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Deliverable 4.16 Specification of the new features of the Aïoli platform

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Abstract:

This deliverable presents the specification of the new features to be implemented into aïoli (a reality-based 3D annotation platform for the collaborative documentation of cultural heritage artefacts) within the framework of the SSHOC project. These specifications concern the technical robustness of the platform, the collaboration framework, the managing of controlled vocabularies, the compatibility with CIDO-CRM, as well as the interlinking with other tools for visualising hypothetical reconstruction of archaeological sites.

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Executive Summary

This is the first deliverable of the Task 4.6 "Semantic annotation of Heritage Science Data" within the WP4 "Innovations in Data Production". This task focuses on the integration of an innovative web service for the reality-based 3D annotation of heritage artefacts within the SSHOC infrastructure. Designed within the general issue of the daily production of semantic-aware digital data for heritage sciences, the aïoli platform represents a relevant framework for the massive and large-scale collaborative documentation of cultural heritage artefacts. This deliverable presents the specification of the new features to be implemented into the platform within the framework of the SSHOC project. These specifications concern the technical robustness of the platform, the collaboration framework, the managing of controlled vocabularies, the compatibility with CIDOC-CRM, as well as the interlinking with other tools for visualising hypothetical reconstruction of archaeological sites.

Abbreviations and Acronyms

AIOLI	A reality-based 3D annotation platform for the collaborative documentation of heritage artefacts
ARM	Array Relational Mapping
CH	Cultural Heritage
CRM	Conceptual Reference Model
CRUD	Create, Read, Update, Delete
CSS	Cascading Style Sheets
DBMS	Database Management System
EOSC	European Open Science Cloud
HTML	Hypertext Markup Language
IR	Infrared
JSON	JavaScript Object Notation
JSON	JavaScript Object Notation
METS	Metadata Encoding and Transmission Standard
OOP	Object-Oriented Programming
ORM	Object Relational Mapper system
RDF	Resource Description Framework
RTI	Reflectance Transforming Image
SKOS	Simple Knowledge Organization System
SQL	Structured Query Language
SSHOC	Social Science & Humanities Open Cloud

UAV	Unmanned Aerial Vehicle
URL	Uniform Resource Locator
W3C	World Wide Web Consortium

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1. Presentation of the platform

Archaeologists, architects, engineers, materials specialists, teachers, curators and restorers of cultural property, contribute to the daily knowledge and conservation of heritage artefacts. For many years, the development of digital technologies has produced important results in the collection, visualisation and indexing of digital resources. Whilst these advances have made it possible to introduce new tools that are making documentation practices evolve within the cultural heritage community, the management of multi-dimensional and multi-format data introduces new problems and 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 for long-term preservation purposes. 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 for the "Aïoli" project, focusing on the development of a reality-based 3D annotation platform, which allows a multidisciplinary community to build semantically enriched 3D descriptions of heritage artefacts from simple images and spatialised annotations coupled with additional resources. This platform introduces an innovative framework for the comprehensive, large-scale collaborative documentation of cultural heritage by integrating state-of-the-art technological components (image-based 3D reconstruction, 2D-3D spreading and correlation of annotations, multi-layered analysis of qualitative and quantitative attributes, ...) within a cloud infrastructure accessible via web interfaces from PCs, tablets and smartphones online and onsite.

2. Innovation in data production

Managing heterogeneous data for documenting cultural heritage artefacts raises the need for a stable denominator (from a conceptual and technical point of view) for structuring data & annotations coming from a continuous process of observation & analysis carried out by multiple actors (with different profile and description approaches). The starting point of the Aïoli project[1] is to consider the heritage object (the physical one) at the heart of the documentation process by crossing "reality-based 3D" and "semantic description" in a strongly integrated way. By correlating simple images (probably the most stable support for registering field observations since the invention of the photography), the Aïoli platform generates a dynamic 3D morphologic scaffolding for structuring data & annotations. At the same time, this 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 achieved by interlinking all phases that characterise the overall documentation process within an 'informative continuum' by combining three a continuous 3D mapping and annotation process; a morphology-based documentation framework; a flexible & scalable technology.

[1] Aïoli: a reality-based 3D annotation platform for the collaborative documentation of heritage artefacts: www.aioli.cloud

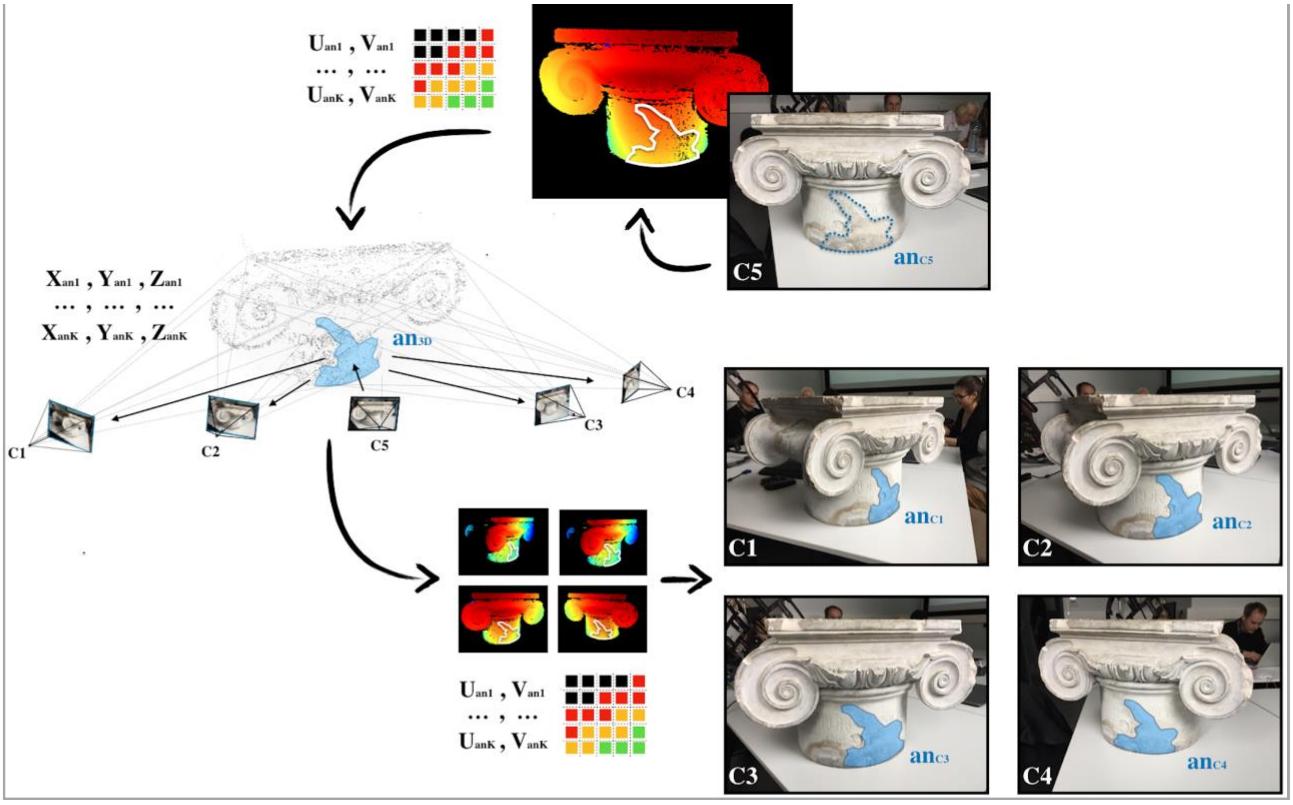

FIGURE 1. 2D/3D SPREADING OF ANNOTATION WITHIN A SET OF SPATIALLY ORIENTED PHOTOGRAPHS

This platform 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 [Pamart et al., 2019];
- 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 [Manuel et al., 2014];
- A multi-layered morphology-based data structuring model to accurately describe real objects in all their geometric complexity and according to multidisciplinary observations;

By relying on the automation of photogrammetric image spatialization processes, the heart of the platform resides on a multidimensional correlation engine. Thanks to this process (Fig.1), the annotations carried out on any image of the object are automatically projected on all the other images and continually correlated geometrically, visually and semantically, with other annotations with a near spatial location.

3. Current state of the software implementation

3.1. System architecture

The current prototype of the Aïoli platform is composed of three main elements:

- **The thin client** is a web browser, compatible with HTML5 and JAVASCRIPT. It assures the cross-compatibility of devices, allowing users to create, handle and share content with all devices, PC, smartphones and tablets, by using the same account.
- **The interface side** is the central node of the application. Here, we manage users, applications and data. All the created and/or uploaded files are stored on this server, such as the 3D point cloud, the indexed images, as well as the segmented 2D/3D regions. This server uses a MySQL[2] relational database to keep data for the application readily available and an Apache Web server[3] to interact with the client.
- **The server side** is in turn composed of three elements. The facade, the modules which perform logic operations and the data access layer. These elements intersect with repositories for taking in account specials cases, complete CRUD (Create, Read, Update, Delete) operations or add specials processes on special data types. The facade exposes a set of generics functions which can be directly called by generic URLs. These calls are made by a routing layer which drives users' requests to the suitable functions and return a formatted JSON result readable by any client application. Then, on one side, there are CRUD functions *(e.g. create new object, read an object by id, read all objects for a type, read a relation of an object, update an object, delete an object by id, …)*; on the other side, there are relative functions aimed at driving processing pipelines (e.g. image orientation, point cloud generation, projection of regions, complex queries on user and computed descriptors, …). All these functions can be called by specifying the module and the procedure in a URL.

3.2. Processing services

The processing server, based on DOCKER technology[4], provides containers for every step of the processing pipelines. Some of these processes require high computational power, which is the reason why we built our infrastructure in order to keep all processing applications independent from each other for: i) Minimising the used resources, ii) Avoiding heavy maintenance procedures and iii) Assuring scalability scenarios. We provide here some details on some implemented processes.

- For the first 3D spatialisation process (see section 4.1), the uploaded images are transferred by the thin client to the processing service which executes a pre-processing step, the photogrammetric

[2] MySQL: https://www.mysql.com/fr/

[3] APACHE: https://en.wikipedia.org/wiki/Apache_HTTP_Server

[4] DOCKER : https://www.docker.com/

computation, the 2D/3D indexation, then the optimisation of the obtained 3D point cloud for web visualisation (by using the Potree[5] point-based renderer).

- For the 2D/3D annotation process, all the geometric entities (points, lines, polygonal regions) drawn by the users on a 2D images are collected by the thin client and interpreted by the interface server as simple list of UV coordinates belonging to an image with a given spatial orientation (resulting from the spatialisation process), then transferred to the processing server in order to launch the propagation and correlation functions. Once the 2D/3D propagation and the extraction of geo-visual descriptors computed, the resulting 3D regions and relative image masks are transferred to the interface server, then to the thin client as optimised point-based 3D and vector-based 2D representations.

3.3. Data structuring

In order to use the data model in a real information system easy to handle in an Object-Oriented Programming (OOP) context, we focused on mapping inheritance models. In a first time (development of the first prototype) we have chosen a relational database management system (MySQL). The choice of the mapping inheritance model influences the structure of the database itself, thus we had to adapt the physical model and use an Object Relational Mapper system (ORM) for solving the object-relational impedance mismatch due to the wrong compatibility between Object Oriented and Relational paradigms. We used a single table method for several reasons: it's the fastest inheritance model, it doesn't require any join for retrieving a persistent instance of an object whatever the depth of the hierarchy, and finally creating, updating, deleting are done with a simple request. According to the specific needs of our project, we developed a homemade ORM: it should better be called ARM (Array Relational Mapping) because it doesn't map the relational data to an actual object, but it maps it to an associative array which looks like an object. This operation is performed more easily and quickly than creating and mapping real objects.

3.4. User interface

The entire interface is based on the joint use of HTML5, CSS style sheets, and JavaScript. CSS and HTML5 form the responsive base of the interface, which adjusts the layout according to the screen's dimensions and its orientation. In addition, a JavaScript script continuously adapts the interaction modalities according to the sensors detected on the device (presence or not of a touch screen or a stylus, a camera, etc.) and manage the positioning of the various tabs, which are configurable and moveable by the user according to his preferences.

[5] POTREE : http://www.potree.org/

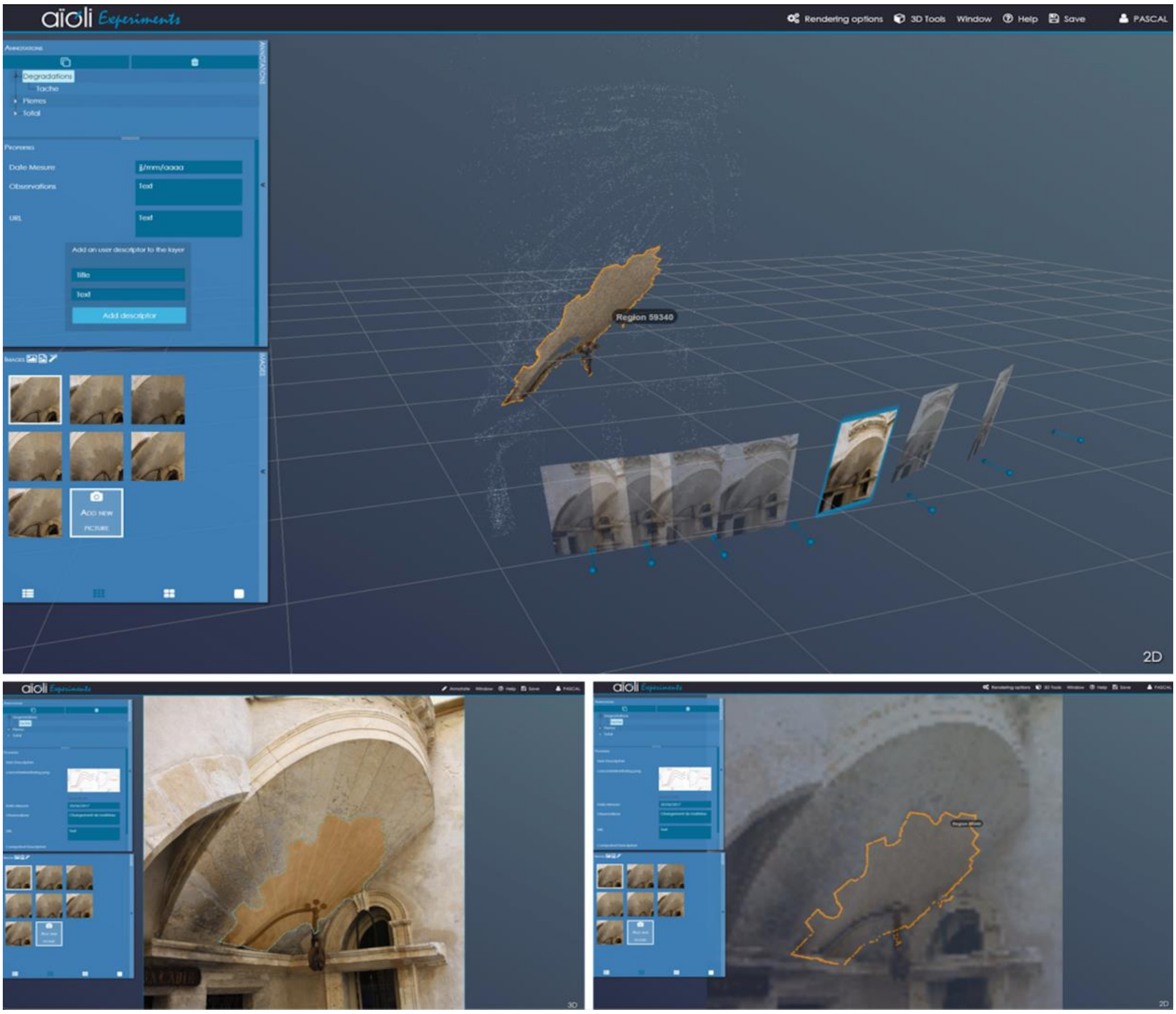

FIGURE 2. THE 2D/3D WORKSPACE OF THE AÏOLI PLATFORM

On the other hand, a WebGL[6] viewer, developed from the PaperJS[7] and PotreeJS libraries, allows to connect the 2D and 3D resources and to manipulate them within a 2D / 3D hybrid space. In a first step, we load the project's sparse point cloud into a 3D scene. Then, for each photograph, a change of reference is made from the transformation matrices resulting from the pose estimation, in order to obtain their relative position with respect to the point cloud in the spatial reference frame of the viewer. Then, we create for each of them a virtual camera with the same intrinsic parameters, and converted extrinsic parameters, to which we superimpose photography in dimmed opacity. Thus, at every 2D view can be associated a coherent 3D visualisation. In this way, photographs can be displayed in 2D as a base for annotation layers, or in 3D as a

[6] WebGL: https://www.khronos.org/webgl/

[7] PAPER.Js: http://paperjs.org/

navigation medium. In addition, 2D and 3D navigations are unified to provide systematic consistency between two workspaces (Fig.2).

The general scene browser also exploits this consistency in order to allow users handling annotations as generic spatial regions by propagating their selection from any 2D vector-based projection to the correspondent or 3D point-based representation. In the 2D space, the annotations are initiated from the user's plot: the successive positions of the cursor are converted into a vector path sent in the pipeline propagation. They give rise to the production of dense point clouds, displayed in 3D, in overlay of the sparse cloud used as support.

In this logic of making possible visualisation of all spatial elements, user descriptors and file attachments belonging to any annotation (video, sound, picture, URI, …) are also positioned in the 3D scene, and can be figured directly on the numeric instance, in a window that opens on mouse-hover. Several basic tools are available today (such as measurement, profiles, …) and allow a direct interaction with the created 3D representations.

4. Beta testing program

4.1. Testing the platform within several application contexts

In order to try out the experimental features of Aïoli, a beta-testing programme started on October 2018. This programme is currently ongoing and is involving selected actors of cultural heritage scientific and professional community (archaeologists, architects, engineers, conservation scientists, curators and restorers, …). Within this framework, a wide range of heritage artefacts, belonging to different scales and photographed by different sensors, have been used for experimenting the implemented features (archaeological sites, buildings, archaeological artefacts, archaeological fragments and parietal art, …). Different devices were successfully tested for the photogrammetric acquisition (digital reflex, tablets, and smartphones), also including UAV-based acquisitions. The aim of this on-going program is not only to pinpoint technical difficulties, but also to collect feedback on the features and discuss the issues and the challenges of the data sharing (images, 3D models, annotations, descriptions, …). The feedback is collected by a questionnaire at the end of the beta testing period and the collected inputs are discussed with the research & development team.

4.2. Case studies

This on-going beta-testing programme also represents the opportunity to explore and design the potential uses of the platform within the CH community. So far, the Aïoli platform has been tested by about 60 volunteers, from different countries, different types of institutions (mainly from academic and scientific community, but also private companies), and covering different domains of Culture Heritage Studies (architecture, archaeology, conservation-restoration, geomatics, photography, building industry). The following sections present the case studies.

4.2.1. 3D Mapping of degradation patterns of heritage buildings

Author: Amélie Bénard

Institution: Interdisciplinary Center for Conservation and Restoration of Cultural Heritage (CICRP, Marseille).

Cultural object: Caromb Church, France

Context: Aïoli platform has been used in the context of preventive conservation, for the Caromb Church in France. From various mapping surveys (degradation, materials, building phases etc.) made at different times, the idea was to experiment a temporal monitoring of the degradation, such as the biological colonization (Fig.3). One of the perspectives in this type of building analysis is to explore the potential of the 3D annotation for classifying the degradation patterns by basing on the ICOMOS-ISCS 8 Illustrated glossary on stone deterioration. The ultimate goal is to experiment the comprehensive 3D description of the state of conservation of a building, to allow the correlation of spatial, morphological and semantic attributes.

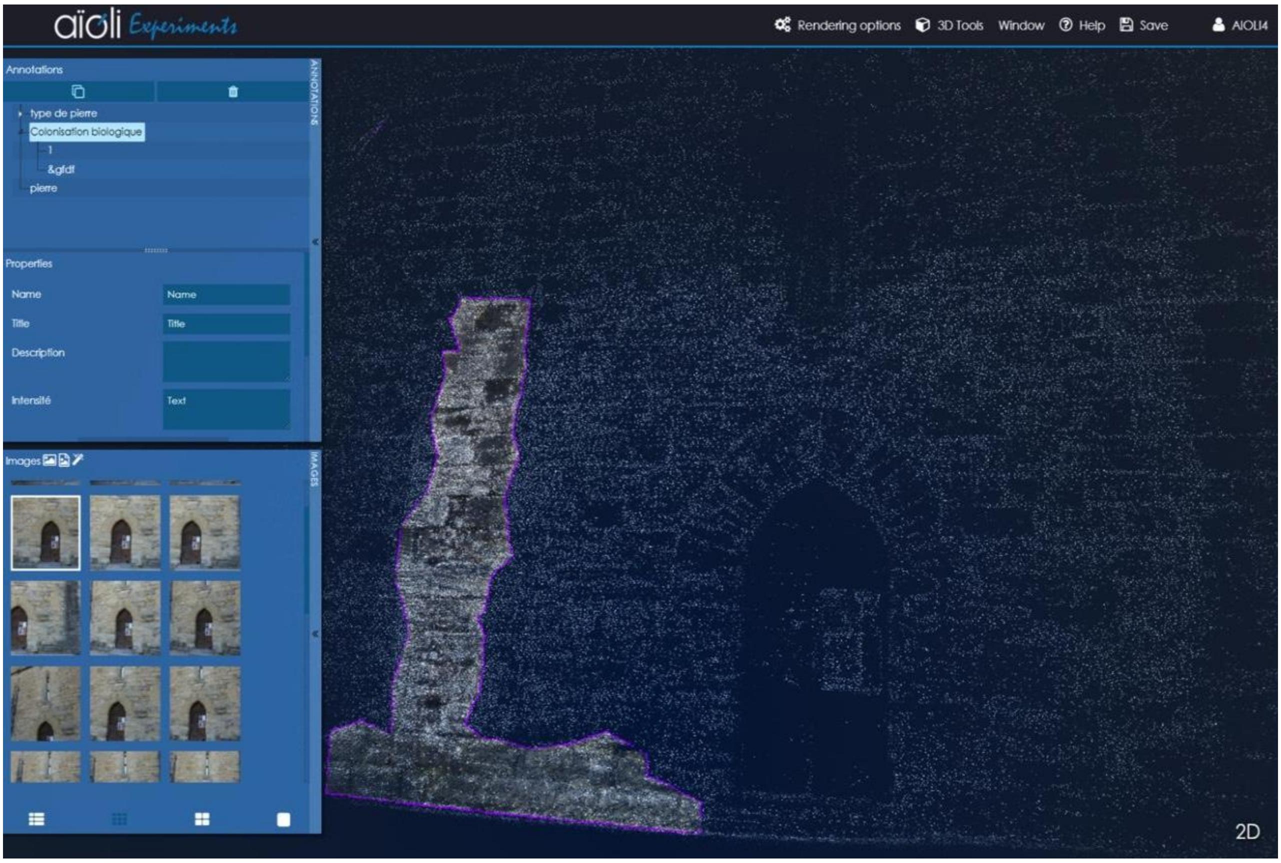

FIGURE 3. MAPPING OF BIOLOGICAL COLONIZATION ON THE EAST WALL OF THE CAROMB'S CHURCH, FRANCE

8 ICOMOS-ISCS : http://iscs.icomos.org/glossary.html

4.2.2. Morphological analysis of archaeological fragments

Author: Andrea Maraffa (PhD)

Institution: Università degli studi di. Reggio Calabria, Italy.

Cultural object: Fragments of theatrical masks (Archaeological Museum of Lipari)

Context: Aïoli platform was used in the frame of a PhD thesis on the theatrical masks of Lipari to isolate and analyse the morphological features of archaeological fragments of the masks. The software was tested on all the samples of masks (entries, fragments of entire and "mute" fragments") of the New Comedy. For each sample of mask lots of information was extracted about the morphological and geometrical features of the artefacts, for example: complex vertical profiles, bending radius of the main elements (mouth, eyebrows, cheeks, nose, eye). The aim was to define a sort of hierarchical clustering for the macro-typologies of masks (Fig.4).

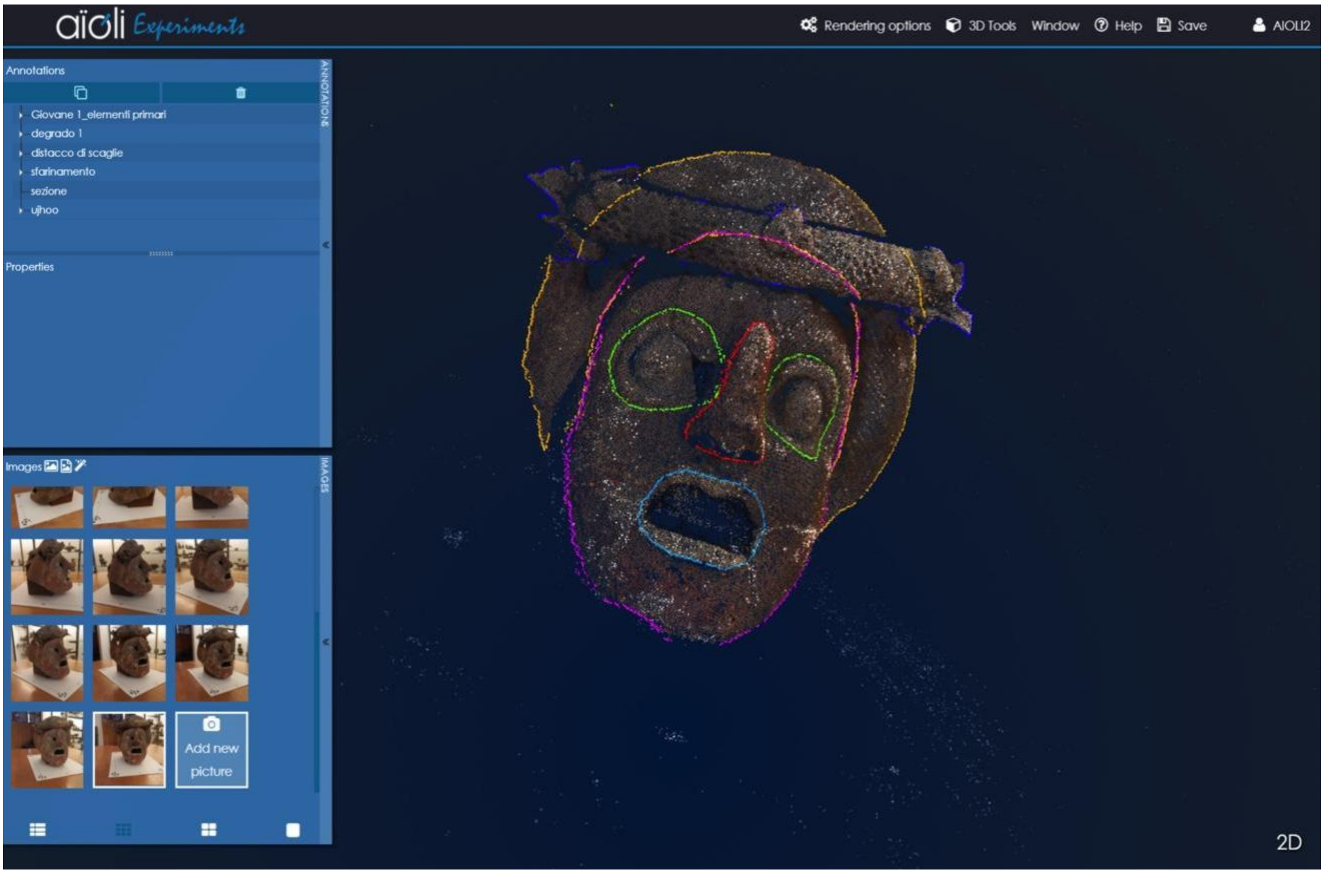

FIGURE 4. 3D ANNOTATION OF A THEATRICAL MASK

4.2.3. Stratigraphic survey for the archaeological analysis of ancient buildings

Author: Piero Gilento (PhD Marie Skłodowska-Curie actions (MSCA))

Institution: Paris 1 - Panthéon Sorbonne

Cultural object: Domestic unit in the Umm as-Surab village, Jordan

Context: Aïoli platform was used to support a stratigraphic analysis applied to the study of the standing architectural remains, i.e. Building Archaeology. More specifically it was part of a research project on construction techniques and building typologies in the Jordanian Hawrān area, in northern Jordan. For the study of domestic architecture at Umm as-Surab village, the site was divided into topographic units (TU), which could be composed of one or more architectural complexes (AC): this is the result of the sum of several building elements (BE).

Some building elements, such as a domestic unit has been analysed through Aïoli, to describe the masonry technique, in order to define the chronology of the architecture into three main Construction Periods (Fig. 5).

FIGURE 5. STRATIGRAPHICAL UNITS FROM A DOMESTIC UNIT IN THE UMM AS-SURAB VILLAGE, JORDAN

4.2.4. Follow-up of conservation-restauration activities on a painting

Author: Nicolas Bouillon

Institution: Interdisciplinary Centre for Conservation and Restoration of Cultural Heritage (CICRP, Marseille)

Cultural object: The Crucifixion by Louis Bréa (Altarpiece - wooden painting, XVIth century), France.

Context: One of the most developed case studies experimented so far, was focused on the documentation of the restoration of the Altarpiece of the Crucifixion painted by Louis Brea in 1512, and conserved in the church of the Franciscan Monastery of Cimiez in Nice.

This case study was performed to see to what extent Aïoli platform can be used to ensure a better understanding of the works in conservation and restoration practices. The value of such a tool is related to the specificities of the study and restoration of a painting work. Restoration operations are involving many actors (curators, restorers, scientists, art historians, archivists, photographers…), and restoration issues are solved through the addition and complementarity of knowledge and skills. This interdisciplinary work is challenging because of different times and locations and also different professional constraints. This can lead to a fragmentation of available technical documentation and constitute a barrier in the decision making-process necessary for the successful progress of a restoration work.

This case study of the Crucifixion Altarpiece has been used to show how the observations made by different actors can be documented, for example technical imaging (Fig. 8), physicochemical analysis (Fig. 7), alterations of the pictorial layer (Fig. 6), wood grain analysis (Fig. 9). This documentation process was being questioned to see how the annotations could be structured according to different scenarios, in order to best respond to the methodological and terminological specifications of each professional field and to make information meaningful for each actors of the collaborative project. An important issue was also to link the annotations with different types of attachments such as reports, technical documentation and different types of images (IR, thermography, RTI…).

FIGURE 6. MAPPING OF DEGRADATIONS IN 1991 IN THE CRUCIFIXION RETABLE BY LOUIS BREA

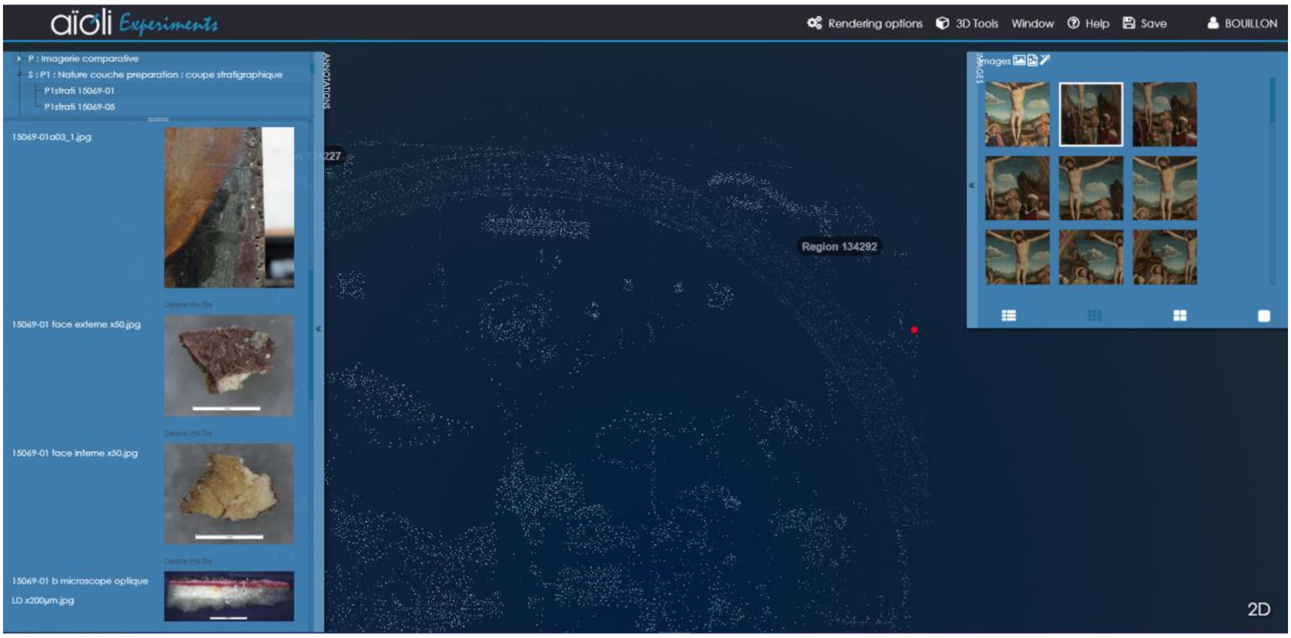

FIGURE 7. STRATIGRAPHIC CROSS-SECTION OF A SAMPLE IN THE CRUCIFIXION RETABLE BY LOUIS BREA

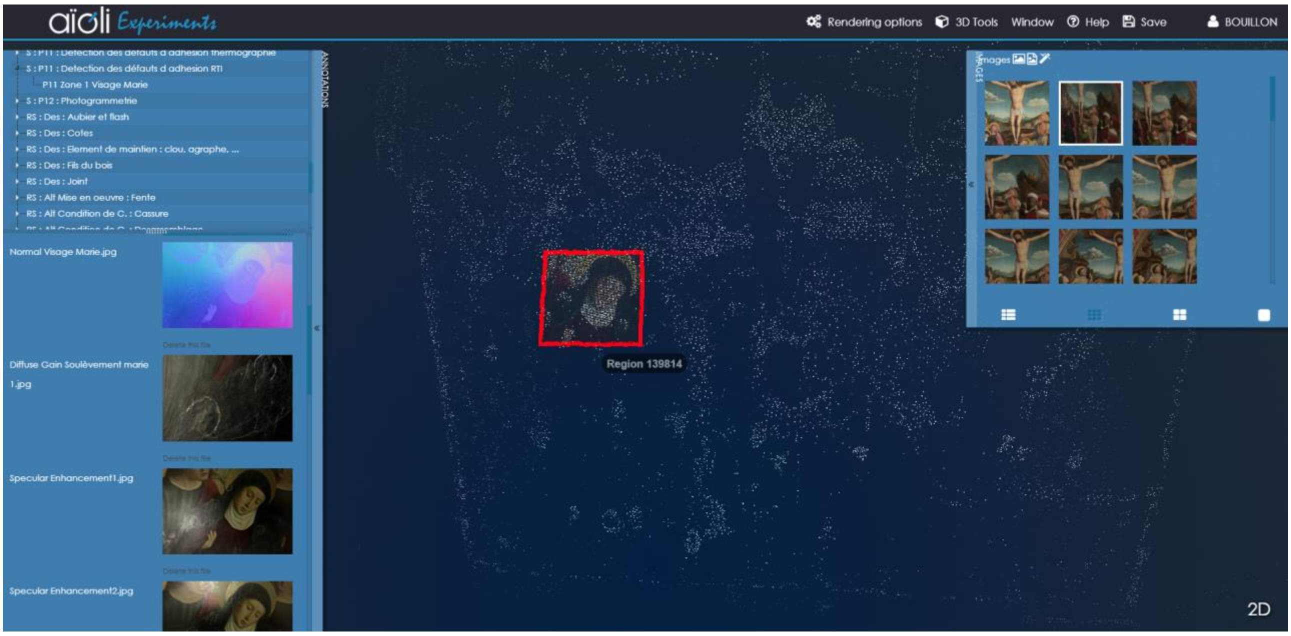

FIGURE 8. DETECTION OF CONTACT FAILURES USING REFLECTANCE TRANSFORMATION IMAGING IN THE CRUCIFIXION RETABLE BY LOUIS BREA

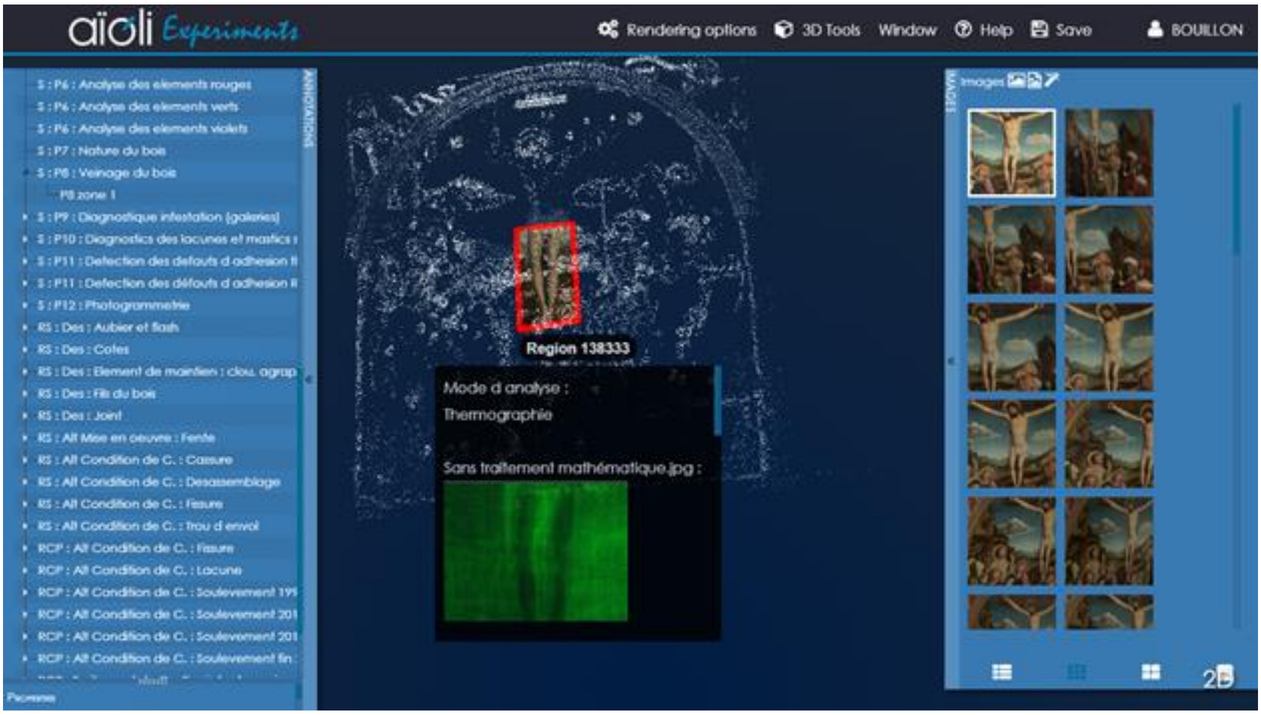

FIGURE 9. WOOD GRAIN ANALYSIS WITH INFRARED THERMOGRAPHY TECHNIQUE IN THE CRUCIFIXION RETABLE BY LOUIS BREA

5. Specification of the new features

Beyond the beta-testing program, the dissemination activities on the Aïoli project concerned the organization of tutorials within the main scientific events of the digital heritage sector in 2018 (Digital Heritage 2018, San Francisco ; Visual Heritage 2018, Vienna), a presentation day at the French Ministry of Culture (December 2018), as well as the workshop "Share — Publish — Store — Preserve. Methodologies, Tools and Challenges for 3D Use in Social Sciences and Humanities" [M'Darhri et al., 2019], co-organized by CNRS-HumaNum, CNRS-Archeovision, CNRS-MAP, INRIA and CNR-ISTI in Marseille in February 2019, within the framework of the PARTHENOS[9] EU project.

Within the specific context of SSHOC, the main activities related to the task 4.6 and to the development of the Aïoli project have been presented and discussed during the WP4 meeting at the SSHOC Kick-off meeting (March 11-12, 2019, Utrecht), during the WP4 Workshop "Developing the SSHOC Reference Ontology" organized by FORTH (May 21-22, Heraklion, Crete), as well as during several video meetings with WP4 task leaders and members. These meetings have been used as framework for defining the following specifications of the new features to be developed in the platform.

9 PARTHENOS : http://www.parthenos-project.eu/

The general feedback from users and colleagues involved in the above-mentioned actions is very positive: Aïoli represents an effective framework for gathering, documenting and analysing CH artefacts within multidisciplinary context. But the current informatics implementation presents some limitations today and new features should be introduced in order to foster the use of Aïoli into a wider community.

- The improvement of the computing robustness of the platform, to cope with massive uses (see section 5.1) and facilitate collaborative work scenarios (see section 5.2) ;
- the definition of an RDF based architecture which uses different SKOS dictionaries to assign types to 2D/3D annotations and help users describe them (see section 5.3).
- the definition of a mapping mechanism aimed at ensuring the full traceability of the multi-users 2D/3D annotation process within the CIDOC conceptual reference model, as well as within the higher-level ontology introduced by the SSHOC project (see section 5.4);
- the interlinking of reality-based 3D models with reconstructive hypotheses for archaeological studies (see section 5.5)

5.1. Robustness for large-scale uses

Following the experiments of the first prototype of the platform by a first group of beta testers, several technical problems must be faced to move toward massive use scenarios.

After a state-of-the-art look at recent methods for managing large volumes of data (big data), a no-sql document-oriented database seems to be the best choice. This type of database will meet all the constraints related to the massive and collaborative use envisaged for the platform. We chose CouchDB [10] as the implementation of this database (being developed by the Apache foundation to ensure sustainability and clear licensing for the future), this ensures full documentation provided and a follow-up of the database system. This database, which can be requested via HTTP, allows us great flexibility for the creation of heterogeneous documents, but not only. It also allows you to retrieve data ready for use in the application. Indeed, this database responds to the JSON format (JavaScript Object Notation), which allows you to have objects that can be used directly in response to requests, without having to go through an ORM. Finally, what makes this Database Management System (DBMS) particularly appropriate in our case study is its event-oriented design, which avoids us to develop an overlay for listening to events as part of the platform's multi-user collaborative uses.

Our platform is today running on a server appliance composed by 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. This first installation demonstrates suitable performances and robustness for supporting more than 20 simultaneous connections. Within the SSHOC project, we will provide a technical solution for installing the platform in larger server appliances. In this sense, we will move toward several scenarios in order to start its diffusion within the CH community at the international scale.

[10] CouchDB : https://couchdb.apache.org/

Finally, at the interface level, the technical implementation of the platform presents two main limitations today that has been highlighted by the beta users: i) it currently works only online and needs a 4G connection at least; ii) it currently works in arbitrary georeferencing, means the computed descriptors are only locally expressed, with an important limitation in terms of correlation potential. We plan the development of an off-line/online synchronisation process in order to extend the use to some particular work conditions (e.g. the surveying of an archaeological site with no access to the internet), , as well as a complete approach for scaling/georeferencing issues. References

5.2. The collaborative framework

Given the emphasis put on the multi-user's 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 the settings, users could select their discoverability level (called visibility, which could either be public or private), to enable the other users to see them within the community. This setting will allow the users who would like to remain invisible to do so, while giving the opportunity to the others to share their work to some/all of the other users. When a user visibility is set to public, all other users can invite him as a collaborator, which then allows them to interact and to work on shared projects. Projects could be set by some sharing options and visibility options. These two settings will allow the users to share some projects to specific people (as long as they are collaborators), or to publish their projects on the community space. Collaborative projects can be defined by two categories of settings:

- **Sharing options** will allow specified collaborators to open the project as if it were their own, with a limited access through a Read/Write/Execute right policy. Once a project is shared with a collaborator, the latter can open the workspace and use the application to annotate regions, describe layers and regions and consult the project, based on the rights given by the project owner. Of course, for a project, only the owner could access and modify the global settings, such as the title, thumbnail picture or visibility status (Fig. 8). In these settings, the owner can easily modify the list of allowed users, in order to give his collaborators an access to all (or some) of the project content. The read/write/execute rights policy then determine the ability for a non-owner user to add layers, upload new images, describe already annotated regions, or link new data.
- **Visibility options** concern the project discoverability within the public area. As any other collaborative platform, Aïoli gives the possibility to willing users to give a read-only access to their work, through what we called the community space. This interface gathers all the projects published by their respective owners and allows anyone (with an Aïoli account) to access any project set to visible.

These two categories of settings will allow covering the range of uses Aïoli can have at the moment. For frameworks subject to confidentiality constraints, users can set their project to be undiscoverable by other users, but accessible to some of their collaborators. On the contrary, users that want to disseminate results to the public can set their projects to visible and use the community space as a showcase as well as for exploring new cooperation opportunities.

5.3. Integrating controlled vocabularies

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. In the meantime, controlled vocabularies allow to avoid singular / plural issues or misspellings regarding annotations. Many vocabularies exist and are structured according to the RDF standard defined by the World Wide Web Consortium (W3C[11]), to allow easy publication within the Semantic Web[12].

In the Aïoli platform, any annotated region is linked to a flexible data container that the users can customise according to their description needs (by avoiding rigid descriptive sheets). User descriptor fields can be defined as text, numbers, currency, dates, hyperlinks, memo. Users can also add file attachments (documents, images, videos, audio) to any annotation. Values can be freely entered by the user on automatically generated forms.

Within the SSHOC project we'll work on the definition of an RDF based architecture, which uses different SKOS[13] Thesauri (e.g. Art & Architecture Thesaurus, Iconclass, etc.), as well as custom lexicons uploaded by the user, to assign types to annotations and help users describe them.

The integration of these feature will take into account the following technical aspects:

- the implementation of interface elements to format, insert and manage lists of concepts (multi-lingual, multidisciplinary) used for the description of heritage objects in several contexts (conservation, historical study, museum etc.);
- The definition of a robust mechanism to store and verify links to external controlled vocabularies within the Aïoli database;
- The integration of Uniform Resource Identifier (URI) elements for navigating through vocabulary terms and definitions, as well as of word autocompletion features.

5.4. A CRM-compatible description of the collaborative 2D/3D annotation process

In order to provide users with a complete framework of description able to integrate two-dimensional and three-dimensional data and information coming from internal/external sources, it is necessary to define a formal interconnection between the annotated data and a semantic graph of information. Such interconnection needs a formal framework able to integrate data structure together, therefore, an ontological integration model of the data is the first and foremost task to tackle.

11 W3C: https://www.w3.org/

12 Semantic Web: https://www.w3.org/standards/semanticweb/

13 SKOS: https://www.w3.org/2004/02/skos/

Within the SSHOC project we'll define the interconnection between the Aïoli "2D/3D collaborative annotation framework" and the heritage information by using the CIDOC-CRM Ontology[14], a standard ontology providing definitions and a formal structure for describing the implicit and explicit concepts and relationships used in cultural heritage documentation. In particular, we'll focus on the mapping of the "Aïoli" classes and attributes with the following CIDOC-CRM domains:

- The Scientific Observation Model (CRMsci[15]) is a formal ontology intended to be used as a global schema for integrating metadata about scientific observation, measurements and processed data in descriptive and empirical sciences.
- CRM Digi[16] is an ontology and RDF Schema to encode metadata about the steps and methods of production ("provenance") of digitization products and synthetic digital representations such as 2D, 3D or even animated Models created by various technologies.
- CRMgeo[17] is a formal ontology intended to be used as a global schema for integrating spatiotemporal properties of temporal entities and persistent items.

The mapping of Aïoli 2D/3D annotation process within the CIDOC conceptual reference model will take into account 3 main aspects:

1. The description of the 'Aïoli' project (heritage asset, main author, collaborators, project context, etc.);
2. The description of the photogrammetric process (methodological approach, input images, processing parameters, final output, etc..) ;
3. The description of the annotation process (2D/3D canvas, annotation layer & shape, description fields & values, computed geometric & visual descriptors, etc.).

From a technical point of view, we'll connect Aïoli via an API to a light-weighted CRM-compatible process annotation model which is partially based on the 3D-COFORM (FP7-ICT: Grant agreement ID: 231809) project [Pena Serna et al., 2011; Rodriguez-Echavarria et al., 2012] outcome and will be synchronized with SSHOCro (to be developed by FORTH within the framework of the SSHOC project, task 4.7).

This annotation model provides an efficient way to generate an annotation via a user interface by making use of annotation templates representing notions based on CIDOC CRM and its extension CRMdig. Therefore, the user can choose the kind of annotation he wants to generate from the templates (e.g. add a comment or create a destruction event annotation) and the Annotation Module will present the corresponding user interface. Hence, the user is able to create the desired annotation based on CIDOC-CRM specification which is compatible with the repository infrastructure.

14 CIDOC-CRM: http://www.cidoc-crm.org/

15 CRMsci: http://www.cidoc-crm.org/crmsci/

16 CRMdig: http://www.cidoc-crm.org/crmdig/

17 CRMgeo: http://www.cidoc-crm.org/crmgeo/

This annotation process model supports the formulation of individual or aggregated annotations over any of the supported MM types (text, 2D images, 3D objects, etc.), based on a common and uniform approach. It describes the metadata of an annotating event as a named graph, containing the annotation statements as part of the same semantic CIDOC graph for later searching and reasoning. In order to associate RDF triples with parts of 3D objects or other media, it makes use of a generalized notion of area.

The proposed Process Annotation Model presented in following figure (Fig. 10) has two basic entities: the Annotation Event and the Annotation Object. The Annotation Event is the parent event that creates the Annotation Object. The Annotation Object is the entity describing the association between the annotated objects. We propose two sub-classes of the Annotation Object: the Knowledge Object modelled as a Named Graph and the Same-As, which is used to declare co-reference links [Axaridou et al., 2014]. The Knowledge Extraction is a specialization of Knowledge Object that is used to model information that will be (semi)automatically extracted from legacy data. Our annotation model can be seen as generalization of the Open Annotation Model[18], because it uses Named Graphs, which describe any form of linking, and as specialization of it, since oac:hasBody can point to a Named Graph.

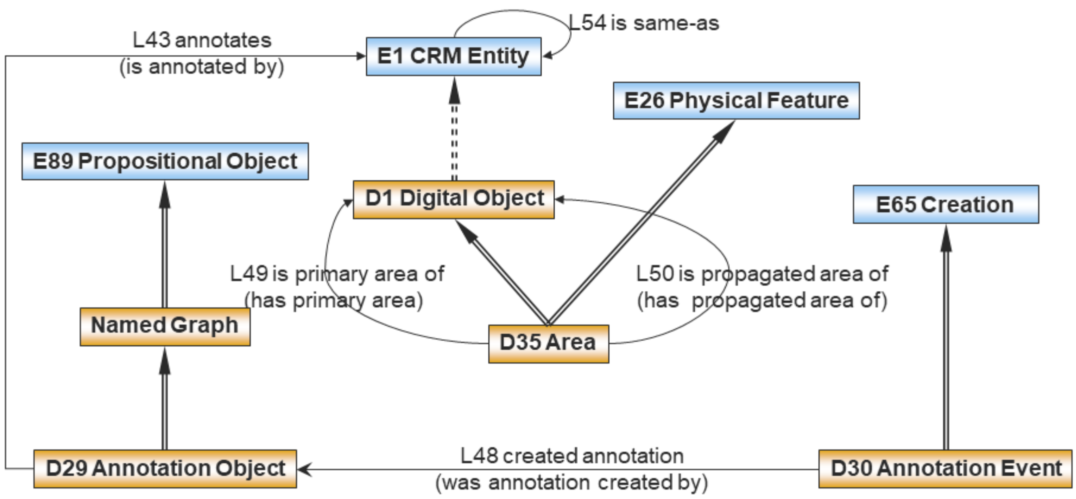

FIGURE 10. PROCESS ANNOTATION MODEL

In order to define in a unique and uniform way, areas on the variety of multimedia objects stored in the repository, it is suggested the use of the generic and extensible METS schema[19], by means of defining the term "area" to describe a part of interest in basically any media object stored in the repository. However, since

18 Open Annotation Model : http://www.openannotation.org/spec/core/

19 METS Schema, Metadata Encoding and Transmission Standard. http://www.loc.gov/standards/mets/, 2011. Open Annotation Model. http://www.openannotation.org, 2011

the METS schema does not provide <mets:area> attributes for 3D models and HTML documents, extensions to METS should be defined (e.g. by defining new attributes to mets:area element and by adding new values for SHAPE).

The annotation model of the above figure is simple but very rich and extensible. It allows to associate parts of different media with parts of a 3D shape. These associations are classified into different categories of relationships as defined in CIDOC-CRM, which is the core conceptual schema and, in its extension, CRMdig. Relations can carry comments and are represented in the semantic graph for later searching and reasoning. The Area's concept eases the propagation of semantic annotations among different representations, e.g. different resolutions of a 3D shape. Since we record the provenance information in CRMdig from the acquisition event on, and we relate all events (acquisition, processing, segmentation, annotation, etc.) to our internal representation of the physical object (artefact), we can always ask for Areas being defined on different digital 3D representations and the annotations attached.

By this way, reality-based 3D annotations created with Aïoli will be correlated with multiple pieces of information and concepts, as expression of scholarly justified opinions.

5.5. Connecting reality-based 3D models with hypothetical reconstruction

Among the uses of the Aïoli platform are the preparatory operations for the realization of reconstructive hypotheses that represent how an archaeological context should have appeared in a specific era of the past.

Within the framework of the future development we will focus on the definition of a specific workflow that combines the creation of reality-based 3D models with the creation and visualization of reconstructive hypotheses. This will be ensured by the definition of an export/import compatibility between several processing steps (Fig.11).

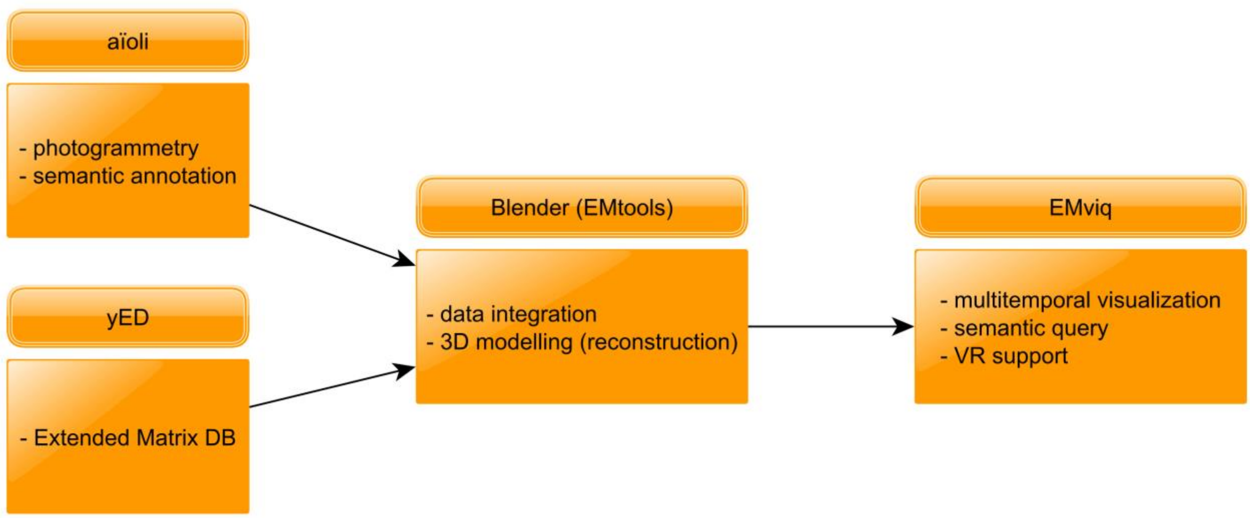

FIGURE 11. INTEGRATION OF TOOLS FOR A SOURCE-BASED RECONSTRUCTION WORKFLOW

Within the Aïoli platform it is possible to upload a series of photographs taken with photogrammetric criteria to obtain a 3D model with point cloud. The semantic annotation tools inside the platform allow to highlight portions of the model and associate an ID following proper naming conventions. The semantic segmentation of the 3D models follows, in this workflow, a stratigraphic criterion, that is, the identification of stratigraphic units of the actions of creation and modification of the monument identified on the basis of a relative time sequence.

In other words, functional elements such as column or window door walls are not isolated, but identifiable actions such as, for example: phase 1 window creation; phase 2 window tamponade; phase 3 opening of a smaller window inside the tamponade. This approach allows us to contextualize the elements of which the monument is composed both from a spatial point of view and from a chronological one (think of the elements that belong to one or more phases of life of the monument) providing all the elements necessary for the creation of reconstructive main phase of life of the archaeological site.

In parallel with the stratigraphic analysis carried out in the Aïoli platform, an Extend Matrix[20] is developed in the form of a graph database in GraphML[21] format (ISO standard) in which the chronological relationships between the stratigraphic elements highlighted on the photogrammetric model are formalized and stored.

Through the export tools of the Aïoli platform, point clouds and a descriptor in JSON format are exported and processed and transformed into polygonal meshes (stratigraphic proxies) before being imported into the 3D Blender software. At the moment this step is performed manually using software for the conversion of point clouds into meshes such as Cloud Compare[22]. Within the CNR-VHLab laboratory an EMtool add-on[23] has been developed to connect the stratigraphic information present in the EM (GraphML) with the proxies and 3D reality-based models and to help in the production of reconstructive models. Within Blender a first hypothesis reconstructive volume (the so-called reconstructive proxies) is being developed that offers a useful tool for multidisciplinary discussion between the different members of the research team and that will be used as a set of geometric shapes for semantic interrogation runtime. Once a reconstructive hypothesis is consolidated from a scientific point of view, a definitive model of representation is produced, realistic and provided with shaders and textures.

Using another add-on developed within the VHLab 3D Survey Collection (3DSC)[24], the entire dataset (RB, SB, EM) is exported in OBJ[25] format.

20 http://osiris.itabc.cnr.it/extendedmatrix/

21 GraphML: http://graphml.graphdrawing.org/

22 CloudCompare: https://www.danielgm.net/cc/

23 https://github.com/zalmoxes-laran/EM-blender-tools

24 https://github.com/zalmoxes-laran/3D-survey-collection

25 OBJ format: https://en.wikipedia.org/wiki/Wavefront_.obj_file

The 3D datasets are then converted and ingested into an interactive tool for query and real-time inspection. EMviq[26] is a complete, interactive 4D visualization and interrogation tool for Extended Matrices (GraphDBs) focusing on automatic extraction of semantic descriptors from GraphML data. The tool offers interactive visualization - including immersive VR (through consumer-level HMDs) - ease-of-use and performance, in order to establish a fast and robust pipeline within a multi-disciplinary team. EMviq also provides replicable techniques targeting real-time applications and immersive visualization, including multi-temporal scene-graph design to maximize re-use and runtime performance.

The approach and current solutions will be also investigated on a CNR case study, in order to assess the overall pipeline.

Current developments are targeting modern Web3D through the integration of such solutions with responsive, cross-device front-ends, like the ones offered by ATON project[27] to create an online tool accessible through common web-browsers.

Future directions will also investigate solutions for the automatic creation of semantic 3D descriptors (proxies) from annotated point clouds produced by Aïoli, offering a smoother workflow.

6. Conclusions

In this deliverable we presented the main features of the Aïoli platform and the specifications of the new features to be implemented within the framework of the SSHOC project. These specifications define the development plan of the new version of the Aïoli platform (Deliverable 4.17) which will be available towards the end of the project (M36).

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26 http://osiris.itabc.cnr.it/scenebaker/index.php/projects/emviq/

27 http://osiris.itabc.cnr.it/scenebaker/index.php/projects/aton/

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