayani, Livio de Luca, Iwona Dudek, Bruno Dutailly, Hélène Gautier, et al.

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PARTHENOS

Pooling Activities, Resources and Tools for Heritage E-research Networking, Optimization and Synergies

Share — Publish — Store — Preserve. Methodologies, Tools and Challenges for 3D Use in Social Sciences and Humanities

White paper

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WHITE PAPER

Share — Publish — Store — Preserve. Methodologies, Tools and Challenges for 3D Use in Social Sciences and Humanities

This White Paper is the result of the PARTHENOS Workshop held in Marseilles at MAP Lab. (France), February 25th-February 27th, 2019.

During the organization of this workshop, we were all strongly affected by the premature death of Matteo Dellepiane. Matteo had participated in the first PARTHENOS workshop on 3D. He was an outstanding researcher whose work on geometric reconstruction and visual appearance was recognized by the entire community working on 3D and cultural heritage internationally. As a member of the Visual Computing Lab of CNR-ISTI, he contributed to the development of several tools now widely used by our community for the processing, visualization and publication of 3D models for the purpose of documentation and dissemination of Cultural Heritage. Even though Matteo was not with us in Marseilles during this workshop, the fruit of his work has served us well and will support our scientific community facing the long-term challenges in this field.





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Executive Summary

Through this White Paper, which gathers contributions from experts of 3D data as well as professionals concerned with the interoperability and sustainability of 3D research data, the PARTHENOS project aims at highlighting some of the current issues they have to face, with possible specific points according to the discipline, and potential practices and methodologies to deal with these issues.

During the workshop, several tools to deal with these issues have been introduced and confronted with the participants experiences, this White Paper now intends to go further by also integrating participants feedbacks and suggestions of potential improvements.

Therefore, even if the focus is put on specific tools, the main goal is to contribute to the development of standardized good practices related to the sharing, publication, storage and long-term preservation of 3D data.

1. Introduction

1.1. Rationale

Today, 3D data have become an inherent part of research material in Humanities and Social Sciences. The 3D technologies are progressing rapidly but are not easy to manage and a balance has to be found between stable and cutting-edge tools. Furthermore, there are still issues particularly with interoperability, and hence sharing, publishing and long-term preservation.

This White Paper is the result of a second workshop organized by CNR (Italy), CNRS (France), Inria (France), Huma-Num's Consortium 3D for Humanities (France) and the CNRS-MAP/CNR-ISTI International Joint Lab within in the scope of PARTHENOS Work Package 4 on Standardization, with support from the technical partners and on behalf of the PARTHENOS Research Infrastructure. This was held in Marseilles (France), from February 25 to February 27, 2019, and entitled "**Share — Publish — Store — Preserve. Methodologies, Tools and Challenges for 3D Use in Social Sciences and Humanities**". After a first workshop in 2016 dedicated to the challenges of creation, interoperability and preservation [1], this one mainly focused on interactive 3D data management tools, most of them developed by the organizers, highlighting their strengths and weaknesses.

More precisely, the objectives were to:

- Share general knowledge on 3D issues in Humanities and Social Sciences;
- Deepen technical knowledge about specific 3D tools;
- Contribute to a better understanding of technologies potential and users' needs;
- Confront practices and experiences and raise for discussion;
- Promote and contribute to best practices and standards to ensure 3D data interoperability and sustainability.

[1] Pierre Alliez, Laurent Bergerot, Jean-François Bernard, Clotilde Boust, George Bruseker, et al.. *Digital 3D Objects in Art and Humanities: challenges of creation, interoperability and preservation. White paper: A result of the PARTHENOS Workshop held in Bordeaux at Maison des Sciences de l'Homme d'Aquitaine and at Archeovision Lab. (France), November 30th - December 2nd, 2016*. PARTHENOS. *Digital 3D Objects in Art and Humanities: challenges of creation, interoperability and preservation*, Nov 2016, Bordeaux, France. pp.71, 2017. 〈hal-01526713v2〉

We selected four main topics to focus on during the workshop, corresponding to the life cycle and the various uses of 3D data in Humanities and Social Sciences: sharing, publishing, storing and preserving.

For each one, the related theme, the issues it deals with and specific tools addressing these issues, has been introduced by domain specialists in brief presentations followed by training sessions where participants used the tools presented with their own data and discussed the limitations and potential improvements of the tools. Those themes and discussions are the basis of the core chapters of this white paper.

A specific aspect that deserves to be highlighted compared to the first edition is the way we proceeded to get a wider impact, beyond PARTHENOS. Indeed, we decided to open the discussion through launching an open call [2] for participation in order to gather interdisciplinary profiles of people who could contribute various viewpoints that were presented during a break out session [3]. Thus the workshop was attended by 16 participants representative of different domains, with complementary backgrounds. Indeed, we aimed at including not only archaeology - the reference domain- but also Humanities and Cultural Heritage at large with all related domains such as digital humanities, architecture, geomatics or computer graphics. The goal was to ensure coverage of a wide range of use cases from different research communities and to ensure that the background of the participants would not bias the discussion.

As a consequence, this white paper is based on contributions from all the participants, reporting the main conclusions of the discussion. They also contribute to feed one of the main outputs of the PARTHENOS project, the *Standardization Survival Kit* (or SSK : http://ssk.huma-num.fr/#/) produced in the WP4 framework, through the creation of research scenarios which are fully accessible online.

Such a framework may be further enriched by other experts in the field who will take advantage of the video recording of the master classes. Indeed, you can access the videos that have been recorded and edited through the PARTHENOS collection of Huma-

[2] This call received nearly 60 applications from 11 European countries among which we selected 17 participants according to criteria of knowledge of 3D technologies and their uses, their projects carried out or in progress, their disciplinary background, and their motivation to participate according to our own expectations around the PARTHENOS project. One participant finally has to cancel his participation and we ended up with 16 participants.

[3] The videos of this session will be available online at the address: https://www.canal-u.tv/producteurs/humanum/parthenos.



Num's Canal-u's channel (the French digital video library for higher education and research) following this link: https://www.canal-u.tv/producteurs/humanum/parthenos. All the presentations preceding the training sessions will also be available through the PARTHENOS Internet platform[4].

We report here the results of the discussion at the workshop, further improved and extended by subsequent work done after the workshop by the speakers, the organizers, and the participants involved. Our aim with this White Paper is to briefly review the status of key 3D tools used by different communities willing to share, publish, store and preserve data they produce and to promote further discussion and action regarding their use and the data produced.

[4] See: http://www.parthenos-project.eu/

1.2. Publishing and Accessing Knowledge through the PARTHENOS SSK, Another Way of Sharing

In the context of research, standards usually take the form of documents informing about practices, protocols, artefact characteristics or data formats that can be used as reference for two parties working in the same field of activity in order to produce comparable (and interoperable) results.

The experience gained within the various communities and infrastructures represented in PARTHENOS[5] that have been in need of adopting existing standards, has led to the identification of three use cases where it would be possible to reconcile standards and researchers in the Humanities:

- In the context of a research project, there is always an initial phase during which scholars should be made aware of some core standards that are systematically related to the definition of interoperable digital objects.
- On the other hand, when researchers, individually or within teams, have built a research workflow based on the use of the best practices and relevant community standards, we lack a place to **publish** and **share** such information.
- Finally, some of these workflows, or protocols, can at some point become themselves standards, and therefore a "pre-standardization" framework that stabilizes the knowledge is essential.

The Standardization survival kit[6], or SSK, addresses these issues by supporting and providing expertise to researchers in their use of standards. It encourages the publication and sharing of the best practices in a given research context, and it acts as a preservation system for the submitted workflows as they can become standards for the communities.

[5] http://parthenos-project.eu/
[6] http://ssk.huma-num.fr



1.2.1. General Presentation and Features

To document the close link to be made between the use of a given standard, or a subset of it, and a corresponding research activity, the natural choice is to use the Taxonomy of Digital Research Activities in the Humanities (TaDirah[7]) (Schöch 2015, Borek et al. 2016), exactly designed to cover the core tasks of Digital Humanities Research, even though, when it comes to Heritage Science, other vocabularies have to be used.

To link those activities between one another, there emerged the concept of research scenarios which are the descriptions of research processes built on the use of standards. These scenarios aim at providing contextual information and relevant examples on how standards can be applied in a given research project. They have been created and added by domain experts, from real life researcher-oriented use cases. Each scenario within the SSK works like a high-level research guide for scholars. They are made up of successive steps involving specific tasks, and can be followed as a complete process to solve a given problem with the most standardized means. Scenarios can be seen as a living memory of what should be the best research practices in a given community. For that reason, the SSK can be considered as a framework showing concrete use of standards, rather than simply a catalogue of resources.

For each step, relevant resources to perform the given task are proposed, divided into two categories:

- the “general resources” that include the primary documentation and tools
- the “project-specific resources” that point to concrete use cases in which a similar task was accomplished.

The material contained in these sections is of various kinds, among which the most important is a state-of-the-art bibliography, which includes all the documentation needed to carry out a given task. The bibliographical references are up-to-date and gathered within a Zotero library, which was specially created for this project. The SSK also offers more technical resources, such as stylesheets, code samples, software or services, and training materials like tutorials.

[7] http://tadirah.dariah.eu/vocab/index.php

1.2.2. Navigating the SSK

As a tool, the SSK is dedicated to the researchers in the wide scope of Social Sciences, Humanities and Heritage disciplines, regardless of their skills or practices with digital tools. The exact disciplines addressed in the scenarios are taken from the AURéHAL[8] ontology, in the « Humanities and Social Sciences » section. Besides the disciplines, the researchers can find the relevant material by selecting:

- the research objects (images, artifacts, manuscripts, etc.)
- the research techniques (mapping, encoding, scanning, etc.)
- the research activities (discovering, archiving, publishing, etc.)
- the standards (ISO, EAD, TEI, etc.).

Users can browse by using those facets, and switch easily between scenarios, steps and resources:

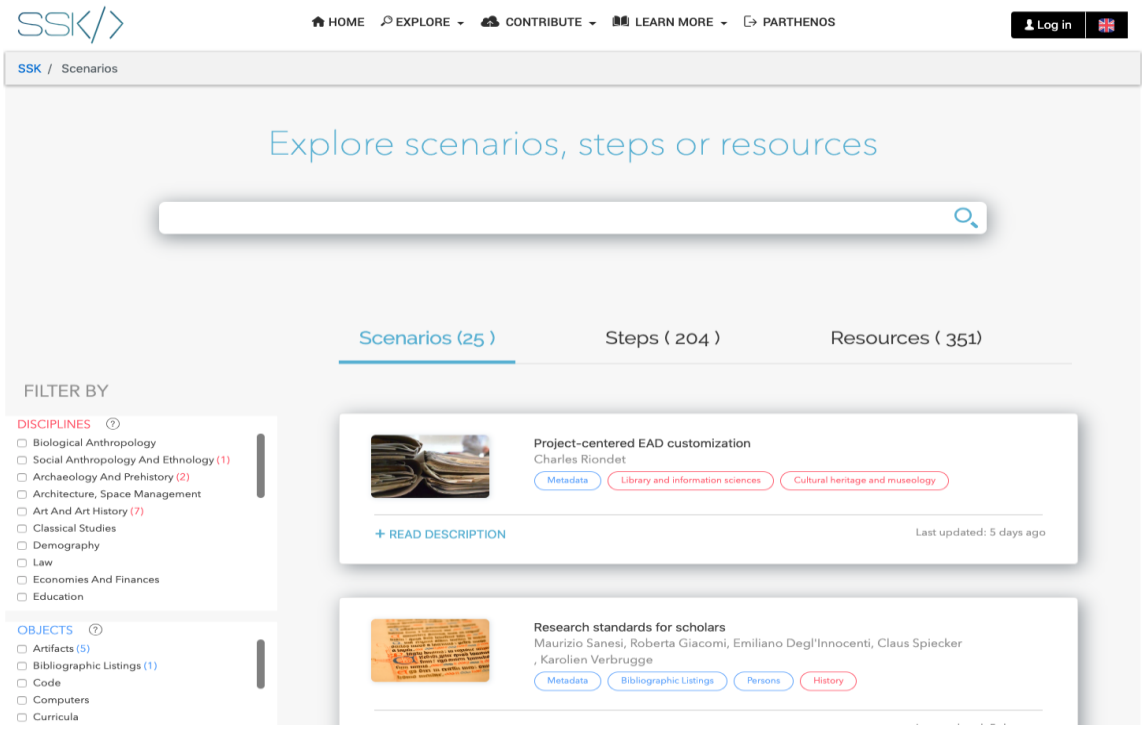


Figure 1: Navigation page in the SSK

[8] https://aurehal.archives-ouvertes.fr/domain?locale=en



1.2.3. Actual Limitations and Suggested Improvements

Among the concerns and flaws of the tool listed by the participants:

- The validity and reliability of the scenarios, since they come mostly from individuals (or labs), without clear peer or institutional review. There could be also a problem of consistency between scenarios, depending on the level of expertise and/or the amount of time allocated by the author(s). That would be problematic as scenarios should be seen as best references in their domain.
- Lacks of terms & vocabularies to describe specific fields or objects. We should add more exhaustive ontologies or allow users to propose new ones.
- Need of more connection between scenarios in order to build more global workflows.
- Risk of redundancy: if scenarios are too similar, it will be difficult to discriminate between them and to find the best one.
- Including the communities by allowing comments, remarks, suggestions on the scenarios, to allow potential enrichment.
- Inserting images within steps would be good.

Reinforcing the links between the SSK and similar digital initiatives, like Open Methods, or Dariah Teach.

1.3. Impact on PARTHENOS: the New Scenarios Envisioned

Resulting from the work of all the participants to the workshop, split into small groups, five scenarios have been proposed to be included in the SSK. They are still in progress but should be added to the platform in April 2019.

1.3.1. RTI Archiving

Authors: Patrick McInerney, Costas Papadopoulos, Emilie Saubestre, Martina Trognitz

Reflectance Transformation Imaging, a computational photography method based on the principle of raking light has been extensively used in fields such as archaeology, museum studies, and art history to capture and enhance subtle surface details. Low-angled and multidirectional light creates texture details and enhances planar irregularities. There are two methods to capture RTI images: the Dome Method and the Highlight RTI Method. In both methods, objects are photographed with a single camera in a fixed position. The only element that changes in the process is the position of light. In the Dome method, the light position is known since lights are fixed. In the highlight method, the position of the light is captured by using reflective spheres that are then used by specialised software to create the RTI image. The images stack is then computed into a polynomial texture map. In a dedicated viewer, the resulting file can be viewed under individual light positions and different rendering algorithms.

This scenario focuses on the preparation of captured RTI data for archiving. The main component of an RTI dataset is photographs. Additionally, some software-dependent formats will have to be considered for archiving. Resulting formats for RTI images were developed in 2001 by the Hewlett Packard Laboratories and further extended by Cultural Heritage Imaging (CHI).

1.3.2. Export of ortho-photos

Authors: Christoph Hoffmann, Nenad Jončić, Michel Jordan, Justin J.L. Kimball

In this scenario, we demonstrate a methodology to translate a 3D model into a 2D orthophoto using Agisoft's Metashape/Photoscan. The dataset that we use here is based upon a studio-created photogrammetric 3D model, however, it can be utilised broadly within any photogrammetric 3D model. This scenario assumes that the reader has a photogrammetry of a real-world object which they can use along with this methodology.

1.3.3. Doing 3D Reconstruction in Archaeological Context

Authors: Vincent Baillet, Chiara Zuanni



3D reconstructions have a long history in archaeology and cultural heritage, although there are varying practices, data capture and processing methods, tools, and visualisations. There are not clear ways of determining the accuracy and precision of the reconstructions. Furthermore, scientific and engagement purposes inform different dissemination practices, and therefore pose different challenges to the preservation of these outputs.

1.3.4. Classification of 3D Models: Working from 2D to 3D

Authors: Eleonora Grilli, Imanol Muñoz-Pandiella, Erica Nocerico

The use of 3D models is, nowadays, widely diffused for the documentation and dissemination of cultural and archaeological heritage. Nevertheless, to provide useful 3D data, it is necessary to associate some semantic information that can help operators to understand the heritage. This scenario aims at pointing out a pipeline to manage various types of 3D survey data and to associate them with heterogeneous information and attributes to characterize and describe the surveyed object.

1.3.5. UAV Data Acquisition and Management for Multitemporal Surveys of Archaeological Sites

Authors: Alessio Calantropio, Gabriella Carpentiero, Lorenzo Teppati Losè

Aerial photogrammetry is a powerful technique that can be used for recording and analyzing excavation phases of archaeological sites. Based on the authors experience, there are some strategies that can speed up the data acquisition, processing and analysis steps. This works aims to underline best practices and lesson learned in the scenario of UAV data acquisition and management for multitemporal surveys of archaeological sites with a photogrammetric approach.

2. Collecting and Sharing Data Linked with 3D

2.1. Mission Statement

For the last few years, the cross-disciplinary community working on digital technologies applied to cultural heritage has been involved in national and international projects for building next generation tools and information systems for analysing the state of conservation of heritage artefacts, studying their temporal transformations, extracting their morphological features, and correlating heterogeneous data coming from several disciplines. Even if the impressive and fast evolution of digital technology has produced more and more proficient hardware and software for automated data acquisition and processing, at the same time, the main actors of everyday production of knowledge on cultural heritage need today a new generation of tools for embedding their knowledge into digital representations. Moving from a data-driven to a semantic-driven digital documentation approach is an essential challenge, especially in Cultural Heritage, where knowledge is always the result of a combination of complementary skills and disciplinary profiles. The semantic enrichment of digital resources is generally achieved through an annotation process that links a document with additional information that can take several forms (keywords, semantic classes, process description...). Semantic annotation is the process that creates semantic labels to support advanced research. The annotations, thus defined, make it possible to create a complex information structure by the use of different data models (tags, attributes, relationships, ontologies...). The annotation of 3D models raises problems related to their manipulation, especially for the definition of complex annotations. On the other hand, images have proved to be an effective and easy-to-use media for defining annotations and for recording other information from scientific imagery but do not provide accurate geometric information. The integration of these different media into a common annotation methodology would offer a promising approach. For an overview of the different systems and approaches for annotating visual models, see this Overview Box[9].

[9] A. Manuel, R. Scopigno, "Overview Box 3 - Tools supporting annotation on 3D models" in Pierre Alliez, Laurent Bergerot, Jean-François Bernard, Clotilde Boust, George Bruseker, et al.. *Digital 3D Objects in Art and Humanities: challenges of creation, interoperability and preservation. White paper: A result of the PARTHENOS Workshop held in Bordeaux at Maison des Sciences de l'Homme d'Aquitaine and at Archeovision Lab. (France), November 30th* -

2.2. Collect and Share - Aïoli, a Reality-Based 3D Annotation Platform

2.2.1. General Presentation and Features

Archaeologists, architects, engineers, materials specialists, teachers, curators and restorers of cultural property, contribute to the daily knowledge and conservation of heritage artefacts. The management of multi-dimensional and multi-format data introduces new challenges, in particular the development of relevant analysis and interpretation methods, the sharing and correlation of heterogeneous data among several actors and contexts, and the centralised archiving of documentation results. Despite their different approaches and tools for observation, description and analysis, the actors of cultural heritage documentation all have a common interest and central focus: the heritage object, the physical one, whether it is a site, a building, a sculpture, a painting, a work of art, or an archaeological fragment. This is the starting point of Aïoli, a reality-based 3D annotation platform, which allows a multidisciplinary community to build semantically-enriched 3D descriptions of heritage artefacts from simple images and spatialized annotations coupled with additional resources. Developed by the CNRS-MAP Lab, this platform introduces an innovative framework for the comprehensive, large-scale collaborative documentation of cultural heritage by integrating state-of-the-art technological components (fully automatic image-based 3D reconstruction, 2D-3D spreading and correlation of semantic annotations, multi-layered analysis of qualitative and quantitative attributes...) within a cloud infrastructure accessible via Internet interfaces from PCs, tablets and smartphones online and onsite.

Our approach puts the heritage object (the physical one) at the heart of the documentation process by considering reality-based 3D and semantic description in a strongly integrated way. By correlating simple images (probably the stablest support for registering field observations since the invention of the photography), our platform generates a dynamic 3D morphologic scaffolding for structuring data and annotations. At the same time, this

December 2nd, 2016. PARTHENOS. *Digital 3D Objects in Art and Humanities: challenges of creation, interoperability and preservation*, Nov 2016, Bordeaux, France. pp.71, 2017. 〈hal-01526713v2〉



data structure becomes a way of enabling the communication between several actors involved in the documentation and the study of the same object. This is made by interlinking all phases that characterise the overall documentation process within an 'informative continuum' by combining three essential features:

- ***A continuous 3D mapping and annotation process***

  Our approach creates a sort of bridge between the real object and its digital representation by introducing a solution for memorising spatialized annotations made by different actors.

- ***A morphology-based documentation framework***

  Based on a spatial overlapping factor, our multi-layers description model allows the simultaneous structuring of data and geometry as well as the continuous correlation of semantic annotations (with relative attributes).

- ***A flexible & scalable technology***

  Our platform is built on a cloud computing service allowing the gathering, processing and sharing of semantically-enriched 3D data within online and onsite documentation scenarios.

Our system introduces an original informative linkage between the physical object space and its digital representation by facing to two interconnected technical issues: the onsite retrieval of structured information according to the physical object's annotation; the onsite collection and processing of new data to be spatially referenced and semantically correlated with previous data. This is done by integrating the following features:

- An **incremental image-based 3D spatialisation** process to manage the geometric merging of several images coming from different actors at different temporal states;

- A **2D/3D annotation framework** enabling users to draw, visualise and register relevant surface regions by handling simple 2D images spatially oriented around a dynamic 3D representation;



- A **multi-layered morphology-based data structuring model** to accurately describe real objects in all their geometric complexity and according to multidisciplinary observations.

Our platform is today running on a server appliance composed of 90 cores (developing 180 high frequency threads equivalent to 250 gigaflops) of computing power, completed by 256GB of RAM and supported by 8TB of storage. Given its technical implementation, the platform can be easily installed in larger server appliances.
Further information about the *aïoli* project (including demonstration videos, case studies, beta testing programme) are available on the platform website: www.aioli.cloud.

2.2.2. Use Cases

In order to try out the experimental features of aïoli, a beta-testing programme started on October 2017. This programme is currently ongoing and is involving selected actors of cultural heritage scientific and professional community. During this programme, a wide range of heritage artefacts, belonging to different scales and photographed by different sensors, have been used for experimenting the implemented features. This beta-testing programme was also an opportunity to explore the potential uses of the platform within the CH community. In the case of curation and restoration of cultural property, building specialists could analyse, for instance, the type of stone, alteration morphology, lost material and biological colonisation, in order to help preventive conservation (Fig. 2 *cf usage* 1). In the frame of study and restoration of paintings, experts could use the annotation tool to map the materials such as pigments identified thanks to techniques such as Scanning Electron Microscopy (SEM) or Laser-Induced Breakdown Spectroscopy (LIBS) and also examine the underdrawings using technical imaging (Fig. 2 *cf usage 2*). The 2D/3D annotation framework can be very useful for isolating and analysing the morphological features of archaeological fragments (Fig. 2 *cf usage 3*). Finally, aïoli may be used to help stratigraphic studies by spatializing and retrieving 3D information (dimensional layouts, orientation attributes …) such as lapidary signs (Fig. 2 *cf usage 4*).

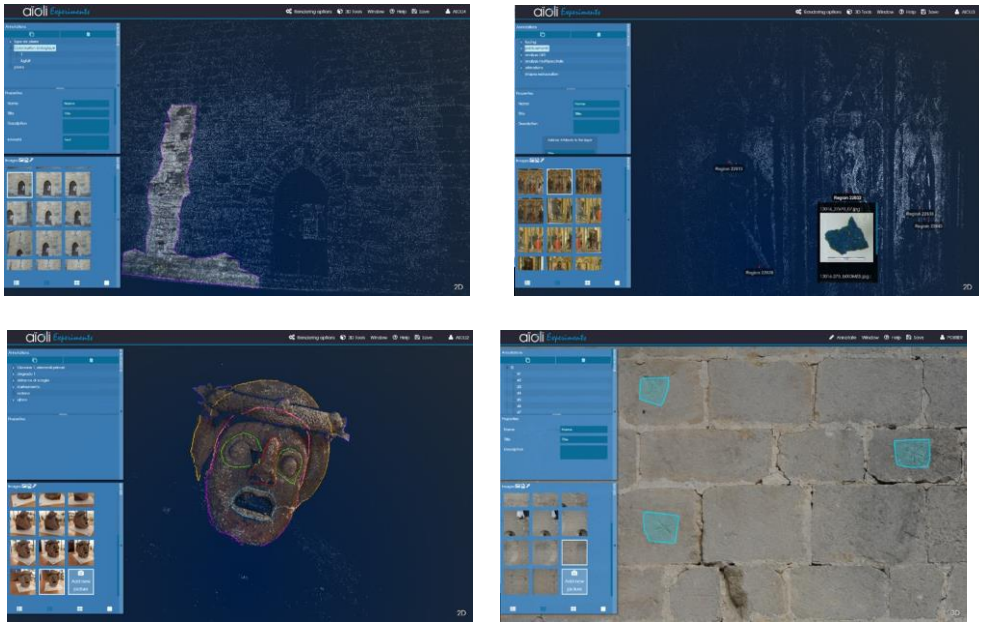


Figure 2 : Screen captures of the case studies carried out within the beta testing programme: usages. Usage 1 (top-left) – Mapping of biological colonization on the East wall of the Caromb's church, France; Usage 2 (top-right) – Spatialization of a pictorial sample from the painting Triptyque de Venasque, Musée du Petit Palais, Avignon, France; Usage 3 (bottom-left) – Morphological analysis of a theatrical mask of the archaeological Museum of Lipari, Italy; Usage 4 (bottom-right) — Annotation of lapidary signs on the meridional wall of the castle of Les Baux-de-Provence, France

The next step in this beta-testing programme is to move towards a progressive integration of collaborative experimentations, to put forward new scenarios of comparative and co-operative analysis of cultural heritage.

2.2.3. Actual Limitations and Suggested Improvements

The technical implementation of the platform presents some limitations today:

1) it currently works only online and needs at least a 4G connection;
2) it currently works in arbitrary georeferencing, then the computed descriptors are only locally expressed, with an important limitation in terms of correlation potential.

A new version of the platform should be available soon including some new features.



Given the emphasis put on the multi-users aspects, the interface for aïoli must ease the collaborative work on shared projects. This will be enabled by adopting a social network-like approach for the user-end uses in future releases.

A guide to the photographs acquisition for the successful reconstruction of the point cloud by our platform is being written to help users to understand the constraints related to the specificities of this acquisition type.

Since many photogrammetric reconstruction tools exist and many projects have already been processed and reconstructed using these tools, we plan to allow the import of data from other photogrammetric processing chains such as Agisoft Metashape.

The multiplicity of actors involved in the description of the same object requires that the meaning of the terms used for each of the specialities can be established in a reliable way. Controlled vocabularies are used to determine terminology that is intended to promote consistency of terms used within the same domain. Many vocabularies exist and are structured according to RDF data models to allow easy publication within the Semantic Web. Thus, in the description sheets, the integration of a new type of field linked to a controlled vocabulary is currently being developed.

We also plan the development of a off-line/online synchronisation process in order to extend the use to some particular work conditions, as well as a complete approach for scaling/georeferencing issues.

3. Visualize and Publish

3.1. Mission Statement: From Local Visualization to Web Publishing of 3D Data

3.1.1. Introduction

Visualization and analysis of 3D data are moving from desktop to Internet. Several approaches have been proposed over the last years for effectively driving the publication of 3D material on the Internet.

Luckily, the first solutions - closed, plugin-based, non-standard, and poorly performing - are just a distant memory. The introduction of WebGL (the standard API for Computer Graphics Internet programming) brought a complete revolution, igniting the development of Web3D solutions efficient, standardized, plugin-free, and able to transform 3D content in a standard component of any webpage.

Nowadays, the resulting panorama is composed of plenty of libraries, tools, frameworks, and platforms, enabling the immediate and interactive rendering of 3D data directly inside all common Internet browsers. This ensemble is composed of a very heterogeneous set of online 3D viewers: from low to high-level software, from proprietary to open-source systems, from commercial to academic platforms.[10]

Unfortunately, at a closer inspection the Web3D ecosystem reveals several empty spots (unsolved issues, uncovered users, and neglected fields), mostly due to the fact that this large variety of solutions is often just focused towards mainstream publishing actions, and thus unable to cope with the needs of more specialized and technical 3D users.

Cultural Heritage professionals constitute a representative sample of users belonging to this community.

[10] Potenziani M., Callieri M., Dellepiane M., Scopigno R., 2018. Publishing and Consuming 3D Content on the Web: A Survey, in Foundations and Trends® in Computer Graphics and Vision, Volume 10 (4), December 2018, Pages 244-333. https://doi.org/10.1561/0600000083



3.1.2. General Issues about 3D Internet Publishing

Thanks to the democratization of the technologies aimed at 3D acquisition (like photogrammetry or laser scanning), nowadays Cultural Heritage research teams produce a huge amount of digital 3D models.

Sharing all these data over the Internet is more and more felt as a primary need, and not just for following dissemination purposes (e.g. to cope with museums aims, or to enable exploiting digital reconstructions in teaching activities), but mostly because of more technical and professional uses (e.g. to support the remote and collaborative study of artworks, or to enable the creation of a comprehensive digital documentation of a restoration project).

To efficiently stream and render CH 3D datasets over the Internet is not trivial (because they are reality-based 3D data, and so high-resolution and intrinsically complex). Even now, there are few solutions specifically tailored to specific fields (cf. the tools presented in the next sections) that allow users to visualize and manipulate these 3D models online with excellent results.

Thus, the needs of the CH community are now going beyond the plain Internet visualization functionalities, starting to focus on those second-order features (analytical tools, data enrichment, copyright protection, etc.) that mark the border between “visualization” and “publishing”.

Enabling these more sophisticated visualization modes prompts basic questions and open issues, like for instance:

- Data enrichment is fundamental for transforming 3D models from mere data to a fully qualified content. It allows linking other content to 3D, enabling transmedia interlinking, multimedia annotations, documentation, etc. Currently very few platforms can manage data enrichment in a complete, structured, and standardized way. How an effective enrichment strategy could be implemented? What are the real needs of the community?
- 3D data have to be stored on a Internet server. The hosting service often is demanded by external institutions, either commercial or public. The related service can be provided by a tier under specific conditions of use, or also under specific costs. The conditions of use may not guarantee the protection of data in terms of

property and copy. Is this really perceived as an issue from the CH community? May it have any impact on the publication of their 3D datasets?

- Managing reality-based 3D models over the Internet is not simple. Fixed resolution datasets must be completely downloaded to be available in the viewer. This may strongly impact on the performances of the Web3D applications (bandwidth requirements and latency times). Efficient multi-resolution data management based on compressed and progressive encoding and streaming, does exist and can mitigate these issues. On the other hand, multi-resolution formats need data pre-processing, and make difficult implementing sophisticated visualization strategies (i.e. multi-texturing, collaborative editing, etc.). Are these issues critical for CH professionals? What is it possible to do for overcoming them?

The work of this session is organized consequently, with the aim to present the results of the discussion and the insights gathered on these topics.

3.2. OpenSpace3D

3.2.1. General Presentation and Features

OpenSpace3D[11] is an open platform with a large range of uses, from a simple 3D model visualization to an advanced Augmented Reality or Virtual Reality application.

Developed and published by the **I-Maginer** / **Arinfo** company, OpenSpace3D is accessible to people without skills in computer development, to create applications for computers and mobile. OpenSpace3D is aimed at helping to study, evaluate, share and present to the public 3D data, work and concepts.

It is possible to create industrial grade applications or prototypes quickly through the visual programming method.

OpenSpace3D has a multitude of pre-programmed functions to create applications for:

- Augmented Reality;
- Virtual Reality;
- virtual tours;

[11] OpenSpace3D is the 3D Viewer of Consortium 3D for Humanities: https://shs3d.hypotheses.org/4275



- serious games;
- video games;
- connected objects or robots with Raspberry pi or Arduino.

OpenSpace3D is developed from the **Scol** language, modular and scalable and distributed under **LGPL** licence.

This general framework was used to configure a generic interface for a viewer dedicated to examine 3D models in the field of Cultural Heritage, even though it can fit other purposes. The way to produce this kind of application was thought in order to make it easier and can be synthesized in three steps:

1. Drag and drop your 3D model inside the OpenSpace3D's window;
2. Import the template of the 3D viewer;
3. Export your application into Windows, Mac, Android.

The main features of the 3D viewer template are:

- About object properties:
    - Switch between a set of materials in order to propose different kinds of visualization or layers of information;
    - Get some characteristics of the mesh or the point cloud selected (size in meters, number of triangle or dots);
    - Define the position, orientation and scale of the object, by entering the coordinates or by moving with manipulators.
- About light settings:
    - Activate and define the light of the sun; the 3D scene can be geolocalized;
    - Activate and explore a surface with a light moving alongside a dome;
    - Activate or deactivate shadows and / or ambient occlusion.
- About camera settings:
    - Switch between a fly or a first person point of view to explore the scene;
    - Switch between a navigation designed for objects (free orientation) and architectural exploration (where the horizon stay horizontal);
    - Choose the focal length or an orthographic view.
- And other actions:

- Create and orientate a plane section;
- Define the size of dots in point clouds;
- Annotate the model;
- Measure some distance in the model.

OpenSpace3D is used in many professional sectors – Industrial, Marketing / Events, Education, Research, Architecture and Games. Concerning Cultural Heritage, it allows visualization of 3D and point cloud models, and by adding a dedicated template, it adds tools to review and study these models that can also be enabled in Virtual Reality. OpenSpace3D can be used for museums and teaching to make playful applications to share with the general public.

3.2.2. Use Cases: Rock Art Visualization

Context:

Rock art documentation in Brittany (France) is the object of a research programme led by University of Nantes. The highest density of engravings is around the Carnac area and can be superposed with the territory concerned with a UNESCO project.



Figure 3: Screenshot of OpenSpace3D for the visualisation of neolithic architecture with Rock Art (cross-section of the Mané er Groez dolmen, Carnac)

Main issues OpenSpace3D allows to resolve:

Engravings can be found in a variety of situations, from isolated stela to complex architectures spreading over several kilometers in the landscape. Neolithic funerary architecture has a particularity strong relationship with the landscape, so we have to take this scale of representation into account. The difficulty of representation for this area can be solved thanks to a 3D representation of this territory in such a way that it is possible to go through a wide range of scales: from the infra-millimetric detail of the engravings to several hundred square kilometers of the geographical area.

It should be possible to show different layers of visualisation or information on a surface. For instance, for an engraved slab of stone, it could be interesting to switch between a coloured and relief-based representation, and to show different steps of rock art analysis coming from the ICEO protocol (Images Compilées sous Eclairages Obliques), such as outline synthesis, material removal synthesis and the interpretation of signs and symbols engraved. This is even more relevant since the engravings could be eroded and really difficult or impossible to detect with the naked eye.

It is important to share the data with other specialists (archaeologists, curators, etc.) who don't necessarily have much experience with 3D tools. Interacting with 3D models could then be difficult. The application created with OpenSpace3D gathers a wide bunch of tools in order to extract the information they are looking for. It is important too to transmit this knowledge to visitors, and especially when a UNESCO project is going on. With the same scene as basis, it is possible to create a new application designed for a museum, with all possible ways to interact with the 3D content, from augmented or virtual reality to connected objects.

In order to provide an answer to these issues, 3D models should be prepared in a specific way (Grimaud and Cassen 2019[12]). Then 3D data will be compatible with real-time visualization.

[12] Grimaud V., Cassen S., 2019. Implementing a protocol for employing three-dimensional representations in archaeology (PETRA) for the documentation of neolithic funeral architecture in Western France, in *Digital Applications in Archaeology and Cultural Heritage*, vol. 13, june 2019. https://doi.org/10.1016/j.daach.2019.e00096

3.2.3. Actual Limitations and Suggested Improvements

Offering support for 3D models directly compatible from 3DHop could simplify the process between the online visualisation tool and end user applications.

Also adding more dedicated documentation and examples that specifically aim at 3D models presentation, museums, architecture and teaching to help users to start with Openspace3D.

Some developments about the conservation of some information such as translation and rotation, and annotation should be perfected in order to make a standard useable with other tools.

3.3. 3DHOP

3.3.1. General Presentation and Features

3DHOP - 3D Heritage Online Presenter[13] (http://vcg.isti.cnr.it/3dhop) is a software solution aimed at building advanced presentations of high-resolution 3D datasets on the Web (Figure 4).

Developed by CNR as a publishing framework, it has been expressly designed for the Cultural Heritage (CH) domain. In this specific application field, digital 3D models are nowadays widespread, both for “technical” use (documentation, restoration support, study, and measurement), as well as for dissemination, teaching, and presentation to the public.

Enabling these uses require reality-based digitized geometries, essential to convey to the public the correct and qualitative information that lower-resolution hand-modeled 3D objects may not be able to provide. For this reason, the capability to efficiently stream and render high-resolution 3D models makes 3DHOP particularly suitable to the online presentation of CH artifacts.

In fact, the ability to work with gigantic 3D structures is one of the key features of 3DHOP. For doing this, the framework implements a cluster based view-dependent multiresolution

[13] Potenziani M., Callieri M., Dellepiane M., Corsini M., Ponchio F., Scopigno R., 2015. 3DHOP: 3D Heritage Online Presenter, in *Computers & Graphics*, Volume 52, November 2015, Pages 129-141. https://doi.org/10.1016/j.cag.2015.07.001



approach, Nexus [14] (http://vcg.isti.cnr.it/nexus), on top of the SpiderGL [15] library (http://vcg.isti.cnr.it/spidergl), obtaining very good performances, both in rendering and data transfer.

Thanks to Nexus, 3DHOP enables the interactive visualization of huge 3D meshes and point clouds (tens of million triangles/points), eventually equipped with per-vertex colors, normal vectors, and multiple textures, exploiting a compact representation in a compressed format.

However, efficient data handling is not the only characteristic that makes 3DHOP a valuable tool for the specific niche of CH users.

Indeed, exploiting intuitive interaction/manipulation paradigms and sophisticate linking schemes, 3DHOP simplifies the creation of interactive transmedia webpages in which 3D data are strongly connected with the other multimedia information typically composing a webpage.

[14] Ponchio F., Dellepiane M., 2015. Fast decompression for web-based view-dependent 3D rendering, in *Web3D 2015, Proceedings of the 20th International Conference on 3D Web Technology*, June 2015, Pages 199-207. https://doi.org/10.1145/2775292.2775308

[15] Di Benedetto M., Ponchio F., Ganovelli F., Scopigno R., 2010. SpiderGL: A JavaScript 3D Graphics Library for Next-Generation WWW, in Web3D 2010, *Proceedings of the* 15th Conference on 3D Web Technology, July 2010, Pages 165-174. https://doi.org/10.1145/1836049.1836075



Figure 4: A 3DHOP application developed by CNR-ISTI. In this example, a high-resolution 3D digitization (10 million triangles) of the Capsella Samagher, an antique reliquary, is presented with additional information (images and text). These information are linked to the 3D geometry through geometric hotspots (light-blue regions).

Moreover, thanks to its modular nature and a declarative-like setup, it is easy to learn and may be configured and customized at several levels, making it accessible for people with different programming skills, without requiring solid knowledge in Computer Graphics (CG) programming.

Finally, 3DHOP also provide a full set of interactive tools, most of them expressly focused on CH applications. A representative selection of these tools includes:

- *light tool*: enables the control of the lighting on the virtual scene. In addition to the global lighting control, through this tool the user can also interactively change the position of a point light source, moving and placing it everywhere around the 3D scene;
- *measurement tools*: two different tools enable the interactive retrieval of metric information. Specifically, the *point picker tool* gives access to the 3D coordinates of



a specific point selected in the virtual scene, while the *distance tool* enables the calculation of the linear distance between two 3D points ();

- *sectioning tool*: enables the visualization of planar sections of the model on the scene. Three orthogonal sectioning planes are provided, the proper use of them not only give accurate references points (for measurement or other needs, for instance), but also allows to visualize the internal parts of the 3D objects composing the virtual scene;
- *hotspot tool*: enable the interaction with geometric points of interest placed on the 3D scene. This tool allows the user to setup geometric hotspots on the virtual scene. These clickable objects can be used to link additional information to a 3D model or specific parts of it.

3DHOP is based on the WebGL component of HTML5, i.e. the JavaScript standard API oriented to Computer Graphics programming on the Web. Thanks to this, 3DHOP works without the need of plugins on the most common platforms (Windows, MacOS, Linux), on the most modern browsers (Chrome, Firefox, Edge, Safari), and on all the available devices (personal computers, tablets, mobile phones).

3.3.2. Use Cases

3DHOP has been released as open source (GPL licence) package. The downloadable archive, with a series of tutorials, how-tos, examples, and other resources, are freely available on its website.

Since the release date (April 2014), the framework has been welcomed by the user community, as the numbers concerning the accesses to the official website and the the software downloads, can easily witness. To date, the 3DHOP website counts around 48,000 accesses (an average of 800 accesses per month), while in the same period the 3DHOP package has been downloaded more than 4,400 times (an average of 74 downloads per month).

From these numbers, it can be seen that 3DHOP is currently used in many real-world projects, able to cover a heterogeneous set of publication domains, needs, and purposes. A couple of these has been selected as representative use cases to be shown here.

The first case study presented[16] is a publishing action commissioned by the Peggy Guggenheim Collection museum and focused towards dissemination purposes.

In the specific case, this contribution retraces the steps of a real campaign that, starting from a very peculiar artifact (the modern-art painting Alchemy, by Jackson Pollock), 3D digitized for conservative and diagnostic purposes, led to the design of a Web3D application (see Figure 5) used in a virtual exhibition, as well as museum kiosk in a real exhibition. This interactive application aimed at exploiting the high-resolution 3D model for explaining to the museum public the gestures, actions, and techniques characterizing Jackson Pollock's art.

In pursuing this purpose, the 3DHOP code has been extensively customized for obtaining a 3D viewer tailored to the most interesting aspects of the analysed artwork. By exploiting the modularity of the framework, this project showed how to use very few interaction tools to set up a minimal interface, suitable for not overloading the museum visitors with too many technicalities.

[16] Callieri M., Pingi P., Potenziani M., Dellepiane M., Pavoni G., Lureau A., Scopigno R., 2015. Alchemy in 3D – A Digitization for a Journey Through Matter, in *Proceedings of 2015 Digital Heritage International Congress*, Volume 1, October 2015, Pages 223-231. https://doi.org/10.1109/DigitalHeritage.2015.7413875

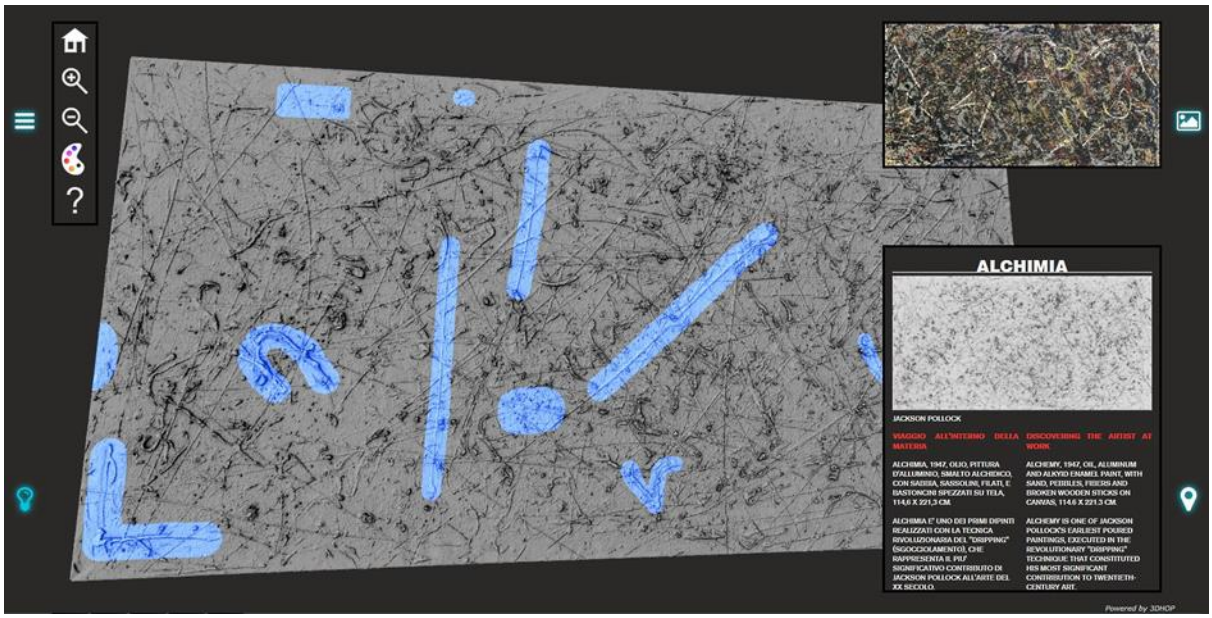


Figure 5: The Alchemy interactive 3D viewer developed using 3DHOP. Three different 2D interface elements are visible, superimposed to the 3D model: the main menu pane, the 2D mini-map, and the informative component.

The resulting Alchemy interactive 3D viewer uses the 3DHOP hotspots to create interactive elements, while custom components were developed to ease the navigation (the mini-map, the modified trackball), and enhance the visualization (custom shaders).

This use case also highlights another interesting 3DHOP feature. Indeed, exploiting the fact that 3DHOP is a client-side system, this project shows that is possible to develop a viewer both accessible on-site as a (museum) kiosk running on a local Internet server, and on the Internet as a classic Web3D application running on a remote Internet server, with almost no changes to the code.

Both Internet and kiosk applications have been exploited in the Guggenheim temporary exhibition “ALCHEMY BY JACKSON POLLOCK. Discovering the Artist at Work”, running in Venice (Italy) from February to September 2015, totaling more than 180,000 visitors. Later on, the kiosk was used in a similar initiative at the Guggenheim Museum in New York (USA), while the Web3D app is still accessible today (http://vcg.isti.cnr.it/alchemy).

Apparently, similar to this case study, the second contribution presented[17] is actually very different in the publishing purpose. Indeed, even though both the proposed use cases explore the possibilities of a specialized Web3D content creation, the first one proposes an example of publishing aimed at supporting dissemination to the public, while the second one has been developed for supporting scientific analysis.

More specifically, this contribution introduces a publishing action aimed at a technical data presentation. In this case, the main goal was to build a tool supporting experts in their work of study and documentation of an archaeological find (the “Annona” Roman marble sarcophagi, II-IV century AD).



Figure 6: The Annona Sarcophagus Web3D platform developed using 3DHOP. Detail of the specialized panel enabling the visualization of the selected areas where the VIL specialistic analysis were performed.

The project exploits all the data produced during the campaign of study on this artefact, integrating them with a high-resolution 3D digitization of the same, so as to support enhanced analysis, comparisons, and even a digital 3D polychrome reconstruction by virtual painting.

[17] Siotto E., Palma G., Potenziani M., Scopigno R., 2015. Digital Study and Web-based Documentation of the Colour and Gilding on Ancient Marble Artworks, in *Proceedings of 2015 Digital Heritage International Congress*, Volume 1, October 2015, Pages 239-246. https://doi.org/10.1109/DigitalHeritage.2015.7413877

Finally, all those data are made accessible on the Internet, using the 3DHOP framework to design and develop a visual media platform (Figure 6) aimed to provide domain's practitioners with a new interactive 3D assessment tool.

Through a substantial customization of the 3DHOP original user interface, the resulting Internet viewer is able to exploit the 3D models as main channel to manage and display all the achieved scientific analysis and historical information about the artefacts, integrated into a single reference system.

3.3.3. Actual Limitations and Suggested Improvements

3DHOP can be considered a fully qualified solution. Since the beginning it has been well accepted by the community, and nowadays it is largely used by many universities, important institutions, and freelancer Web3D content creators.[18]

Despite being an established tool, 3DHOP is still an ongoing project: it has significantly grown since the first release and is still growing.

Since it is a modular framework, many features and components were added over time, and many others will be added in the future for supporting the creation of more flexible and effective interactive visualizations. The enhancements and extensions on the to-do list include:

- Novel navigation and visualization components (new trackball types, new scene manipulation functions, configurable shaders to be selectively attached to each instance);
- Dynamic definition of the 3D scenes (novel methods for dynamically adding/removing entities, or for modifying their transformations and properties);
- Authoring services (visual editor or wizard tools to make easier the setup of a visualization scheme).

[18] Potenziani M., Callieri M., Scopigno R., 2018. Developing and Maintaining a Web 3D Viewer for the CH Community: An Evaluation of the 3DHOP Framework, in Proceedings of 16th Eurographics Workshop on Graphics and Cultural Heritage, Volume 1, November 2018, Pages 169-178. https://doi.org/10.2312/gch.20181356

The PARTHENOS workshop on the uses of 3D data in Humanities and Social Sciences has been a good opportunity to submit the 3DHOP to a selected and qualified audience, gathering impressions and suggestions about the framework and its future development.

Analysing the participants feedback, there particularly emerges a general request for focusing the effort on the 3D data enrichment through an improved annotations management *("...it's important to put the same level the 3D object with the archaeological context..."*, *"...a more intuitive annotation system would definitely be of benefit..."*, *"...in the future, I think that the annotations and the sharing of metadata could be developed further..."*), somehow confirming the need/willingness to converge towards authoring helpers, possibly implemented as a service.

Again on annotations, remarks concern also their standardization (*"...to develop an annotation standard for 3D models just as TEI was developed for annotating text documents in XML format..."*), and a goal to possibly join forces with other platforms presented during the workshop (*"...I would love to see is that Aioli and 3DHOP join forces in how annotations are stored, in order to get to a more standardised way of annotating 3D models..."*).

Finally, minor indications involve the 3D data pre-processing (*"...what I found difficult is, sometimes, to create and compress texturized models with NEXUS..."*), the opportunity to rely on coding structures that are more Internet-based (*"...maybe for the future it would be great to avoid the coding for the user and to use some tag representation like XML..."*), and the possibility to manage different textures on the same geometry.

However, generally speaking, once again the 3DHOP framework has been very well received, with much positive feedback witnessing the participants global satisfaction:

- *"...great tool with very wide possibilities that can be used each in a customized way [...] very smart..."*
- *"...this tool is a nice solution to share our 3D acquisition..."*
- *"...it is a very powerful tool which allows users to adapt it for very different and specific applications..."*
- *"the tool is very well designed and I have already used it under several occasions [...] the documentation is very clear and even a user with a very basic knowledge of HTML can set up and run a model in minutes..."*



- *"...I've been using 3DHop since several years and for different dissemination projects [...] in my opinion, one of its greatest strength is its versatility and customization..."*
- *"...3DHOP has proven its potential and is widely used in heritage for both student, as well as professional projects [...] it is great that its developers are committed to its sustainability and user-friendliness..."*
- *"...great tool, easy to use, with very wide possibilities that 3DHOP can be used like solution for publishing 3D models of archaeological objects..."*
- *"...I really liked 3DHOP, I think that it has a huge potential and, the most important, not only on a CH context..."*
- *"...3DHOP is fantastic tool, and in my mind is the go-to tool for sustainable 3D visualisation..."*.

3.4. Visual Media Service

3.4.1. General Presentation and Features

The Visual Media Service[19] (https://visual.ariadne-infrastructure.eu) offers a very easy solution for publishing online different visual media and for visualizing them under a common framework (Figure 7).

Developed by CNR in the framework of the EC projects ARIADNE and PARTHENOS, it is implemented on top of the 3DHOP (http://vcg.isti.cnr.it/3dhop) and Relight (http://vcg.isti.cnr.it/relight) technologies. It was designed as a service-oriented platform for assisting the deployment of Internet presentations pivoted on three complex visual media assets: high-resolution 2D images, RTI, and 3D models.

These types of media are still not very common on the Internet, because their visualization may require the download of the entire file (long transmission times discourages the users), and possibly having to select/install dedicated software (viewers).

[19] Ponchio F., Potenziani M., Dellepiane M., Callieri M., Scopigno R., 2016. ARIADNE Visual Media Service: Easy Web Publishing of Advanced Visual Media, in *Proceedings of the 43rd Annual International Conference on Computer Applications and Quantitative Methods in Archaeology*, Volume 1, March 2016, Pages 433-442.

The Visual Media Service approach is to build an automatic service able to transform these media into progressive formats that will allow easy and efficient access and visualization on the Internet.

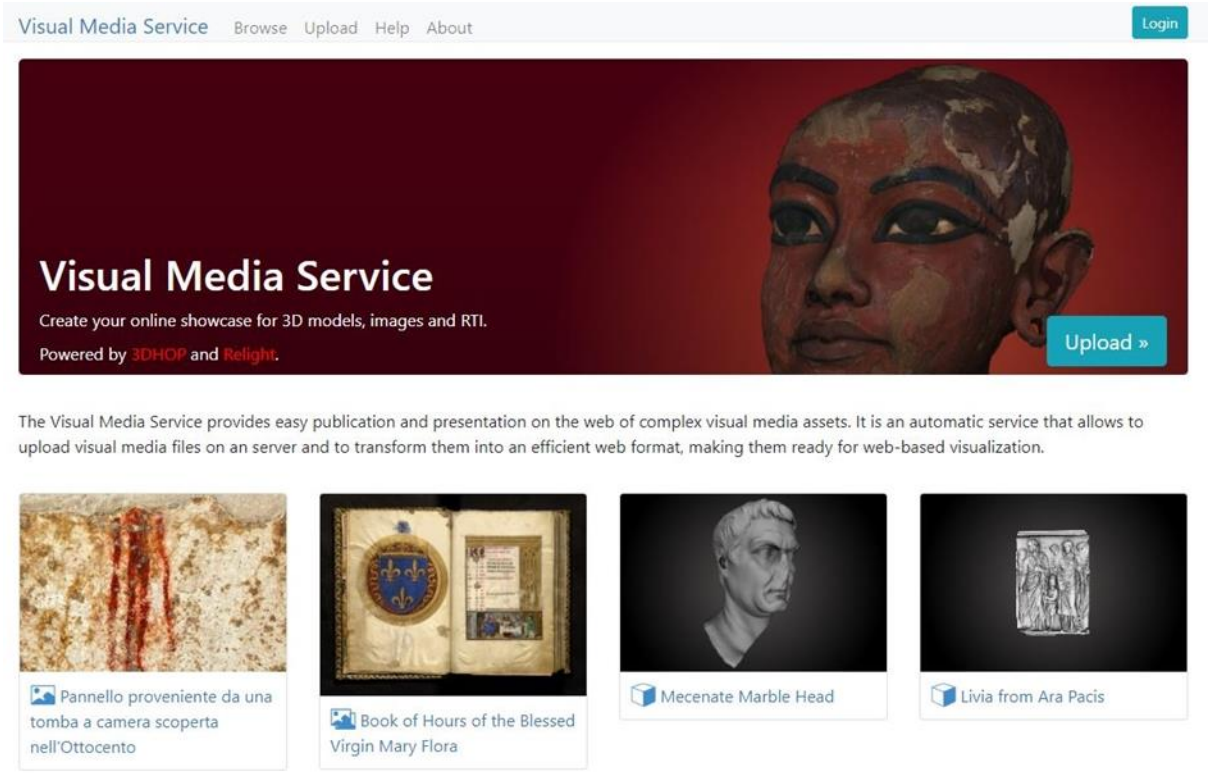


Figure 7: The Visual Media Service Internet site landing page. Accessing the service, the user finds a simple Internet form that allows to upload its own data (3D models, hi-res 2D images, or RTIs) and to provide some basic information about the published media.

The efficiency of the final presentations is gained by endorsing these efficient data representation schemes, but also by the design of proper GUI (viewers). With this setup, even unskilled users can easily create an efficient webpage to display complex 2D or 3D content.

The service is based on a simple Internet interface that allows uploading the visual media file of interest and (after some processing) to receive the URL where the specific data has been stored and could be accessed for the visualization.

Alternatively, for more experienced users, these basic webpages may be the starting point for the development of more complex visualization, or for the integration of this



visualization inside existing websites, taking advantage of the features of the 3DHOP and Relight platforms.

So, the main advantages of using the Visual Media Service are essentially two: the simplicity of use and the easiness of customisation of the assisted presentation (gained exploiting Internet forms and visual setup wizard); and an efficient data transfer and a high-quality visualization on the Internet (gained thanks to the use of performing multiresolution schemes).

The progressive data structures used also led to another indirect advantage, providing some sort of protection for the original data, too (since a direct download of the multimedia file in a single plain format is not straightforward). This is a valuable strength in the CH domain, since often the owners of high-quality datasets prefer not to allow visitors to freely download them, in order to protect the ownership of the data.

3.4.2. Use Cases

The goal of the Visual Media Service is to provide an online publishing service focused on a selection of high-resolution media, accessible for CH professionals and their datasets.

We chose to manage three different media types in our server: high-resolution 2D images, RTIs (i.e., dynamically re-lightable images), and high-resolution 3D models.

After accessing the service, a simple Internet form allows the user to upload the selected data, plus some basic metadata about the represented model. The service processes the input data in an automatic way and creates an online page.

At the end of the processing and format conversion phase, the user receives an email containing a link to the visualization page (hosted on the Visual Media Service server) and to an admin page, where the associated data can be modified.

The content creator can decide whether keep the visualization private (in this case it will be accessible only if the user provides the direct link) or publish it on the Visual Media Service server (in this case it will be publicly accessible).

The admin page also provides a downloadable archive with the created page (HTML code plus the processed 3D model or 2D image), and the iframe version of the viewer, both to be embedded on a user's local server or archive.

3D Models

In the CH domain there is a pressing need for platforms supporting easy publication of 3D models on the Web, mostly aimed at these sampled/digitized 3D objects. These complex data structures, generally rich of informative content, cannot be confined to the single local archive, but should be shared with the community, to increase knowledge and stimulate further study.

The visualization of high-resolution 3D models in the Visual Media Service is based on the 3DHOP framework. Initially, the model to be visualized is automatically pre-processed and converted in the Nexus format. Then, an HTML and JavaScript implementation of the 3DHOP is created. The resulting Internet page provided to the user consists of the classical WebGL viewer with a default toolbar (Figure 8).

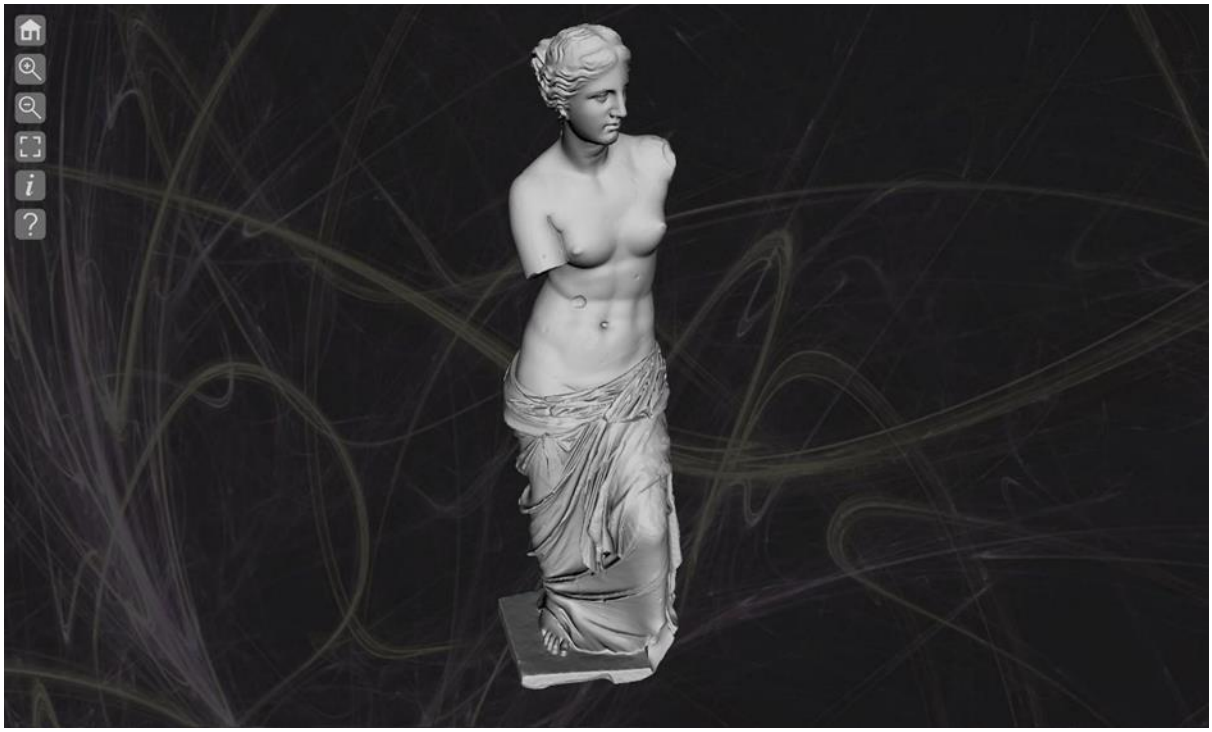


Figure 8: A visualization page automatically generated by the Visual Media Service for browsing a 3D model.

High-resolution Images

High-resolution images are now a commodity resource, with the impressive evolution of digital photography and the wide availability of tools that allows aligning and stitching image patchworks, allowing users to reach huge image resolutions.

In the Visual Media Service, high-resolution images are transformed into a multi-resolution format, supporting progressive streaming. The service transforms each image in a Internet-compliant format: similarly to Google maps, the high-resolution image will be regularly divided into tiles and a hierarchy of images at different resolutions is produced from these tiles. Finally, using the Relight JavaScript component a rendering webpage is created. Here is possible to navigate the image in a WebGL frame equipped with a 3DHOP-like interface (Figure 9).



Figure 9: A visualization page automatically generated by the Visual Media Service for browsing a 2D high-resolution image.

Reflection Transformation Images (RTI)

Re-lightable images are becoming an increasingly used technology in CH. They allow acquiring detailed and interactive documentation of quasi-planar objects. RTIs are particularly useful, especially for objects characterized by complex light reflection attributes. The advantage of this representation is the possibility to change the light direction over the images in real time, and the availability of using enhanced visualization modes to better inspect fine details of the object's surface.

RTIs are managed similarly to high-resolution images (so, adopting a tile-based hierarchical approach), even if the encoding for the Internet streaming is a bit more complex. The visualization of these images relies on the Relight component. It manages the rendering of the RTI in real-time thanks to a particular shader that takes care of the input and calculation of the variable-lighting. Once again, in the end, the interactive visualization happens in a WebGL component providing a 3DHOP-based interface (Figure 10).



Figure 10: A visualization page automatically generated by the Visual Media Service for browsing an RTI image.

3.4.3. Actual Limitations and Suggested Improvements

The Visual Media Service represents a first step toward the automated/assisted integration of complex digital visual assets in the context of archaeological datasets.
It is still a young project: future enhancements and extensions have been already planned, and will be implemented in the next years. Concerning these improvements, the current road map includes enabling the support of:

- Additional types of data (such as: DEM - Digital Elevation Models, acquired by airborne lidar technologies and managed as 2D and ½ terrains; HDR - High Dynamic Range images, directly handled as native HDR data after an automatic and on the fly conversion from the LDR format);
- New specialized analysis tools (enabling more specialized and complex analysis on the supported datasets);
- Increasing flexibility (it includes: a wider set of scene definition customizations, with the possibilities to furtherly personalize the browser layout and the virtual scene features; an improved uploading section, possibly allowing to enrich the uploaded datasets selecting structured metadata schemes).

Initial testing, started on selected data provided by the Archaeology Data Service, Discovery Programme, and other partners of the ARIADNE project, has been quite positive. Now, through feedbacks from an authoritative point of view, the PARTHENOS workshop can be seen as a good chance for confirming or not these preliminary assessments.
Analysing the various impressions expressed by the workshop participants, together with positive remarks (*"…a great valorisation of the NEXUS tool…"*, *"…I liked the idea of a repository of 3D CH models and the more usable way to publish your 3D models respect using directly 3DHOP…"*), there can also be found some interesting suggestions, such as the request for collaborative features (*"maybe for the near future, a good extension can be allowing collaborative work on projects…"*) or for joint collaborations (*"…what about linking it with an annotation system such Aïoli?"*).
However, once again, what clearly turns out is a neat need for standardized methods concerning all the 3D working pipeline: data production, enrichment, visualization, and

sharing (*"…we need to explore ways to publish 3D scholarship as such, in which 3D model is seen as text and all arguments, decision making processes, metadata, and paradata are included/embedded in the model itself, and can be accessed by researchers [..] to date there have been a few attempts to include annotations within 3D models, however, Internet platforms […] are often quite limited in that respect as they cannot capture the depth of a decision making process…", "…it's highly important to standardise the manner of sharing our 3D production…"*, *"…what I think is inherently missing from the service, is a coherent metadata schema to attach to the uploaded model…", "…what about IIIF for 3D visualization?"*). Unfortunately, even if all these remarks are certainly acceptable, just few of them (annotations?) can be realistically adopted by publishing platforms like the Visual Media Service, while all the others risk to be out of the scope of this kind of service (and eventually require discussion by a wider audience of actors/institutions).



4. Store and Preserve

4.1. Mission Statement: Life Cycle of 3D Data for SSH

4.1.1. Introduction

In recent years, three-dimensional representations have become particularly important in the study of cultural heritage. Acquisitions in the field can document a snapshot that can serve as a support in the future for the study of the evolution of the heritage remains, offer restitutions of the various stages of its existence, propose the best operations for its conservation, without evoking the mediation aspects. The value of these heritage representations is considerable.

In this context, the durability of three-dimensional models becomes a crucial issue. However, this is a complex aspect that requires rigour in the method of work, organization, and anticipation of this goal from the beginning of the documentation project. In short, since archiving is the final step in a data management plan, a Data Management Plan should be established. We present here some recommendations issued from the on-going work of the Huma-Num Consortium 3D for Humanities[20].

4.1.2. General Issues about Archiving

The archiving of digital data comes several kinds of issues: preserving the existence of the file which is a kind of a container, ensuring the readability of the file and ensuring the intelligibility of the content.

First, **documents must be preserved through time**. It means that mechanical problems have to be taken in consideration by keeping multiple copies of files, on different supports and in different locations. This procedure should be accomplished in a logical way in order to know what is inside which library, with no risk of forgetting the existence of some files.

Then, we should **ensure access to the document**. Because file formats evolve, future software may not recognize the file from today… So, the content must be saved in human-

[20] Robert Vergnieux, Jean-François Bernard, Mehdi Chayani, Violette Abergel, Pascal Benistant, et al.. Livre blanc du Consortium 3D SHS. France. 2017. 〈hal-01683842v2〉

readable and documented format. Thanks to this precaution, it should be possible to recompile the file according to new specifications. With this issue in mind, the French Institute CINES offers a tool to validate the conformity and the evolution of *.dae and *.ply file format.

Finally, **the intelligibility of the document must be preserved** too. Future users should trust the data they don't produce themselves. So, they have to understand why this 3D model was produced, with which technology, how the data was processed… All this kind of information can't be integrated inside the document, but kept alongside it. The information is presented as metadata (in an *.xml file) and paradata (such as *.odt file) of the main file.

3D documentation produces many files. For instance, a 3D model is, at minimum, composed of a geometry file (*.ply for instance) and texture files (such as *.jpg). Since the 3D model is produced with a scientific purpose, it should be accompanied by the datasets coming from the recording process (such as point clouds of lasergrammetry or all the pictures from photogrammetry). To achieve in an easy way the production of an archive, we have to **select the pertinent file** (i.e. intermediate files shouldn't be present in the digital archive). The collection of these pertinent files inside the folder tree of the documentation project must also be facilitated. In summary, this means that we should take care about the location of the files and their names. Finally, technical documentation in compliance with archive requisites (*.xml file format) are not so easy to produce.

4.1.3. General Pattern of 3D Data Life Cycle

The selection of the file will be easier when the life cycle of 3D is explained. Four main steps are identified (see figure below) from: Collected Data (A0), Processed Data (V0), Hypothesis and Restitution (V2 with eventually several $V1_n$), to Deliverables and Valorizations (V3).

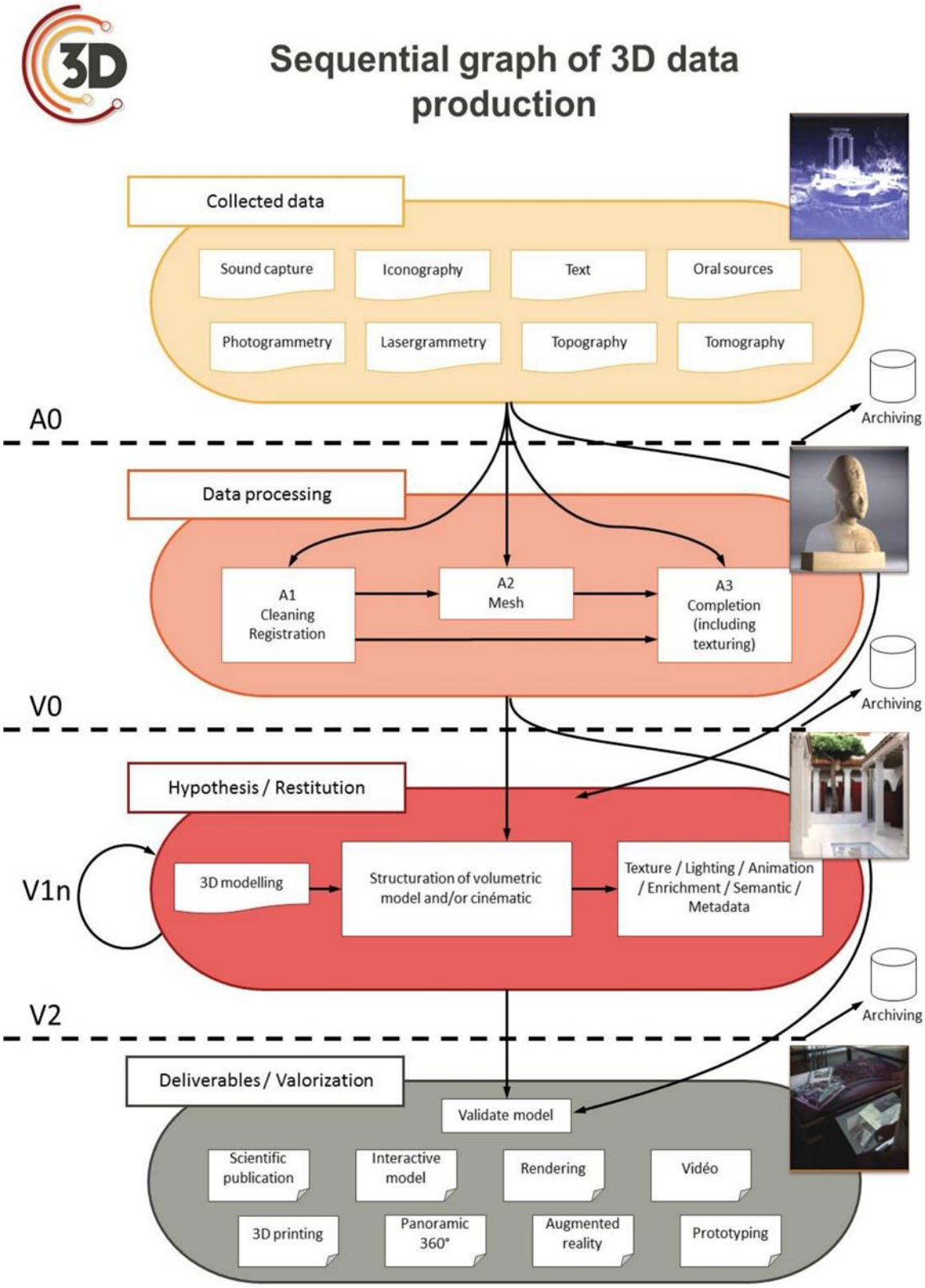


Figure 11: Sequential graph of 3D data production

Collected Data (A0)

Several media could be useful for 3D documentation in Cultural Heritage. We can cite for instance: Photogrammetry, Lasergrammetry, Topography, Computed Tomography, Iconography, Text, Oral Sources, Sound Capture, etc.
These documents are the raw data for the documentation process, and they should be archived in a compatible file format that we can ensure can be read for a long period (see Section 4.1.5.).

Data Processing (V0)

The collected data are then processed. When this step is finished, the result has a label *V0*. Three sub-steps can be identified: Cleaning and registration (A1), Mesh creation (A2) and Completion (including texturing) (A3). This 3D object is the result, at a given time, of a scientific process validated by a researcher.
If there is no future work on this 3D model, this step has to be archived and it is considered as a final object. Otherwise, it is not preserved.

Hypothesis and Restitution (V2 with eventually several $V1_n$)

The work with 3D models can be extended with the expression of hypothesis and restitutions. Each hypothesis could be transposed in a modification of the 3D model. Therefore, there can be many versions of the 3D model. At the end of the process of research hypothesis there is one final version of the 3D model that we named V2 (whatever the number of intermediate versions).
This final step, V2 is the result of a rich and long process that ends with a common agreement on the 3D object: there is a scientific validation of the 3D object.
This is the version of the 3D object that must be archived, not the intermediate versions. But, all the arguments that lead to this restitution should be written up and integrated as a paradata file into the deposit.

Deliverables and Valorizations (V3)

The V2 3D model may be used in different ways and manipulated. For instance, it could be the basis of a scientific publication, integrated in a VR or AR application, 3D printed, rendered as an illustration or a video, etc. These derive directly from the latest validated 3D model and are formatted in different ways. And, since they can be more or less easily reproduced, and made even better as time goes by, they are not relevant for archiving. Moreover, they do not produce additional knowledge about the 3D model.
The data that should be considered for archiving 3D object are of many kinds:

- The 3D model itself, V0 OR V2, depending on the project: if it is an “acquisition” then it is a V0. If there is modelling with hypothesis and restitution, then it is a V2. If a project includes both an acquisition and restitution we suggest that only the V2 version goes to the archive.
- That is the first part of the archive, then:
    - all sources that allow the recreation of the 3D object V0, in the case of acquisition. That is to say, the sources.
    - all sources that explain the processing of the 3D object in the case of 3D data modeling, that is to say a V2 object with the hypothesis of restitution well documented…

These recommendations could represent many files. Therefore, a methodology to easily find all your data and understand what is inside should be adopted. Otherwise, creating a deposit could be very difficult. The next steps are an example of how to solve and anticipate these aspects.

4.1.4. Defining a Classification Plan

A classification plan shouldn’t be too detailed, and should be classificatory. In this way, each file has only one possible place.
For the Rock Art documentation in Neolithic context in Brittany (France), the main folder of the project is named after the archaeological site number, the year of documentation and the site name. Then, for each subfolder, a prefix is used in order to classify them.

- “0” is for some generic information like administrative documents, assets used currently during the documentation process, and miscellaneous information.
- “1” stands for all the files used to produce 3D data: 3D acquisitions (photogrammetry, lasergrammetry, etc.) and historical sources which will help to argument restitution.
- “2” is for software used to transform 3D data, like Photoscan, or Blender, etc.
- “3” is the process to obtain a V0 model, with a distinction between point clouds and meshes.
- “4” is for the process of restitution and hypothesis, and other folders can be created until the step V2 is reached.
- “5” is for all the production derived from the final step of the study (V0 or V2 according of the purpose of the study).

This classification plan can be downloaded from a gitLab repository[21].

4.1.5. Choosing a Perennial File Format

Even if the archive is oriented toward 3D models, a wide range of media can be integrated. In order to allow future accessibility and readability of the file, only open, free, normalized, widely used file formats must be used. Moreover, the existence of a conformity control tool will guarantee the ability to reopen the file in the future. In order to facilitate the choice, following the recommendation of CINES is a good practice.

The CINES is the “Centre Informatique National de l’Enseignement Supérieur” (National Computer Center for Higher Education) that ensures archiving of digital data and documents produced by the Higher Education and French Research community. The CINES is a certified center with DSA (Data Seal of Approval). Archeovision, leading the Consortium 3D for Humanities together with the CINES has worked out the archiving of 3D data by developing 3D data validator for *.ply and *.dae files (work in progress for the dae validator).

The list of all the file formats accepted can be found at this link: https://facile.cines.fr/ (consulted the 26/03/2019). An overview for each media is shown in the following figure.

[21] https://gitlab.huma-num.fr/vgrimaud/PETRA (consulted the 26/03/2019)

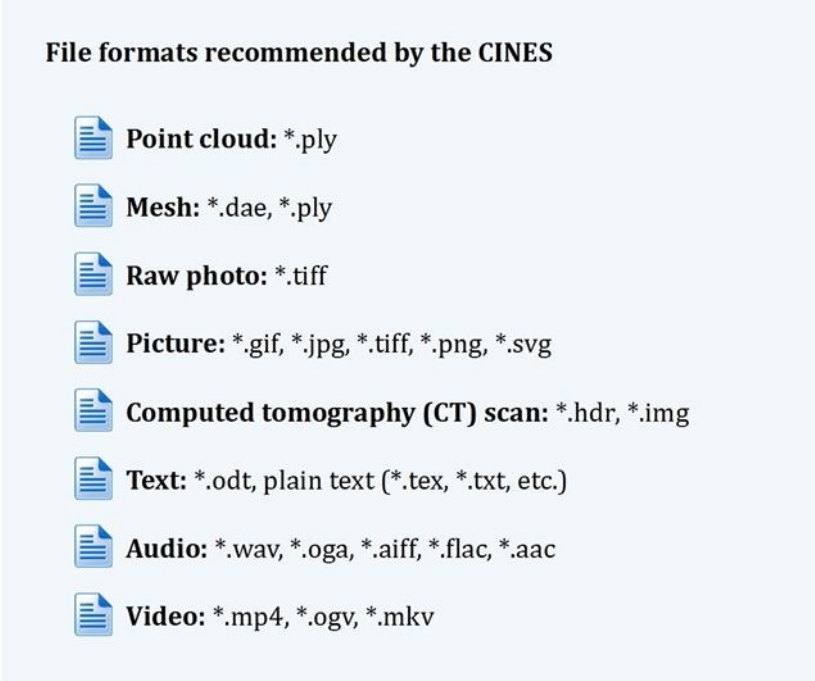


Figure 12: File formats recommended by the CINES according to the main data type used in a 3D project

4.1.6. Defining a Naming Plan

The name of a file is a way to indicate what is inside, what it represents. Sometimes, a lot of files are produced during a study. The name should be simple, short, documented, sustainable, and the creator should also avoid simple errors like special character, spaces, and lower/upper case.

For the Rock Art documentation in Neolithic context in Brittany (France), this system was chosen:

- Mesh: `[archaeologicalSiteNumber]_[typeObjectRepresented]_[nameMesh]_[date].ply`
- Texture : `[baseNameMesh]_[tag]_[ID].jpg`

where :

- `typeObjectRepresented` is for instance “stone slab”, “internal structure”, “tumuluar structure”, etc.



- `tag` is a family of information and `ID` a member of this family

The detail of this naming plan can be found on a gitLab repository[22].

4.1.7. Keeping Track of the Evolution of your Data Management Plan

All this advice is part of a Data Management Plan (DMP) that has to be maintained throughout the project. One of the easiest ways of doing this is to create a *git* repository. All documentation is in one place, and it is possible to keep track of all the modifications.

4.1.8. Conclusion

Archiving 3D models means anticipating a lot of complex issues. The easiest way to resolve these is to coordinate your efforts with another institution, and to create a data management plan stored in a *git* repository. This will guide users through different steps, and produce the data in the right way. It will avoid having to rethink the tree structure of a project, or reopen it in order to convert it into the right file format, rename, and all other fastidious operations at the end of a documentation project. Only one example was given, specific to the Rock Art documentation. Other templates should be given as examples.
The technical part concerning the production of metadata associated to each file is not an easy task without the appropriate software. In order to help on this specific task, the software aLTAG3D was developed by the Consortium 3D SHS.

4.2. The aLTAG 3D Tool

4.2.1. General Presentation and Features

aLTAG3D[23] stands for “a Long Term Archive Generator for 3D data”.

[22] https://gitlab.huma-num.fr/vgrimaud/PETRA (consulted the 26/03/2019)



In France, to preserve 3D data on a high quality basis, with safe backup, the Consortium 3D for Humanities is working on a repository hosted by Huma-Num, a solution for 3D data produced in the context of French Higher Education and Research in Digital Humanities. Every deposit comes with a minimum set of metadata, Dublin Core compatible and OAI-PMH harvestable.

To go further and ensure long-term preservation, Consortium 3D for Humanities is also working along with the CINES: now, thanks to the work achieved (by Archeovision), one of these validators has been integrated in the CINES platform and the archiving process for 3D object is operational, since March 2019.

In every case of long-term preservation, metadata have to be provided. It keeps data comprehensible, by machines as well as humans. Since the process is generally time consuming and complex, the Consortium 3D for Humanities decided to promote the archiving process to the community by giving it a tool to simplify this step (providing metadata for an archive) in the life cycle of the data.

aLTAG3D will deliver metadata about a 3D archive but also generate specific metadata for each file of the archive and general metadata suitable for the management of the archive, creating an archive in total compliance with the CINES requirements.

When the Consortium 3D for Humanities decided to develop the tool aLTAG3D, it came with some other requirements to be added to the main features, among which were: a friendly interface, a powerful engine, scalable to face schema evolution. This last point has already been proved because between the end of the development and the final tests, some required metadata had to be added by the CINES which we had to take into account in the software, and which is now done.

Using aLTAG3D assumes that the upstream work had been done, choosing which files should be in the archive (and which should not) with which format, depending on the type of file (*.ply or *.dae for 3D data …).

The features:

The main feature of aLTAG3D is generating a suitable archive for the CINES, which implies other features such as adding files in the archive and entering metadata at different

[23] aLTAG 3D: http://altag3d.huma-num.fr/

levels. The archive thus produced is ready to be delivered to the CINES, without any added processing.

Another important feature is to generate an information report on the archive, in PDF or HTML format, summarizing information collected via aLTAG3D.

Other features are implemented for a better user experience as follows:

- Create a project;
- Save the current project;
- (Re)Open a saved project;
- Enter metadata in « box »manually;
- Drag and drop files in « box » of the project;
- Generate new boxes to add virtual objects (3D) or sources document in the current project;
- Generate metadata on files automatically, thanks to plugins that have to be activated in the software (see picture);
- Check integrity of the project (in order to generate an archive).

Other features are available for an even better user experience:

- When filling metadata fields, some information is required, some other fields are not. Different colours are used in the interface to indicate this: some fields of the forms are red (mandatory) while other stay dark-grey (optional);
- The colour switch of boxes is used to indicate validation (green) or invalidation (orange) of boxes for archiving;
- The colour switch of form fill to indicate missing (red) or already filled (dark grey) value of required metadata information;
- Change setting of interface colour (choose between dark and light colours);
- Change setting of font size (for better reading);

- Move the panel of metadata to be filled in the screen (detached from the main panel) for a better view of the information (for instance, use multiple screen: one for the graphic boxes, one for the forms to fill);
- Zoom in or out for a better view of the project (see all the boxes at a glance or zoom in a specific part of the project including only a few or just one box).

The picture (figure 13) represents the main interface of aLTAG3D that appears the first time you create a new project: the minimum boxes are represented and in the panel to the right is the form to complete for the highlighted box: archaeological data for the deposit (in French in the picture).

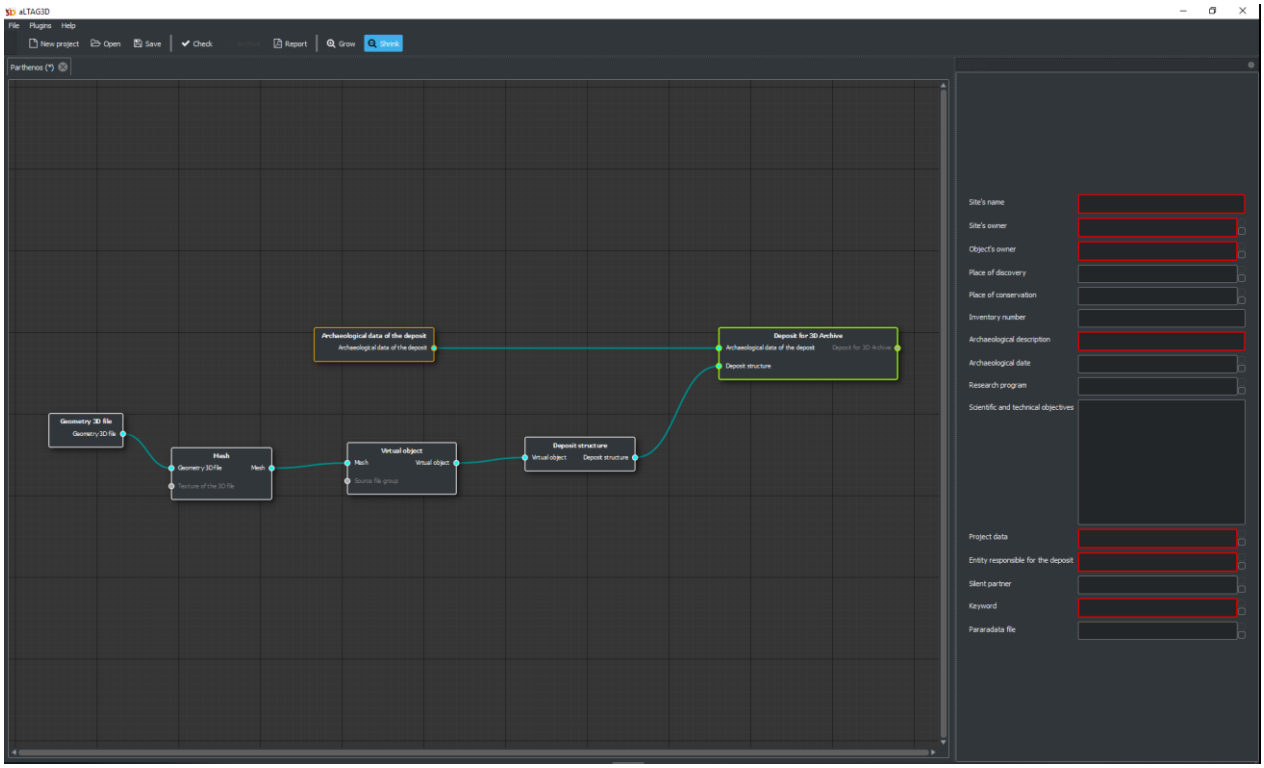


Figure 13: General presentation of aLTAG3D

4.2.2. Use Cases

A. Generate an archive including making all its documents accessible

- Create a new project;

- Edit the form of the project, fill it;
- Add new files in 3D boxes, fill the associated forms (see figure 14);
- Add new source files in source boxes, fill the associated forms;
- Activate plugins in order to automate as much as possible the form filling to simplify the package generation (see figure 15);
- Automatically generate remaining information;
- Check validity of the project (see figures 16 and 17);
- Generate the archive;
- Fill the last form for the management of the archive;
- Generate the archive: a new directory is created on the computer using aLTAG3D. The folder is named SIP and contains 2 XML files, one for the SIP archive, one for the 3D information. It contains also any other files added by the user through aLTAG3D interface.

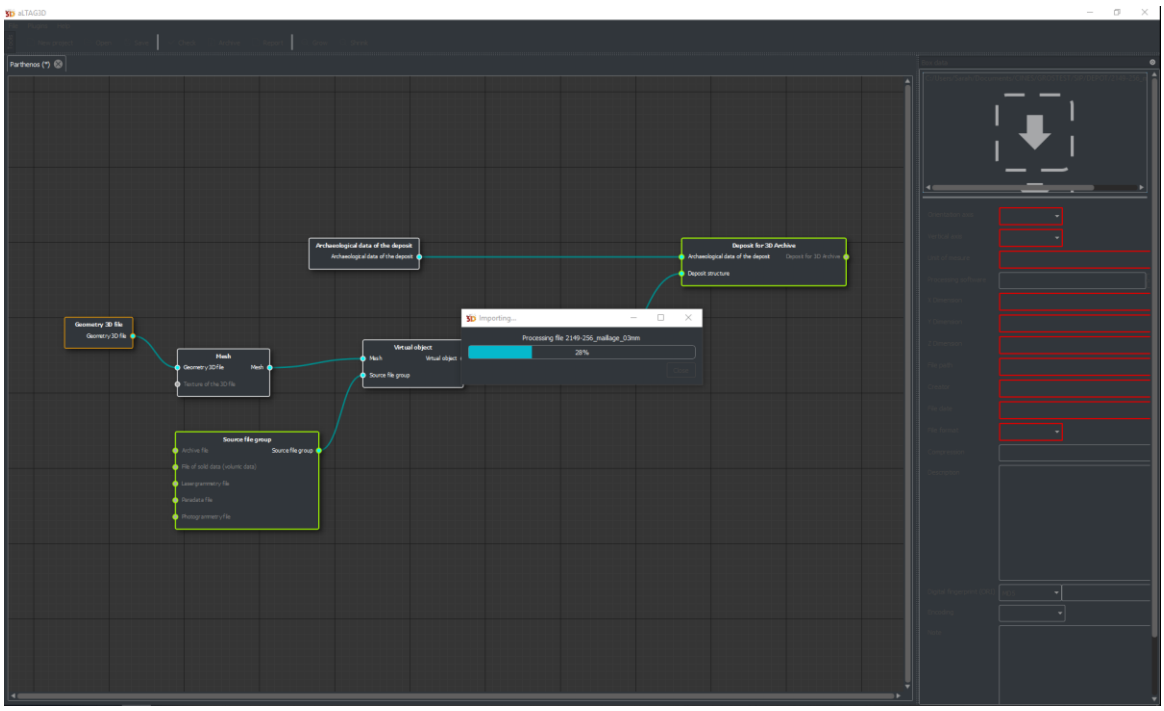


Figure 14: Drag and drop file

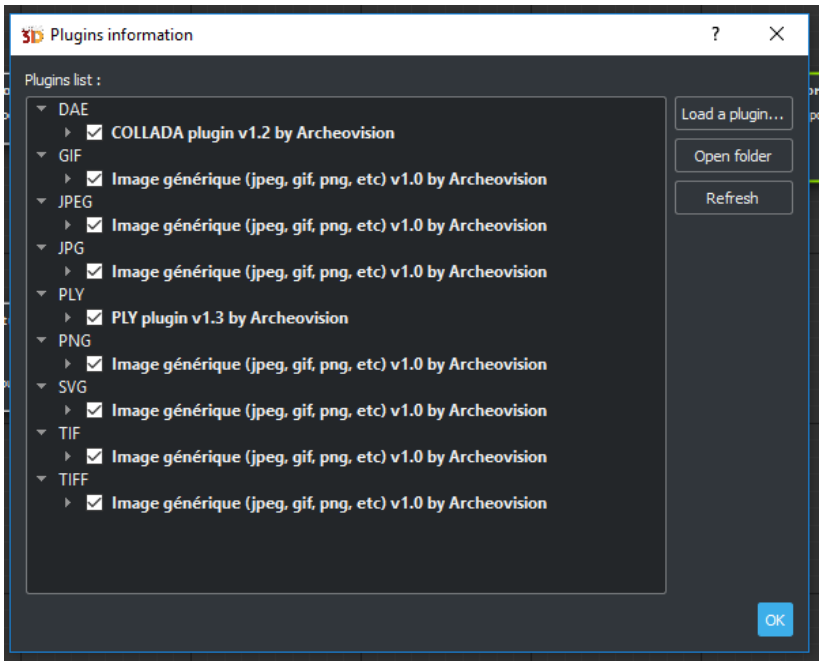


Figure 15: Plugins List

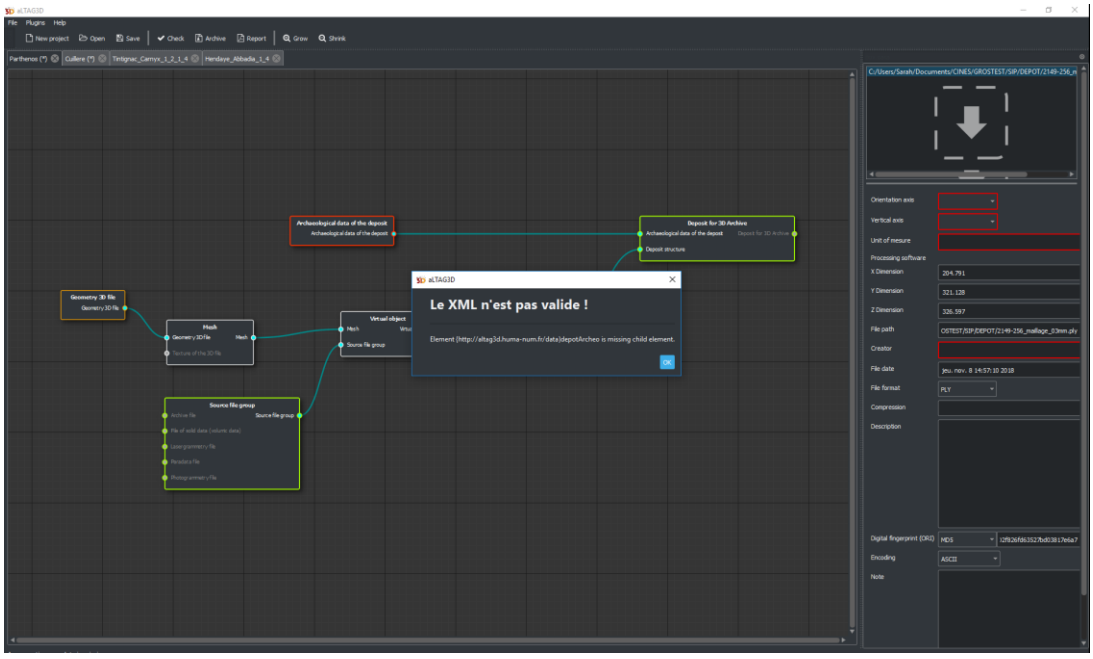


Figure 16: Unvalid Archive

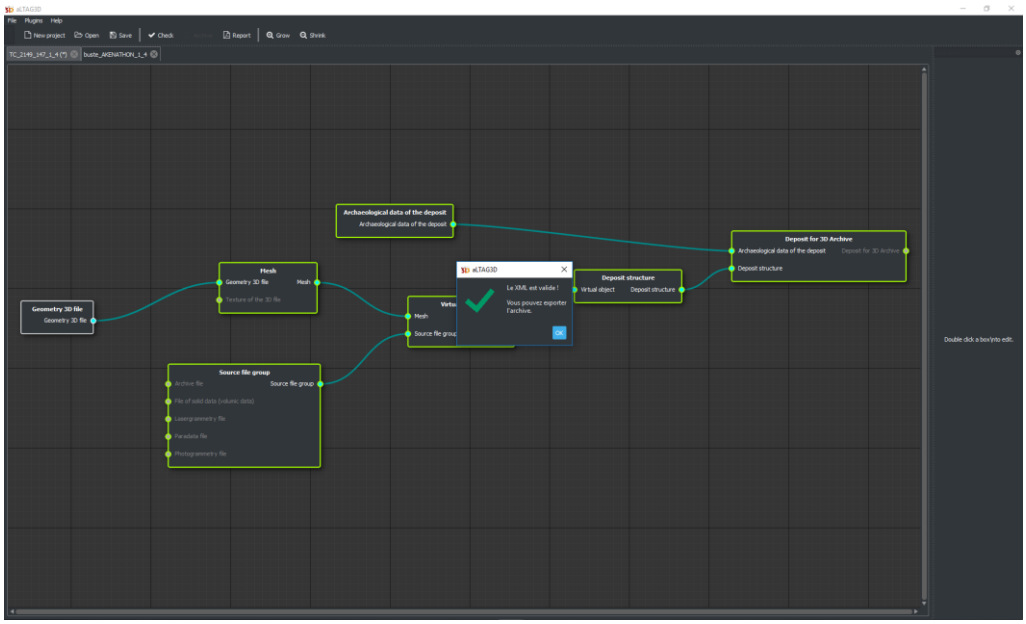


Figure 17: Valid Archive (ready to be generated)

The SIP generated folder/directory can be:

- stored on the user's computer;
- pushed into the 3D Repository or any other national trusted solution;

pushed in the CINES if already stored in the 3D Repository.

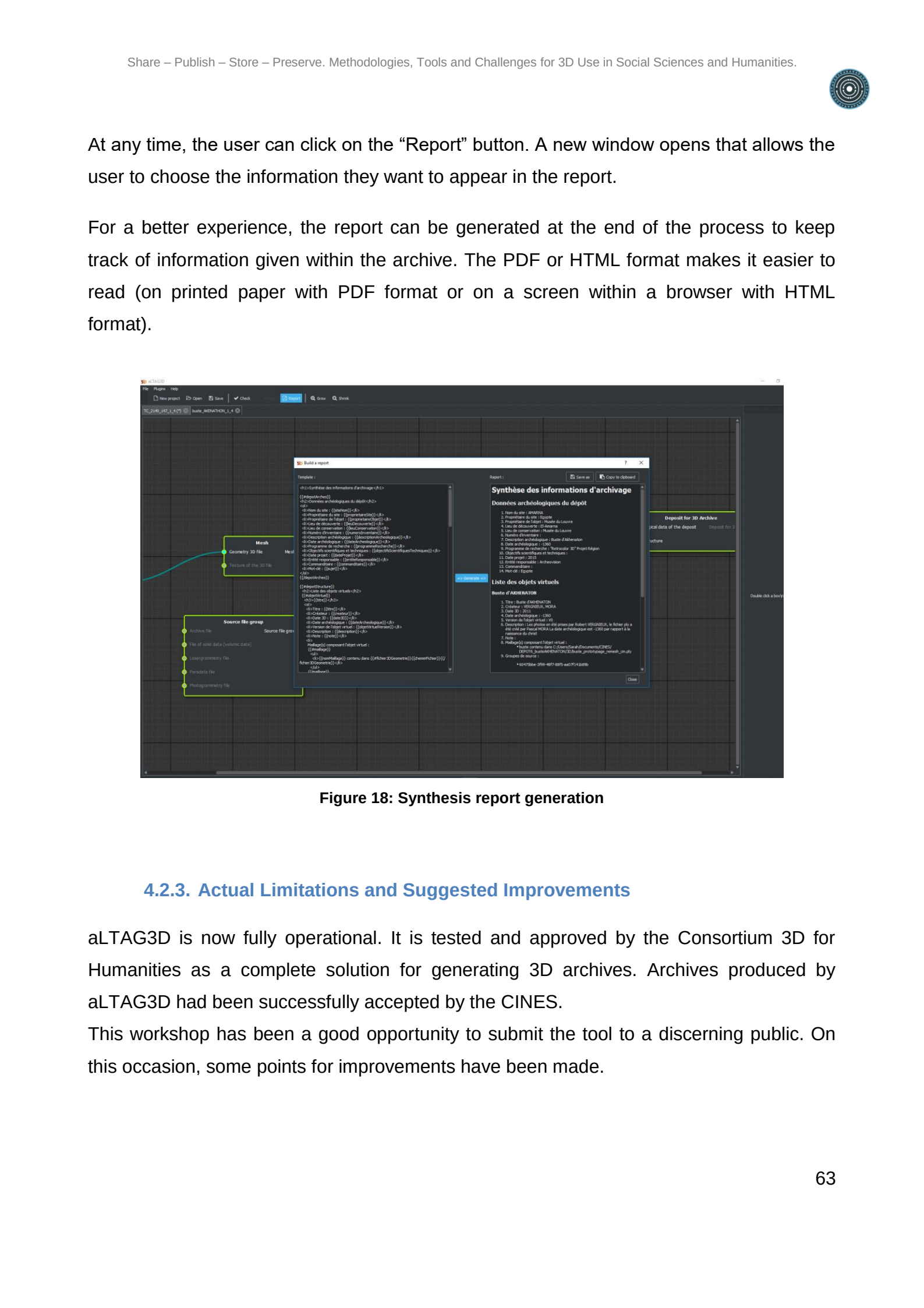
B. Partially generate an archive

It is possible to begin the previous scenario without finishing it. At any moment, the user can save the current project and close the application. It will generate a specific file (*.lta file) on the computer locally. When opening aLTAG3D the next time, the tool will suggest opening an existing project or beginning a new one.

C. Finish generating an archive

Creating an archive could be done several times. The user can carry on with the creation of the archive by launching aLTAG3D with the option "open an existing project". The lta file is read by aLTAG3D and all the information already entered is retrieved.

D. Generate a synthesis report



At any time, the user can click on the “Report” button. A new window opens that allows the user to choose the information they want to appear in the report.

For a better experience, the report can be generated at the end of the process to keep track of information given within the archive. The PDF or HTML format makes it easier to read (on printed paper with PDF format or on a screen within a browser with HTML format).

Figure 18: Synthesis report generation

4.2.3. Actual Limitations and Suggested Improvements

aLTAG3D is now fully operational. It is tested and approved by the Consortium 3D for Humanities as a complete solution for generating 3D archives. Archives produced by aLTAG3D had been successfully accepted by the CINES.

This workshop has been a good opportunity to submit the tool to a discerning public. On this occasion, some points for improvements have been made.

A. Language

First of all, a general translation of the software had been realised just before the workshop since it was originally developed in French. For a better experience, some technical English terms should be added for a complete translation. Furthermore, the switch between the two languages (French and English) is system dependent and not working efficiently, especially if the user is not an administrator on the computer they are using. Some non-French speakers had been detected by aLTAG3D as French speakers and the English version had not set off. This could be improved by adding a button to allow the user to actively choose language between French and English.

B. Limited Availability

Today, the software is only available on windows. A Mac version is already planned. A linux version will soon be available.

C. User Interface, Labelled Boxes

For now, there is no means for distinguishing different virtual objects since every added box has the same appearance, with no name. A strong demand from the community is to be able to name the boxes in the interface to distinguish the different virtual objects. This new feature is under consideration for now.

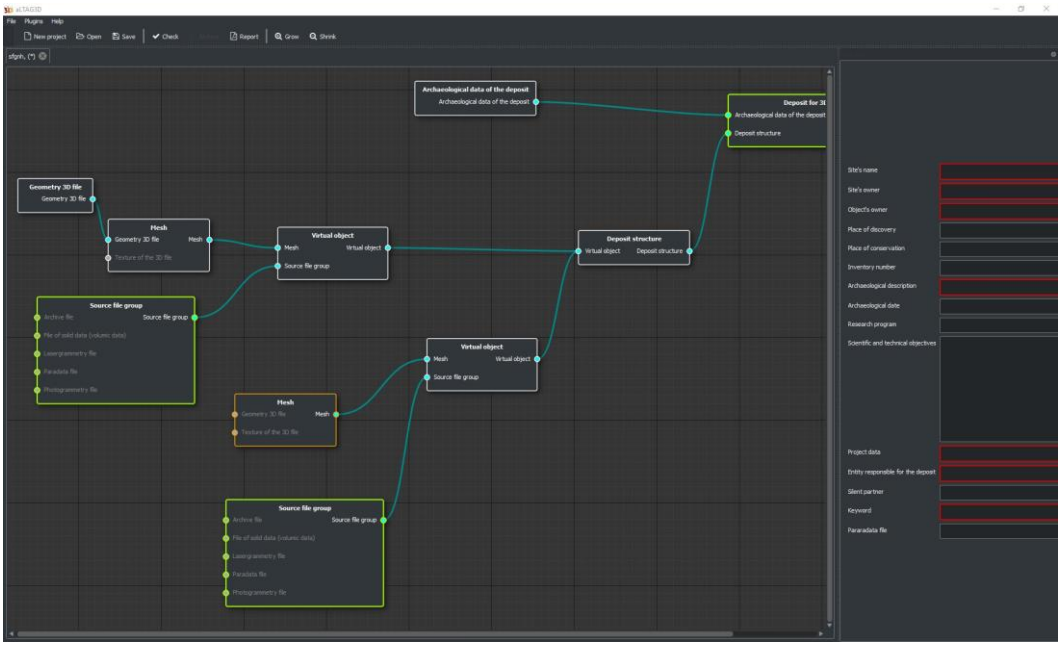


Figure 19: Two virtual objects with the same name

D. Inadequate Naming of Technical Term: Mesh

In English as well as in French, the naming “Mesh” can be confusing because, strictly speaking, the same technical term is used whether you have to add a mesh or a point cloud.

A generic term should be used instead of “Mesh” to remove the ambiguity. Some participants were looking for the box “point cloud” to drop their file in the right box. They didn’t want to put it in the “Mesh” box even though it is the correct one.

E. Controlled Vocabularies

Another improvement can come from the use of controlled vocabularies. For some fields it could be done quite easily since there are not many possible values. But generally, the vocabulary should be imported or connected to an existing one, used and established by the community. This is where the challenge appears. As it is in the next step of the Consortium 3D for Humanities work, this can be addressed relatively soon.

Other positive feedback from the workshop session evaluating the tool aLTAG3D:
The participants were globally satisfied with the interface. They found it very easy to use. For most of them, it was the first time they had a tool that filled in metadata so easily. Except for the improvements described just above, aLTAG3D appeared to be a tool well-received by the community.

4.3. Describing, Saving and Analysing Research Workflows: the MEMORIA Project[24]

4.3.1. General Presentation and Features

Knowledge management systems are today part of many research protocols where they act as a powerful means to share, use, organize and maintain knowledge and information. They remain, however, tricky to apply in the specific context of heritage science where workflows include a long tail of subjective human decisions, of non-explicit research protocols, of poorly formalised pieces of knowledge, of undocumented, non-reproducible, intuitive interpretations, etc. Yet the heritage science community has witnessed over the past decades the emergence of huge quantities of digital outputs, either following massive digitization efforts, or as a result of the growing capacity of actors to produce digital-born material. How can this move be supported in terms of reproducibility, reusability and cross-examination of results if research protocols remain non-formalised one-shot efforts?
Conceived and developed by UMR MAP with a financial help from the Research Department of French Ministry of Culture (DREST), the MEMORIA research program[25] aims at researching a practical solution for the formalization and intersubjective description of research workflows. This initiative is based on the idea that, beyond metadata describing outputs themselves, the scientific community concerned is awaiting the means to ensure their verifiability, reproducibility and comparability.

[24] The PDF of the project's presentation during the PARTHENOS 2nd workshop is accessible under the following address: *<http://memoria.gamsau.archi.fr/projet/pdf/Memoria_MapGamsau_IDudek.pdf>,* I. Dudek, *Store Preserve Visualize - The MEMORIA project*, 2019
[25] MEMORIA project website *<http://memoria.gamsau.archi.fr/projet/objectives.php?lang=en>*

The project's vision is that an *output*[26] should be seen as the ultimate result of a *series of activities* that are as vital to describe and preserve as the output itself. In other words, the underlying objective of the project is to describe not only a result – *i.e.,* a resource, digital or not - but also its production history, *i.e.* the manner how each particular result was achieved.

The initiative hence started with a significant knowledge elicitation effort thanks to which an overall 263 activities (distributed in five groups) were identified, that correspond to the competences of the staff involved in the workgroup discussions[27]. Given this, no claim is made that the MEMORIA's structured list of activities is universal - it only fits the needs of those who created it. (Figure 20)

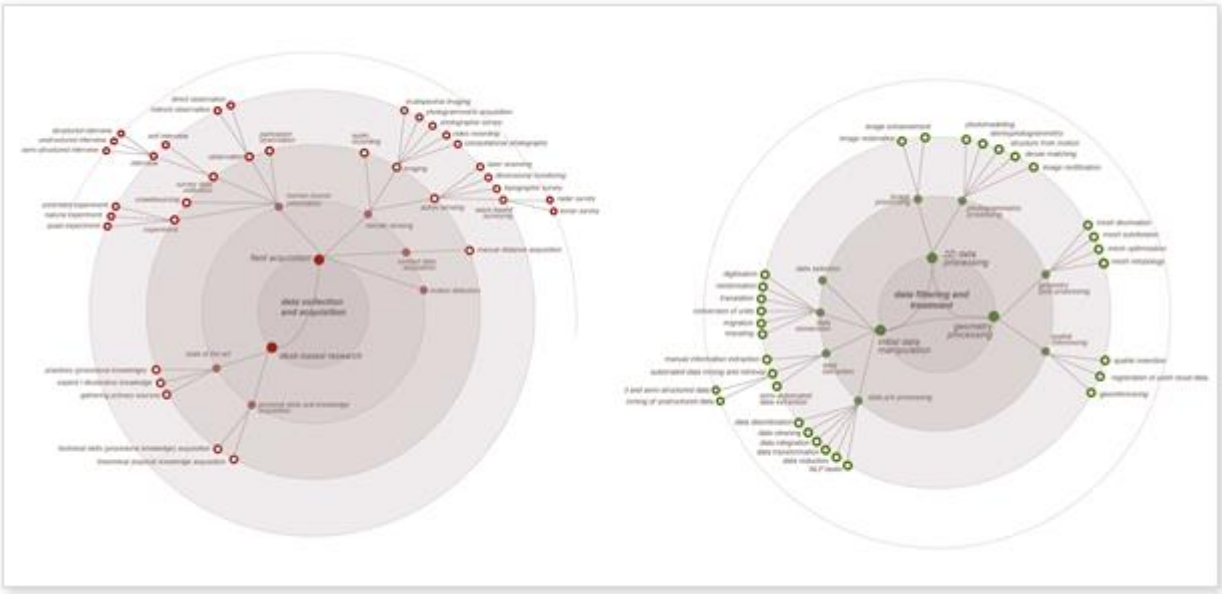


Figure 20: Hierarchical organisation of MAP-Gamsau activities inside groups (data collection and acquisition, data filtering and treatment).

[26] An output is resource, usually digital or digital-born, resulting from a research activity. An output can be a simple document or a set of documents (a screenshot, a 3D model, a video). *cf. MEMORIA vocabulary, <http://memoria.gamsau.archi.fr/projet/vocabulary.php?lang=en&ordre=beta&term=output>*

[27] *cf.* Dudek, J.Y. Blaise, L. De Luca, L. Bergerot, N. Renaudin, How Was This Done? An Attempt at Formalising and Memorising a Digital Asset's Making-of. Proceedings of the 2nd International Congress on Digital Heritage 2015, Vol. 2, Assessment of Methodologies and Tools in DH, IEEE Computer Society, 2015, ISBN: 978-1-5090-0254-2, pp. 343-346, *<http://memoria.gamsau.archi.fr/projet/pdf/DCH2015.pdf>*

Each output can be described as the result of a series of activities that form a research workflow, a *process* as illustrated in Figure 21. Naturally, some activities we all carry out whilst analysing a given dataset, or producing this or that end-result, can be iterative or repetitive – this is part of the underlying model, and transferred through the visual language developed for the project.

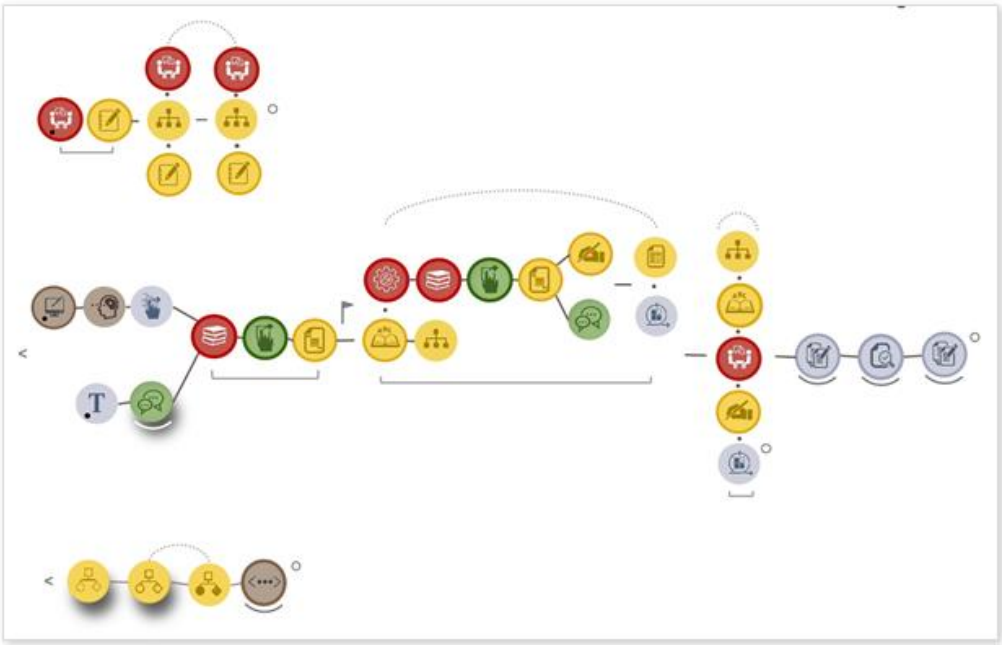


Figure 21: Illustration of how activities (represented by circles, with colours differentiating groups of activities) can be combined to form a process. The top arched connectors and bottom straight underscores identify segments that are respectively iterative and repetitive segments. The figure shows the three successive processes that had to be conducted during the project's "knowledge elicitation" step in order to identify, define, structure and exemplify the activities.

Each activity (*i.e.*, each circle in Figure 21) can aggregate a variety of core information such as tools, people involved, sources, duration of the activity, etc. (Figure 22)

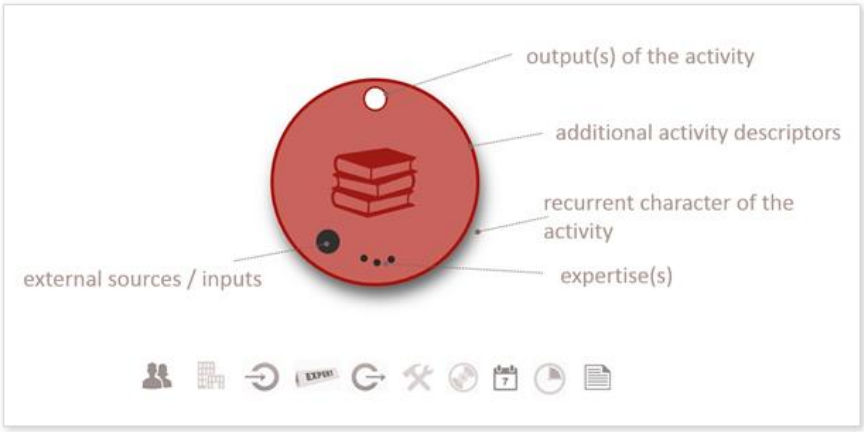


Figure 22: Each activity keeps track of institutional framework in which the work took place (i.e., creator(s), organization(s)), primary sources used and expertise(s), outputs if they result from the activity, techniques and tools used during the activity (instruments, software, ...), duration of the activity, descriptive information concerning the activity, as well as recurrent or repetitive character of the activity.

At the end of the day, resources whatsoever (*e.g.,* 3D model, collections of charts) should be tagged with a set of descriptors (Figure 23) in order to trace all activities mobilized to produce them, and, therefore, in order to reveal the cognitive approach that led to their production.

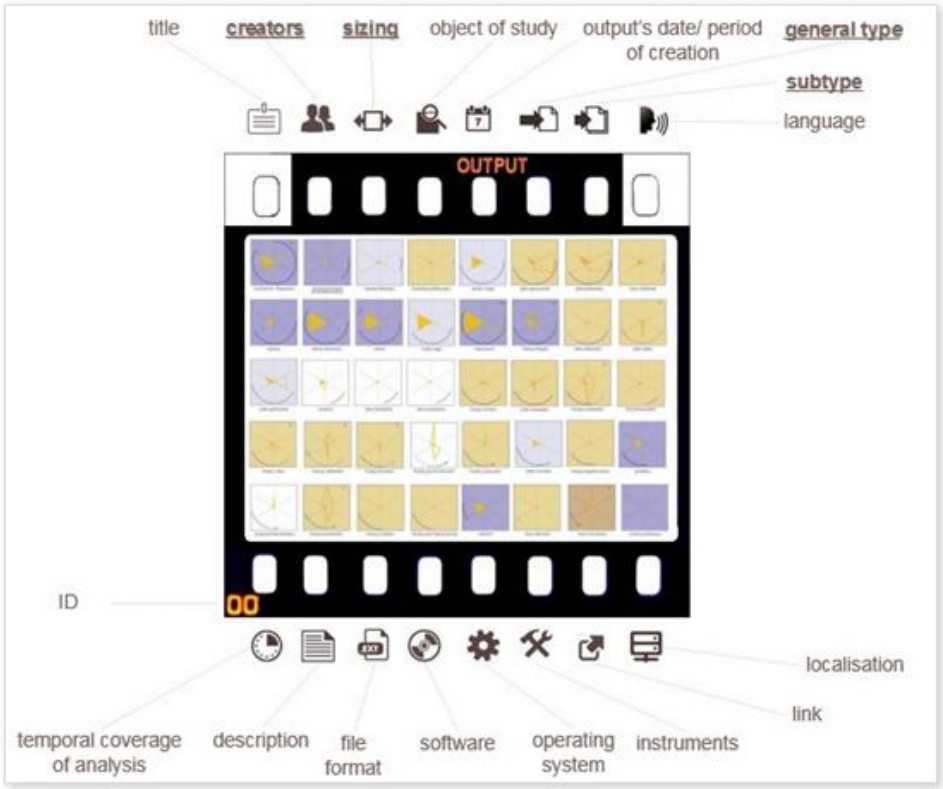


Figure 23: A "film" metaphor to sum up the completion of a resource description - example of an output.

A critical ambition of the project is - in line with some of the distinctive research accomplishments of the MAP research team - to develop, experiment and evaluate visual languages as means to synthesise and share pieces of information on a non-verbal level.
As a consequence, we made an endeavour to design visual interfaces providing, on one hand, access to the results of queries on all resources (sorted by object of study, project, production process, etc.), and, on the other hand, showing the evolution of methods, techniques and tools used over time, as well as types of activities mobilised to produce a given resource. (Figure 24)



Figure 24: Graphic principle of the MEMORIA interface (search mode).

This is definitely a costly effort – an effort some will consider superfluous, but from our point of view it is a vital aspect of any innovative, potent and eye-catching information system, and a key point when wanting to reduce the user's cognitive load and to facilitate reasoning at analysis time.

To sum it up, scientists and academics have over the last decades been the witnesses of a profound shift in research practices, induced by the growing influence of "digital technologies" at large. One of the consequences of the introduction and use of those technologies (and methods) are changes in research pragmatics (*e.g.,* a renewal of workflows, a renewal of data exchange and publication paradigms/practices). In the specific context of human and social sciences also, actors have acquired new tools that strongly influence their research practices. Yet the very nature of the cognitive processes concerned (and in particular the role of individual, somehow subjective interpretation steps) invites us to look into the consequences of the above shift with a sharp eye. With new opportunities often come new issues, new difficulties, and new hazards.



The MEMORIA project addresses some of these issues in an application field where constraints in relation with heritage sciences meet practices, protocols, tools stemming from the engineering and information sciences. One of the key ethical issues[28] is the influence of digital technologies – supposedly positive – on our capacity to perpetuate and transmit to future generations pieces of data as well as elements of knowledge. The mantra behind the MEMORIA project is that what needs to be formalized, shared, transmitted is not only result of a research process, but the result along with the production process (if wanting to make of it a meaningful, reusable scientific document …).

4.3.2. Actual Limitations and Suggested Improvements

The MEMORIA project's ambition should not be confused with objectives of initiatives that address issues such as interoperability, standardisation, long term archiving (*e.g.,* data migration, software/hardware emulation), sharing and publishing data collections, *etc*. In the same way, the project is clearly not about instrumenting connections between existing tools and platforms, but rather about helping researchers and analyst to understand one another, to exchange on methodologies, whatever tools and platforms they happen to work with.

The project's main objective is bringing to the fore and evaluating a new methodological approach to the description, storage and analysis of research workflows *per se*, and this very ambition sets the intrinsic boundaries – and limitations- of the initiative.

Another intrinsic limitation that should be pointed out is the fact that the MEMORIA's structured list of activities is not an all-terrain list - it only fits the needs of those who created it, through an intense elicitation effort. Hence, no claim is made that the initiative will result in a definitive, exhaustive, standardised closed list of activities. The aim is rather to exemplify how a given community can build such a list, and update it as methods and technologies evolve.

[28] *cf*. I. Dudek, J.Y. Blaise, *MEMORIA – la préservation des processus d'étude comme enjeu éthique*, [in] La diffusion numérique des données en SHS, Guide des bonnes pratiques éthiques et juridiques, Ed. V. Ginouvès, I. Gras, collection DIGITALES, Presses Universitaires de Provence, Aix-Marseille Université 2018, ISBN: 9791032001790, pp. 231-240, *<https://hal-amu.archives-ouvertes.fr/hal-01903040>, <https://halshs.archives-ouvertes.fr/halshs-01902564/document>*



At this stage, MEMORIA is still an ongoing research and development initiative and should be seen as work in progress in terms of implementation and in terms of evaluation on a significant quantity of use cases. The issue here is not only finalising a full-scale robust Internet-based information system, but reaching a point where its acceptability, its workload for users, and ultimately its efficiency and usefulness can be assessed.

In that sense we are now planning a new development of the programme, in the context of the SESAMES research initiative (ANR funded programme), with the aim of exemplifying a series of use cases for which the approach can be beneficial. The focus will be put on addressing a frequent issue in heritage science: the imperative of formalising and keeping trace of the various steps that lead from “premises” (archaeological relics, sources) to an assertive 3D virtual reconstruction – an end line product that remains today most often un-associated with interpretation processes.

This experimentation will be carried out in connection with other teams, and in particular with a team of archaeologists (UMR CITERES 7324 LAT). This should help us to question and evaluate the approach in a twofold way: enrichment or adaptation of activities, and feedback from researchers across various disciplines in particular on the usability of the system.

5. Concluding Remarks

The tools introduced during the workshop and in this White Paper embrace the lifecycle of 3D data and objects, from the production to the reuse and the preservation, including processing, documentation, visualization, sharing and storage. As the workshop has illustrated, 3D covers diverse and heterogeneous data and working with 3D data implies using a wide range of technologies, methods and tools, which evolve quickly.

Consequently, the main goal of the workshop wasn't to provide a unique solution that could fit all the needs when dealing with 3D data and objects, but rather to highlight the solutions put in place by some domain specialists and their research teams and to confront them with the various participants' experiences. At the same time, the importance of documenting research practices and producing guidelines has been underlined. PARTHENOS can come into play here, in particular through the Standardization Survival Kit which aims at recording and presenting concrete research scenarios along with documentation and resources in order to provide guidelines and further best practices.

6. Appendix

Short Workshop's Program

DAY 1 25th **FEBRUARY** 2019

09.00-10.00 REGISTRATION

10.00-10.30 Introduction
Adeline Joffres (CNRS/Huma-Num, PARTHENOS), Xavier Granier (IOGS – 3D-SHS consortium), Livio de Luca (CNRS-MAP), Roberto Scopigno (CNR-ISTI, PARTHENOS), Dorian Seillier (Inria, PARTHENOS)

10.30-11.00 [PUBLISH] PARTHENOS, Standards and Research Best Practices: the Standardization Survival Kit (SSK)
Dorian Seillier (Inria, PARTHENOS)

11.15-12.30 Fast-Forward
All the participants

LUNCH BREAK

14.00-15.00 [COLLECT & SHARE] Aïoli: a Reality-based 3D Annotation Platform
Livio de Luca (CNRS-MAP, 3D-SHS consortium)

COFFEE BREAK

15.15-17.30 [COLLECT & SHARE] Hands on Aïoli (training session)
Anas Alaoui (CNRS-MAP), Adeline Manuel (CNRS-MAP), Anthony Pamart (CNRS-MAP, 3D-SHS consortium)

DAY 2 26th **FEBRUARY** 2019

9.00-9.30 [VISUALIZE] OpenSpace 3D for Onboard Visualization
Bastien Bourineau (OpenSpace 3D)

9.30-10.00 [VISUALIZE] Applications Scenarios for CST3D Viewer
Bastien Bourineau (OpenSpace 3D), Valentin Grimaud (Université de Nantes-LARA, 3D-SHS consortium)

COFFEE BREAK

10.15-10.45 [VISUALIZE & PUBLISH] From Local Visualizers to Web Publishing & Viz of 3D Data
Roberto Scopigno (CNR-ISTI, PARTHENOS)

10.45-11.15 [VISUALIZE & PUBLISH] **Introduction of 3DHOP**
Marco Potenziani (CNR-ISTI, PARTHENOS)

11.15-12.00 [VISUALIZE & PUBLISH] **3DHOP Applications**
Marco Potenziani (CNR-ISTI, PARTHENOS)

LUNCH BREAK

13.30-15.00 [VISUALIZE & PUBLISH] **3DHOP (training session)**
Marco Potenziani (CNR-ISTI, PARTHENOS)

15.15-15.45 [VISUALIZE & PUBLISH & STORE] **Visual Media Service**
Marco Potenziani (CNR-ISTI, PARTHENOS), Roberto Scopigno (CNR-ISTI, PARTHENOS)

15.45-16.15 [VISUALIZE & PUBLISH & STORE] **Visual Media Service (training session)**
Marco Potenziani (CNR-ISTI, PARTHENOS), Roberto Scopigno (CNR-ISTI, PARTHENOS)

COFFEE BREAK

16.30-17.30 **Visit of MAP**

DAY 3 27th **FEBRUARY** 2019

09.00-09.30 [STORE & PRESERVE] **Life Cycle of 3D Data for HSS & aLTAG 3D**
Sarah Tournon-Valiente (CNRS-Archéovision, 3D-SHS consortium), Valentin Grimaud (Université de Nantes-LARA, 3D-SHS consortium)

09.30-10.30 [STORE & PRESERVE] **aLTAG 3D (training session)**
Sarah Tournon-Valiente (CNRS-Archéovision, 3D-SHS consortium), Valentin Grimaud (Université de Nantes-LARA, 3D-SHS consortium)

COFFEE BREAK

10.45-12.30 [PUBLISH] **Creation of Standard Scenarios for the SSK (training session)**
Dorian Seillier (Inria, PARTHENOS)

LUNCH BREAK

14.00-15.00 [PUBLISH] **Restitution of Standard Scenarios (training session)**
Dorian Seillier (Inria, PARTHENOS)

15.00-15.30 [PUBLISH & STORE] **the MEMORIA Project**
Iwona Dudek (CNRS-MAP)

15.00-15.30 **Conclusion**

Short Biography of the Speakers and Participants



Anas ALAOUI M'DARHRI

After graduating as a system architect and software engineer, and working in a macromolecular biology institute (CRBM), he joined the UMR MAP 3495 as the lead developer of Aïoli. His main fields of interests are software-related, with a focus on genetic algorithmic and machine learning techniques.



Vincent BAILLET

PhD in Archaeology and Ancient History, specialised in advanced digital technologies (3D modelling, photogrammetry) for the human sciences. I participate in several university projects in France (ANR ArchXant, in charge of the digital anastylosis of the Nereids Monument), as well as internationally (reconstruction of the sanctuary of the Great Gods, Samothrace with Emory University). My research interests are in Greek architectural and decorative study as well as in a global reflection on the use of digital tools in archaeological sciences.



Bastien BOURINEAU

R&D Manager, project manager and lead developer of OpenSpace3D Free software at I-Maginer. Self-taught with more than 20 years of experience in computer programming and 3D graphics.



Alessio CALANTROPIO

Graduated in Architecture, he currently works as a research fellow at the Polytechnic University of Turin (Department of Architecture and Design). Along with the Lab G4CH (Laboratory of Geomatics for Cultural Heritage) and the student team DIRECT (DIsaster RECovery Team) he carried out mapping research in earthquake-hit regions in Italy and other relevant projects in collaboration with the Italian National Firefighters Corps. Since 2017 he works at PIC4SeR (PoliTO Interdepartmental Centre for Service Robotics) as industrial representative for DJI, the world's leader in commercial and civilian drone industry. His research is focused on UAV Photogrammetry and its application for research, mapping, public safety, built heritage, disaster management and damage assessment.



Gabriella CARPENTIERO

Gabriella is an archaeologist working since several years in the field of computer application to archaeology and methodologies applied to cultural heritage. Since the beginning of her career, she achieved technical skills in the documentation, survey and processing of topographical and archaeological survey, as well as satellite image interpretation and geophysical survey in different archaeological projects in Italy, Spain, Morocco, Egypt, Iraq, and Turkey, focusing on the culture of the Roman provinces and Mediterranean interactions.

She obtained a first PhD in Conservation of Architectural Heritage (Università of Reggio Calabria) in 2008 with a thesis on the concept of conservation and restoration of the archives of the Italian archaeologist Ranuccio Bianchi Bandinelli. In 2015, she obtained a second PhD in the Archaeology of

Roman provinces with a thesis focused on the reconstruction of the urban layout of a the settlement of Dionysias (Fayum, Egypt) through Satellite Image interpretation, and geophysical prospection.

She worked as a post-doc at the Department of Classical Archaeology of the University of Siena and since 2017 she is employed at the Soprintendenza Archeologia Belle Arti e Paesaggio del Molise (Italian Ministry for Cultural Heritage), as archaeological officer (county archaeologist).



Livio DE LUCA

Architect, PhD in engineering, HDR (habilitation) in Computer Science, Livio De Luca is research director at CNRS (French National Centre for Scientific Research) and director of the MAP (Models and simulations for architecture and cultural heritage) lab. He's also a member of the French National Committee for Scientific Research. Scientific advisor and member of several national (Culture3DClouds, ANR Monumentum, Fiat Lux, …) and international (3D-ICONS, MC_ITN-DCH, …) research projects, his research activity focuses on digital surveying, modelling and representation of architectural heritage as well as on the design and implementation of semantic-based information systems for describing, analyzing, documenting and sharing digital representations of heritage buildings. As member of international scientific committees and working groups for the digital documentation of cultural heritage, he served as general co-chair of the UNESCO/IEEE/EG DigitalHeritage international congress in 2013 (Marseilles) and 2015 (Granada). He has been awarded the "Prix Pierre Bézier" of the "Fondation Arts et Métiers" in 2007 and the "Médaille de la Recherche et de la Technique" of the "Académie

d’Architecture de France” in 2016.



Iwona DUDEK

Architect (Krakow’s Technical University), PhD in History of architecture and urbanism – CNRS senior researcher at the MAP-Gamsau research team in Marseilles.
Her research focuses on building bridges between advances in the knowledge representation and InfoVis scientific communities and the specific nature of knowledge and information in Historical Sciences. Her research themes and involvements include knowledge modelling, history of architecture and urban forms, diachronic analysis of historic architecture, visual analytics as applied to historical sciences, time-oriented data/information management, spatio-temporal information systems, graphic semiology in the context of InfoVis techniques and tangible interfaces.
Iwona Dudek is the author and co-author of over 70 peer-reviewed publications on topics ranging from history of architecture to information management and InfoVis. She acts as a reviewer or international scientific journals and conferences, organised interdisciplinary scientific events, conducted or participated in research projects funded at national and international level at the intersection of historical sciences and computer science.



Xavier GRANIER

Xavier Granier is professor at the Institut d'Optique Graduate School. After a engineer diploma in Applied Mathematics, he was awarded with a Ph.D. in Computer Sciences thanks to his work on the propagation of light in 3D environments (2001) and with an habilitation in Computer Sciences for his work on 3D modeling work (2009). He has created and led the joint

team-project MANAO (http://manao.inria.fr) from 2011 to 2018, team at the intersection of the two laboratories (LP2N - http://www.lp2n.fr and LaBRI - http://www.labri.fr) and the Inria Bordeaux Sud-Ouest research center, which is developing a research in Computer Graphics and Optics. He coordinates the Consortium 3D for Humanities (https://shs3d.hypotheses.org/), supported by Huma-num national infrastructure (https://www.huma-num.fr/), which works on federating initiatives around the uses of 3D for Humanities. He is scientific director of UMS Archeovision, a pioneer and specialist in 3D tools for archaeology and more generally for Humanities.

His research is multidisciplinary. In addition to his contributions to the simulation of light propagation, he has contributed to the development of augmented reality systems, displays, acquisition tools and appearance models. His publications are in Computer Graphics (ACM Transactions on Graphics, IEEE Transactions on Visualization and Computer Graphics, EuroGraphics Computer Graphics Forum, etc.), in methodology and tools for Cultural Heritage (ACM Journal on Computing and Cultural Heritage, Computer Applications and Quantitative Methods in Archeology, etc.), in Optics and optical systems (SPIE Unconventional Optical Imaging, the Society of Display Display). The complete list is available at https://cv.archives-ouvertes.fr/xavier-granier.



Eleonora GRILLI

Currently on the 3rd year of PhD on "Segmentation and classification of heritage data" at the Fondazione Bruno Kessler in Trento, within the 3D Optical Metrology (3DOM) research unit (http://3dom.fbk.eu) lead by Dr.Fabio Remondino. Her research aims at carrying out an optimal,

repeatable and reliable segmentation procedure to manage various types of 3D survey data and associate them with heterogeneous information and attributes to characterize and describe the surveyed object. In particular, supervised learning segmentation strategies are applied or on the textured UV maps - then projected on the 3D models- or directly on the 3D models.



Valentin GRIMAUD

Architect-archaeologist, Valentin Grimaud is working at the University of Nantes, at the Laboratoire de Recherche en Archéologie et Architectures (LARA). He is specialized on the 3D documentation of rock art and Neolithic monumental funerary architectures. He also participates in the Consortium 3D SHS (on the topic of archiving 3D models).



Christoph HOFFMANN

Christoph Hoffmann completed his education as a librarian in 2014 at the Library of the University of Vienna. After working as a systems librarian at the Austrian National Library and as a cataloger for the Austrian Workers Chamber, he joined the ACDH Team in 2015 as a manager of archival software. He is also engaged in Webdesign and Frontend-Development. As a philosophy student at the University of Vienna, he is interested in the epistemological implications of digital research methods in the humanities.



Adeline JOFFRES

Adeline Joffres is a research engineer, head of International Cooperation within the TGIR Huma-Num (CNRS). In particular, she works on the internationalisation of the TGIR's consortia. She is involved in the French coordination of the

European research infrastructures DARIAH and CLARIN as well as the coordination of H2020 projects such as PARTHENOS. She is also working on the development of cooperation links between TGIR Huma-Num and Latin America as well as with French higher education and research institutions abroad.



Nenad JONČIĆ

Nenad Jončić is a Ph.D. student at the University of Primorska Faculty of Humanities. Born in 1980 in Belgrade, BA and MA gained at the Belgrade University, Faculty of Philosophy, Department of Archaeology. He participates in a work of Center for Digital Archaeology (2005-), on Faculty of Philosophy – University of Belgrade. He also participates in the work of The Provincial Institute for the Protection of Cultural Monuments (2012-2013), on the developing of a new way for recording small finds in archaeological documentation, which is based on 3D SLS scanning technology. This method became a standard in the work of this institution. He participated with a few EU and national research projects concerned with Cultural Heritage.



Michel JORDAN

Michel Jordan is a research engineer in computer sciences and a member of the ETIS laboratory (Information Processing and Systems, UMR8051, Université Paris-Seine / Université de Cergy-Pontoise / ENSEA Cergy / CNRS). He is mainly interested in digital image processing and 3D restitution, with applications in the field of cultural heritage and archaeology. He is responsible for ETIS of the collaborative project VERSPERA.



Justin J. L. KIMBALL

Head Engineer - The Museum of Cultural History (The University of Oslo). An archaeologist by training, Justin Kimball is a specialist in 3D spatial technologies with a deep understanding of photogrammetry and GIS. In his current position, he works as a head engineer at the Viking Ship Museum (Oslo, Norway) where he is a member of the team performing 3D scans of high-profile artefacts—including the Gokstad and Oseberg Viking ships.



Adeline MANUEL

Adeline MANUEL is researcher at CNRS in the MAP (Models and simulations for architecture and cultural heritage) laboratory. After a master pursued in Information and System Science at the MAP laboratory in 2012, she received her PhD at the Arts et Métiers ParisTech in 2016. Her research activities focuses on specific problems of information visualization, spatialization of information, 2D/3D linking, automatic propagation of annotations and 2D/3D analysis tools. She currently develops Aioli, an application for describing, analysing and documenting cultural heritage based on these research topics.



Patrick MCINERNEY Bsc (Computing), HDip (Sociology)

Patrick lectures at Waterford Institute of Technology, Ireland in the Dept of Computing and Mathematics with expertise in the area of 3D modelling, animation lighting and rendering.

Since 1988, he has worked extensively as an archaeological illustrator, surveyor, architectural photographer, working on a number of sites such as: Lisnagun Early Christian ring-fort; Waterford City Excavations (1989-1992); Dysart Castle, Co Kilkenny (1992-1993); Kilkenny Castle (1993-1995), among

others.

He is currently working in collaboration with Centre for Information Systems & Techno-culture (INSYTE) at Waterford Institute of Technology in the area of photographic acquisition of data for use in in the areas of machine reading and the semantic Internet.

Member of CIPA Heritage Documentation and ICOMOS.



Imanol MUÑOZ PANDIELLA

Imanol Muñoz-Pandiella is a PostDoc computer graphics researcher at Universitat de Girona (Spain). He holds a PhD (2017) from Universitat de Girona and Université de Limoges (France). His research interests include realistic rendering, urban modeling and visualization, natural phenomena and weathering processes in cultural heritage.



Erica NOCERINO

Erica is currently a Post-Doctoral fellow at the I&M (Images et Modèles, http://www.lis-lab.fr/im/) group of LiS Laboratory at the University of Marseille (AMU) and at ETH Zürich. Holding two PhDs, one focused on engineering and quality control and the second on geomatics, her research interests focus on 3D digitization techniques, with the aim of developing innovative procedures and guidelines, for the generation of 3D models of known and verified quality, for cross-disciplinary applications in cultural heritage (CH), engineering, but also biology and medicine. Erica serves as secretary of the working group in Vision Metrology of the International Society for Photogrammetry and Remote Sensing (ISPRS) and is expert member of the International Committee of Architectural Photogrammetry (CIPA). She is also involved in teaching and tutoring activities in national and international workshops and

summer schools.



Costas PAPADOPOULOS

Costas Papadopoulos is an Assistant Professor in Digital Humanities and Culture Studies in the Faculty of Arts and Social Sciences at Maastricht University, Netherlands. Costas' research spans the development of virtual worlds to interpret societies of the past, to the application of computational imaging to analyse material culture, to the use of digital ethnographic methods to evaluate digital pedagogy and interactive teaching methods. Much of his scholarship focuses on heritage visualisation using a variety of 2D and 3D media for quantitative and qualitative studies. Costas' work has its roots in archaeology, ethnography, digital humanities, and museum and cultural studies, exploring modelling and representation at the intersections of the physical and the digital. It advances understandings of the experience and perception of heritage; engages with debates on the role of interactive research in digital humanities; explores ways to build epistemological frameworks for multimodal research; and, integrates Arts into STE(A)M learning via socially-engaged research.



Marco POTENZIANI

Master of Engineering (University of Siena), Ph.D. in Computer Science (University of Pisa), Marco is a Computer Graphics specialist. He currently works at Visual Computing Lab (CNR-ISTI). Participated in several international research projects concerning 3D data interactive visualization, Internet applications design, and Digital Humanities.



Emilie SAUBESTRE

After a master degree in Photography at the ENSP (École nationale supérieure de la photographie) in Arles, France, Émilie is currently in charge of the photo lab in Karnak (Egypt) at the CFEETK-CNRS (USR 3172). Her work focus on managing the photographic documentation of the complex of Karnak, using mainly photogrammetry. She recently focuses her work on combining different tools such as 3d modeling and RTI.



Roberto SCOPIGNO

Roberto Scopigno is Research Director at CNR-ISTI with 30 years of experience on 3D graphics (3D digitization, visualization, geometry processing) and its application to the Cultural Heritage domain. He is author of more than 250 international papers, with Google Scholar h-index 51 and more than 11,000 citations. He participated with several EU and national research projects concerned with ICT and Cultural Heritage. Roberto served in the Eurographics Association (served as General Chair 2009-2010), was Chief Editors of international Journals (Computer Graphics Forum and ACM Journal of Computing and Cultural Heritage) and was the organizer of several international events (Eurographics'99, Eurographics2008, Digital Heritage2015, CAA2015, Visual Heritage 2018).



Dorian SEILLIER

Master's degree in Medieval History and in Information Architecture at the ENS de Lyon. Currently a member of the Team ALMAnaCH at Inria Paris, where he works as a UX Designer / Information Architect for the SSK (PARTHENOS project).



Sarah TOURNON-VALIENTE

Sarah is a Software Engineer, working at Archeovision Lab (UMS3657), CNRS. Formerly specialized in databases administration and migration for private telecom firms. Now acting in research databases, specialized in database management, software development and interoperability.



Martina TROGNITZ

Martina Trognitz studied Computational Linguistics and Classical Archaeology at the University of Heidelberg and is currently working on a PhD thesis on the ‘Computer-Based Analysis of Multi-Sided Minoan and Mycenaean Seals’ which involves applying machine learning, clustering and social network analysis to an archaeological research question.

Currently she works at the Austrian Centre for Digital Humanities (ACDH) of the Austrian Academy of Sciences. There she is part of a team dedicated to the digital long term archive ARCHE, which welcomes data from all humanities fields. Before her time at the ACDH, Martina was employed at the German Archaeological Institute (DAI) where she was involved in the project IANUS to build a digital archive for the archaeologies in Germany and developed the IT guidelines „IT-Empfehlungen für den nachhaltigen Umgang mit digitalen Daten in den Altertumswissenschaften“.

Additionally, she is interested in everything involving photography and 3D, including RTI photography, spherical panoramas, photogrammetry and 3D scanning.



Jean-Marc VALLET

Dr Jean-Marc Vallet is geologist-mineralogist. He is conservation scientist and scientific advisor at CICRP (Marseilles, France) and researcher at LABCOM MAP-CICRP (UMR 3495 CNRS-MCC, Marseilles). His main research interests are focused on the understanding of degradation mechanisms that affect wall paintings, polychromy and stones, and on the contribution to the development of non-invasive techniques (3D technical imaging, multidimensional databases, stimulated infrared thermography etc.).He publishes in peer-reviewed journals and proceedings and presents his results in conferences. He is regularly invited for lectures and is involved in international and national research projects. He has been member of technical advisory of EU-projects and is member of several scientific committees for the restoration of built heritage (Palais des Papes in Avignon, Palace of Monaco etc.). He is expert for EC, ANR and CNRS. He is regularly member of organisation and scientific committees of conferences, and reviewer for international science journals and research projects.

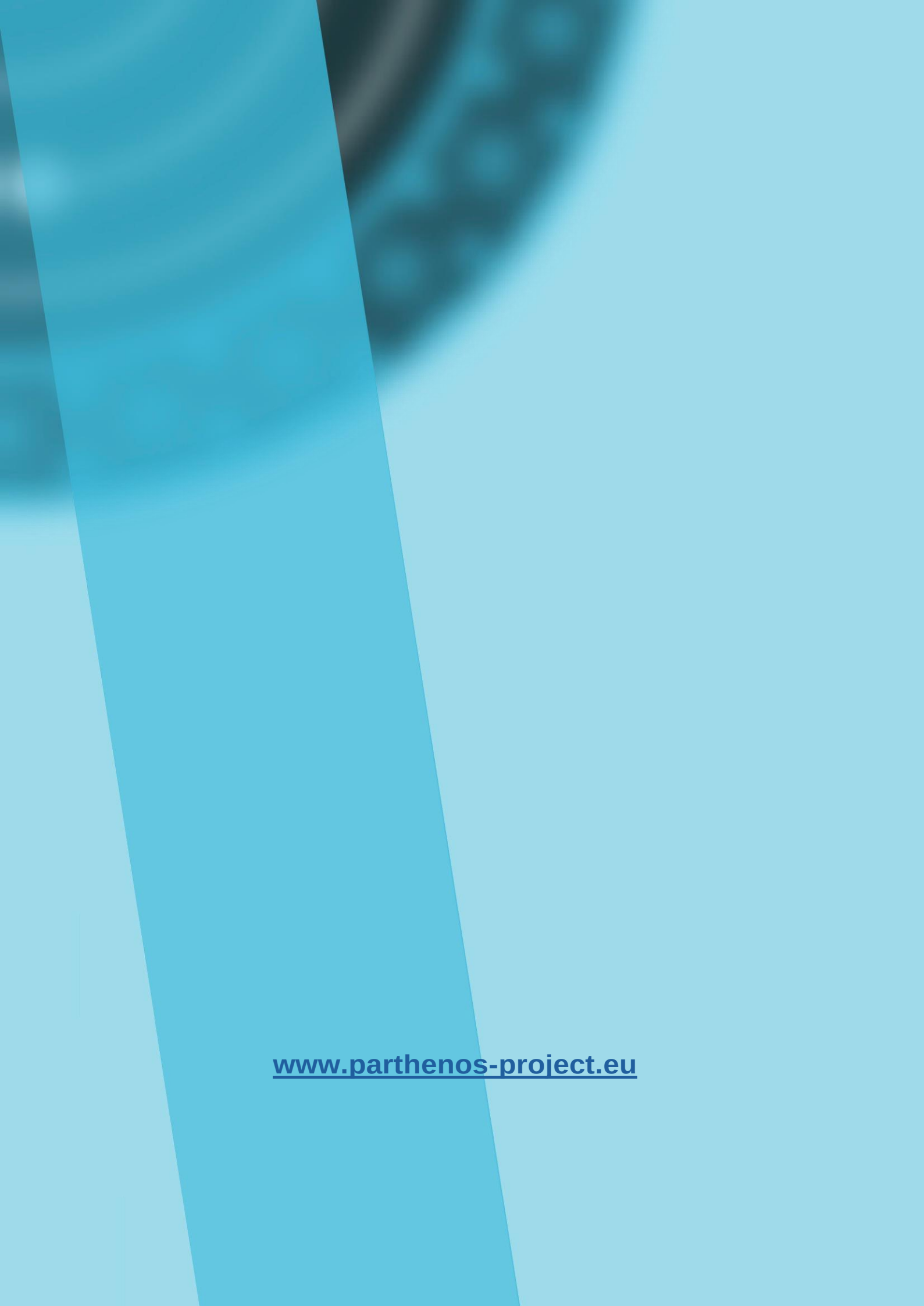


Chiara ZUANNI

Chiara is a tenure-track assistant professor in Digital Humanities at the Centre for Information Modelling – Austrian Centre for Digital Humanities at the University of Graz. Her research focuses on the construction and mediation of knowledge in museums, the impact of digital media on the heritage sector and its audiences, digital data practices in museums. She has a degree in Classics and a MA in Archaeology from the University of Bologna, and a PhD in Museology from the University of Manchester (2016). She has held postdoctoral positions at the University of Liverpool and

at the Victoria and Albert Museum, and has been a visiting lecturer at the University of Bergamo. She is a member of the Institute in Ancient Itineraries (2018-2019, Getty Foundation, King's College London, Umeå University) and she is responsible for the Erasmus+ project 'DigiCulture' at the University of Graz (2018-2021, coordinated by the University of Timisoara).





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