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D3.2 Integration of the INCEPTION 3D and H-BIM technologies

4CH

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Colophon

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List of acronyms and abbreviations

API: Application Programming Interface
ASCII: American Standard Code for Information Interchange
BIM: Building Information Modelling
CAD: Computer-Aided Design
CC: Competence Center
CH: Cultural Heritage
CIDOC-CRM: Center for Intercultural DOCumentation - Conceptual Reference Model
CSS: Cascading Style Sheets
DAE: “Digital Asset Exchange” or “Collada” file format
DB: DataBase
DoA: Document of Action
DT: Digital Twin
DXF: “Design Web Format” file format
E57: Lidar Point Cloud Data File
Getty AAT: Getty Art&Architecture Thesaurus
GIS: Geographic Information Systems
glB: “GL Transmission Format Binary file” file format
glTF: “Graphics Language Transmission Format” file format
HBIM: Historical/Heritage Building Information Modeling
HDT: Heritage Digital Twin
HTML: HyperText Markup Language
HTTP: HyperText Transfer Protocol
HTTP/2: HyperText Transfer Protocol 2.0
ICT: Information and Communication Technologies
IFC: “Industry Foundation Classes” file format
IFC 2X3: “Industry Foundation Classes 2x3” file format
IFC 4: “Industry Foundation Classes 4” file format
IGES: “Initial Graphics Exchange Specification” file format
IAM: Identity and Access Management
ISO: International Standards Organization
JSON: JavaScript Object Notation
JWT: JSON Web Token
OAuth2: Open Authorization 2.0
OBJ: “Object” or “Wavefront” file format
OIDC: OpenID Connect
OPA: Open Policy Agent
RDF: Resource Description Framework
REST: Representational State Transfer
URI: Unique Reference Identifier
URL: Uniform Resource Locator
X3D: “Extensible 3D” file format
X3ML: code-name for an XML based language to describe schema mappings
XML: Extensible Markup Language
XYZ: “XYZ” file format

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Executive summary

The Competence Centre for the Conservation of Cultural (4CH) project is a project approved in January 2021 within the DT-TRANSFORMATIONS-20-2020 call of the Horizon 2020 framework program of the European Community. Its goal is to design and prepare for a European Competence Centre (CC) on the Conservation of Cultural Heritage which will work proactively for the preservation and conservation of cultural heritage (CH).

INCEPTION technologies, on which this document is focused, will be among the pillars of the web services dedicated to 3D assets offered by the Competence Centre. This deliverable provides an overview on the ongoing activities aimed at further developing INCEPTION technologies for meeting the Cultural Heritage sector requirements and integrating them into the 4CH cloud platform.

In particular, activities developed under the “T3.2 - Integration of 3D H-BIM technologies from INCEPTION”:

- developed a semi-automatic semantic enrichment of H-BIM models using the ArCo ontology;
- developed a new 3D web viewer as WebAssembly with better performance and the capability of reading more file types according to the results of the D3.1 in terms of file formats;
- started re-designing and re-developing exiting services following the principles and the requirements expressed in the Design of the CH Cloud and 4CH platform (D3.1) for service integration or federation.

Future activities will be aimed at finalizing the current developments in order to achieve a fully operative web application exploiting the new capabilities offered by the 4CH Cloud Platform. A final report “D3.3 - Final report on services and tools”, updating these preliminary results, will be delivered at Month 36 (December 2023), describing the final implementation of the INCEPTION technologies and the other tools and services provided by the project.

1. Introduction

1.1 Objectives and structure of the deliverable

The main objective of the Deliverable is to reports on the integration of INCEPTION technologies, and their current advancement beyond the results achieved during the INCEPTION project[1] (g.a. 665220), in 4CH cloud platform. Activities have started at Month 13 (January 2022) but are still under development. Thus, the results contained in this deliverable will be further explored towards the end of the project.

The document is structured as follows.

Section 2 reports on the main services and functionalities already offered by the INCEPTION technologies, called ICE – INCEPTION Core Engine. The section provides an overview on the relevancy of these technologies in the 4CH project and briefly describes its components.

Section 3 reports on the newly developed features within the 4CH project that expands the current functionalities of the INCEPTION technologies for maximizing their impact and meeting the requirements of the CH sector. The new possible interaction with other platforms (Europeana and the New Italian Digital Catalogue of Cultural Heritage) makes their use more consistent, as well as the new approach in the development of the 3D web viewer as WebAssembly works also towards their integration in the 4CH Cloud and other platforms (i.e., Data Space for Cultural Heritage).

Section 4 reports indeed on the specific actions for integrating or federating the different INCEPTION services in the 4CH Cloud platform, making it a hybrid solution as already foreseen in D3.1 – Design of the CH Cloud and 4CH platform.

Section 5 briefly outlines ongoing and future activities towards the conclusion of the project, taking also in consideration the integration with other initiatives as the Data Space for Cultural Heritage and projects supporting its population or the Collaborative Cloud for Cultural Heritage.

[1] https://www.inception-project.eu/en

2. INCEPTION Core Engine: 3D H-BIM and semantic technologies for Cultural Heritage

This section reports on the main services and functionalities already offered by the INCEPTION technologies, called ICE – INCEPTION Core Engine. It provides also an overview on the relevancy of these technologies in the 4CH project and briefly describes its components.

2.1 Context

In past years, one of the main drawbacks of Semantic Web technologies in big production environments was the use of 3D. This while the power and expressiveness of Semantic Web potentially adds a lot of value to the 3D world. In fact, the realization of this approach makes possible to involve a widely distributed available knowledge of Cultural Heritage, exploiting the advantages offered by the Semantic Web technologies (Bonsma et al., 2018). One of the core issues is that 3D tends to grow very rapidly in size, especially on individual components / instances like vertices, lines or triangles. On the other hand, the key benefits of Semantic Web suffer from scalability issues when the content grows to millions of instances as is typical for geometrical representations.

Modern mature open exchange standards for geometry like IFC - Industry Foundation Classes (ISO 16739) and STEP (ISO 10303 AP 242) can grasp the original design intent and with this describe geometry in a much more semantically rich manner. This compared to pure visualization exchange formats like glTF, FBX, Collada, U3D, X3D etc.

Therefore, ontologies based on ISO 16739 and ISO 10303 AP 242 like IfcOWL (for the Industry Foundation Classes – IFC standard for BIM data) and GEOM (Geometry) are in essence the practical approach to combine 3D and Semantic Web. The crucial point of this interoperability among data relies on the correct use and extension of existing ontologies or the implementation of new ones. Ontology is indeed as a formal depiction of a shared conceptualisation, and therefore the issue in semantic search engine is how to exploit them to collect meanings based on their formal description (Colucci et al., 2021).

However, even here scalability issues arise on real world data: especially as within the Cultural Heritage domain. This issue becomes even more clear when 3D BIM models are translated in semantic triples since we don't have to deal only with 3D geometries but even with related information, attributes and metadata regarding state of conservation, history, events, or anything connected to a building, a monument or a site.

Within the INCEPTION project, several solutions have been applied to overcome these scalability issues and allow the integration of 3D and Semantic Web on real world project sizes for the Cultural Heritage domain (Iadanza et al., 2019). The ifcOWL and the GEOM ontologies are the starting point in this process, but part of that knowledge has to be mapped also on others such CIDOC CRM (Conceptual Reference Model), PROV (Provenance) Ontology or Time Ontology or Getty Architecture&Art Thesaurus (AAT) (Lopez at al., 2018) just to mention few of the most used ones.

The project 4CH is improving the important steps made already in INCEPTION to increase the benefit from Semantic Web into the 3D domain in general and for Cultural Heritage specifically (Ziri et al., 2019). Then, the models can be furthermore enriched by the mapping the knowledge also on ontologies vertically developed on specific domains such as Europeana Data Model (EDM) for content available in Europeana and ArCO for the Italian Catalogue of Cultural Heritage, as reported in the following paragraphs.

In this scenario, current approaches to semantic modeling of the Digital Twin are emerging, considering the potential of these digital representations to support interventions such as restorations, and to aggregate data and interdisciplinary information (Bolognesi & Signorini, 2021).

Moreover, current research is working in the direction of designing[2] (DS4CH – Data Space for Cultural Heritage) and exploiting[3] (i.e., Eureka3D, AI4Europeana, 5Dculture, DE-BIAS) the infrastructure of the new Data Space for Cultural Heritage as envisaged by the European Commission. Several applications on architectural heritage are at the centre of frontier research connecting virtual 3D models with several applications related to reconstruction, virtual reality, 3D interoperable BIM models and semantic-aware 3D digitisation (Bevilacqua et al., 2022; De Luca, 2020).
Beside an effective use of semantic technologies, it is of utmost importance also the development of search engines capable of querying and retrieving all available resources on Cultural Heritage at European level that cannot otherwise efficiently be accessed and analysed.

2.2 BIM standards and file formats

IFC and BIM are often named in one sentence, although there are many BIM standards (both open and closed) IFC is the only one open standard mature, trying to cover all disciplines and widely well supported, including all large names in the CAD software for the Building & Construction sector. Other well supported standards like DWG are closed standards, and/or have a more limited scope like DXF, CIS/2 and gbXML.
The main idea behind IFC is to enable open exchange within and between all available disciplines within the Building & Construction sector. This holds for both non-geometrical data, i.e., relations, classification, properties, as well as for geometrical data. In practice, both geometry and non-geometrical data are used for storage of a snapshot of the data (IFC). Complex parametrical information is not included in the stored information. Since the geometrical information is used by different technical disciplines for different purposes, the definition of the geometry as an entity is essential. IFC has a strong focus on product information, storing this in an object-based manner, although it has (limited) process related capabilities it is rarely used for supporting processes.

2.3 Semantic Web

The Semantic Web provides a common framework which allows data to be shared and reused between applications. It gives an approach how the data can be structured, related and accessed from software applications. With the semantic web technology, the data from different sources (over the internet) can be related to each other, combined and processed. The Semantic Web has mainly two major features: formats for integration and combination of data drawn from diverse sources. It forms the connection between the real-world objects and the data. It is a format to describe objects. Next to that it allows the application or services to operate with data from different sources like they are the same thing.
The Semantic Web involves publishing in languages specifically designed for data: Resource Description Framework (RDF), Web Ontology Language (OWL), and Extensible Markup Language (XML). RDF, OWL and XML, can describe arbitrary things and objects such as people, meetings, or car parts.
The structure makes it easy to create an algorithm for parsers. Once the descriptions are machine-readable, that enables content managers to add meaning to the content, which means, to describe the structure of the knowledge we have about that content. An application can process knowledge itself, instead of text, using processes like human deductive reasoning and inference, thereby

[2] https://pro.europeana.eu/page/data-space-deployment
[3] https://pro.europeana.eu/page/data-space-projects

obtaining results that are more meaningful and helping applications to perform automated information gathering and research.

2.4 From BIM to H-BIM using semantic technologies

The use of Building Information Modelling (BIM) and Historical/Heritage BIM (HBIM) is becoming more common for management and conservation of historic buildings, and in some cases for archaeological monuments. Researchers have been exploring methodologies for exporting HBIM models to more accessible applications, open standard platform and open formats with the aim of making HBIM more accessible. However, a standard data scheme in which include all the available pieces of information is still under investigation by several projects.

Metadata for 3D objects is indeed another important area that needs further standardisation. The Europeana Network Association 3D content task force, amongst others, considered the state of development of metadata standards for the description, discovery, preservation and re-use of 3D objects. The task force evaluated the following metadata models: LIDO (Lightweight Information Describing Objects), CARARE, CIDOC CRM (Conceptual Reference Model) and Europeana's EDM (Europeana Data Model) schema. These are established schemas in community use with different strengths, some placing more emphasis on capturing information about the digitisation process and the provenance of the 3D object. EDM's strength lies in its ability to integrate information from a wide range of different cultural institutions. It provides for a full description of the conceptual thing that is being provided and binds this together with information about the digital representation and where these may be found online. However, EDM does not currently readily allow for information about the provenance or the technical characteristics of a 3D dataset to be included.

2.5 The INCEPTION Core Engine

The Inception Core Engine (ICE) is the solution, based on a semantic approach, for easily exploring BIM and HBIM models and the web and accessing other contents developed within the INCEPTION project (Bonsma et. Al, 2018; Iadanza et al. 2019; Iadanza et al. 2020). ICE interprets each element of a 3D model as a single entity that can be connected to a specific knowledge. The approach consists of transforming all the geometries of a 3D model of a monument or a site into semantic triples that connect one element to another using specific predicates, defined in a dedicated semantic ontology. The 3D models have to be provided in the form of a Building Information Model (BIM) as an IFC (Industry Foundation Classes) standard file. Once the models and related information are transformed into triples, all of these are stored in a semantic triple store that is accessed via HTTP through a dedicated Apache Fuseki SPARQL server. ICE technologies can power web applications that allow users to enrich their models with new semantic metadata. Indeed, the web client allows to enrich the models with new data (e.g., a date, a value, some textual remarks) as well as attachments (e.g., pictures, thermographic images, 3D models of specific details, videos, etc.), all of which are related to the cultural heritage site or a specific geometrical element.
Similarly, the Core Engine allows not only enriching the model but also easily navigating it together with semantic metadata and attachments. Three different modes are natively included in the ICE (Figure 1): IFC, texture and hybrid views. The IFC view mode allows to select geometric elements, filter them by levels or classifications and query their metadata, while the texture mode does not present selectable elements but offers a visualization capable of offering an intuitive material understanding. The hybrid mode superimposes the previous ones by means of an editable transparency layer and allows you to select IFC geometric elements enriched this time by their real appearance. It is also possible, for each element, to access its metadata: it is possible to read the

unique Global-ID, the name, the IFCType, notes and comments. Through a graphical schema, it is also possible to navigate between categories, parameters and values attributed during the modeling phase. The values, which may contain links to internal references (other models in the platform) or external (in the web). The generality of this approach allows representing both tangible and intangible information. To give an example, a single element (e.g. a brick) can be linked to a wall, as well as to one or more documents, or to some metadata, or even to external information on the web, using nothing but semantic triples. There are also other numerous benefits of switching to a semantic solution. For example, using standard and open protocols makes the system intrinsically interoperable. It is worth recalling, here, that defining a dedicated ontology is much more than just defining a taxonomy (i.e., a tree of categories and subcategories). A semantic ontology, indeed, allows you to define properties and inference rules that link one category to another.

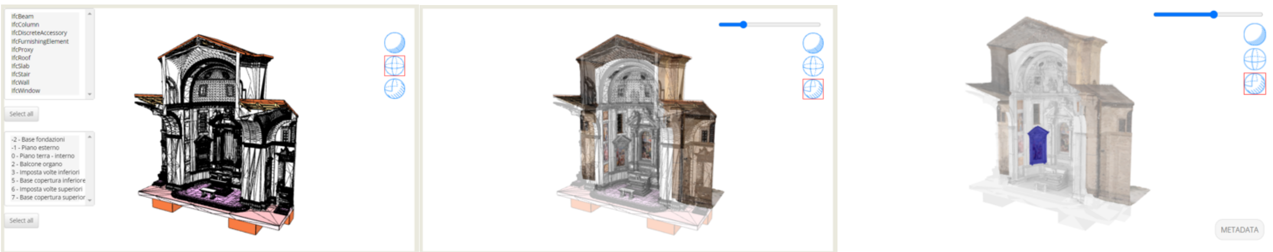

Figure 1: 3D visualization of the H-BIM model processed by ICE services in IFC (left) and hybrid (centre) visualization modes. Through the selection by elements (right) it is also possible to access the detailed information of each object.

2.5.1 Platforms powered by ICE technologies and their components

Two main platforms that uses the ICE technologies are currently running:

- http://www.inceptionhbim.eu/platform - the platform developed during the INCEPTION project, containing models developed during the project and hosted on an Amazon Elastic Compute Cloud (EC2) server;
- http://thinice.arch.unife.it/platform - an updated version based on the latest development of the ICE technologies, containing models developed by the INCEPTION spin-off and hosted on a Windows server at the University of Ferrara.

Even if they are hosted on server at different locations, they share the same architecture, as developed and documented during the INCEPTION project.

- Web application (front-end) for navigating the 3D H-BIM models and their attachments and performing SPRQL queries.
- 3D web viewer supporting 3D and H-BIM models
- Web application (back-end) for uploading new 3D and H-BIM models and their attachments, modifying and updating the existing ones, as well as adding knowledge in the form of metadata.
- Set of services for converting the 3D H-BIM models into semantic triples.
- Data storage infrastructure for archiving data.
- Fuseki Triple Store for the semantic triples.
- The platforms expose REST APIs for interacting with it and retrieving the available data.

All these components are undergoing a significant re-design and re-development for improving the current capabilities and performance and joining the 4CH Cloud Platform as a hybrid solution of federated and integrated services.

3. Latest developments beyond the INCEPTION project results

This section reports on the newly developed features within the 4CH project that expands the current functionalities of the INCEPTION technologies for maximizing their impact and meeting the requirements of the CH sector. The new possible interaction with other platforms (Europeana and the New Italian Digital Catalogue of Cultural Heritage) makes their use more consistent, as well as the new approach in the development of the 3D web viewer as WebAssembly works also towards their integration in the 4CH Cloud and other platforms (i.e., Data Space for Cultural Heritage).

3.1 Improved support of existing ontologies

As stated, among the benefits of the semantic approach there is interoperability with other sources sharing the same standard. For instance, the ICE technologies can now take advantage from the integration of ArCO ontology. ArCo is an ontology network for representing cultural heritage and the catalogue records describing them. It is based on the official General Catalogue of the Italian Ministry of Cultural Heritage (MiC), which collects and validates the catalogue records of (ideally) all Italian cultural properties (excluding libraries and archives), contributed by Cultural Heritage administrators from all over Italy.
This ontology is indeed used by the New Italian Digital Catalogue of Cultural Heritage (Catalogo Generale dei Beni Culturali) recently released by the Italian Central Institute for Catalogue and Documentation (ICCD).
The aim of the integration with the INCEPTION technologies was to exploit every single component of the H-BIM model in the Linked Open Data network for automatically querying and making inferences to New Digital Catalogue of Cultural Heritage.

3.1.1 The two case studies: the creation of the 3D assets

The approach has been tested on two case studies: the Church of Santa Maria delle Vergini in Macerata and the archaeological area of the Gran Carro of Bolsena of the Early Iron Age.

The church of Santa Maria delle Vergini is a majestic building with a Greek cross plan, surmounted by an octagonal dome erected on a drum, supported by four imposing pillars with a quadrangular base; the arms of the Greek cross end in semicircular apses, each with two cross-vaulted "scarsella" chapels. A first plant of the church dates back to 1355 but the consecration of the current configuration of building took place in 1577. The facade, developed on two horizontal registers, does not correspond to the interior space, because it was later completed. The interior of the church has eleven chapels decorated between the late sixteenth and late eighteenth centuries. The church has also undergone the action of various seismic events: among the most recent and important, we can mention those of 1997 and 2016, with particular injuries to the drum supporting the dome, still under restoration (Figure 2).

Figure 2: Aerial photo of the church of Santa Maria delle Vergini in Macerata before the 2016 earthquake (on the left) and the dome damaged in 2016 (on the right).

The site of the Gran Carro of Bolsena is unique for its state of conservation among the pile-dwelling settlements in Italy, and it certainly represents one of the most important discoveries that took place at the end of the 1950s. It is currently submerged halfway along the eastern coast of the Bolsena Lake and it is the first protohistoric deposit identified in the inland waters of peninsular Italy (Figure 3).

Figure 3: Aerial photo of the Bolsena Lake with the indication of the excavation area (on the left) and a picture of underwater excavation activities (on the right).

In both cases, the starting point was to elaborate a BIM model that could operate as the main reference and federator of information about the architectural or archaeological asset. Since the purpose of the modeling is different from the logic of intervention on buildings, it was decided to operate a modeling that was adequate to accommodate the information of material nature and state of preservation, as well as of historical-documentary data from the ICCD Catalogue. 3D-BIM geometry modeling was performed with the use of free-form techniques since the majority of elements (in particular for the archaeological case study) were out of the scope of use of the BIM software used (Autodesk Revit).

3.1.2 Development of new feature for semi-automatic enrichment

On the other hand, from the information point of view, we proceeded to browse the New Catalogue of Cultural Heritage where it is possible to search by elements, authors, cultural places, sectors, locations, possibly filtering the search by specific parameters (Carriero et al. 2019). In this phase, it was decided to extrapolate all the data of the RDF (Resource Description Framework) resource related to the assets, which will be subsequently queryable through SPARQL endpoint by inserting the URI of reference of the element. In this case, the URI of the element has been then used for the informative enrichment of the BIM model, representing a univocal identification according to the standardization of the catalogue.

The data thus elaborated were processed by the INCEPTION Core Engine for accessing the benefits of the Semantic Web, to visualize and aggregate heterogeneous sources of data. In fact, based on the identification code previously identified and annotated on the element during modeling, a function of the ICE services was developed in order to automatically operate a query of the RDF data available online through an SPRQL Query on the Virtuoso EndPoint located at http://dati.beniculturali.it/sparql. The data retrieved from a SPARQL endpoint conforms to the Linked Data approach for publishing data in the Semantic Web context. RDF-formatted data is normally represented as a list of semantic triples but, through a specially developed function, these triples are displayed in the graph as if they were data directly entered during modeling. This approach allows the end user to read them seamlessly and, in the same way, to read data that is always up-to-date and aligned with the catalogue (Figure 4). This approach, in addition to having been developed for the entire federated H-BIM model, has also been extended to detail models, creating a true multiscale model. In the case of Santa Maria delle Vergini, for some of the eleven chapels, in fact, the 3D attachments referring to minor cultural assets (paintings, decorations and sculptures) have also been loaded, creating a complete navigation path able to give a spatial location to the cards of the Digital Catalog (Figure 5). Conversely, on the Gran Carro di Bolsena has been created a hierarchy of 3D models that replicate the same organization deriving from the Catalogue, moving from the overall site, to the excavation sector to the finds where everything is documented in 3D and enriched automatically by the appropriate RDF resource.

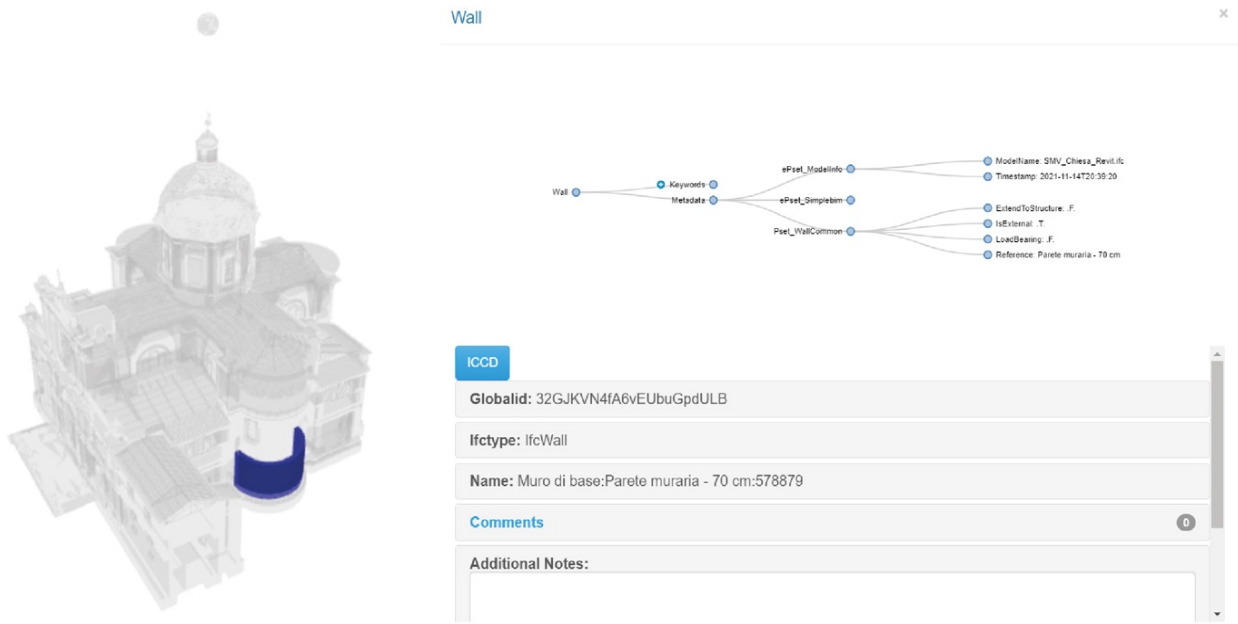

Figure 4: Every element of the building can be used to perform a live SPARQL query that returns all the details for that element, according to the HBIM ontology. Each value can be updated via web, thanks to the SPARQL 1.1 Update functionalities.

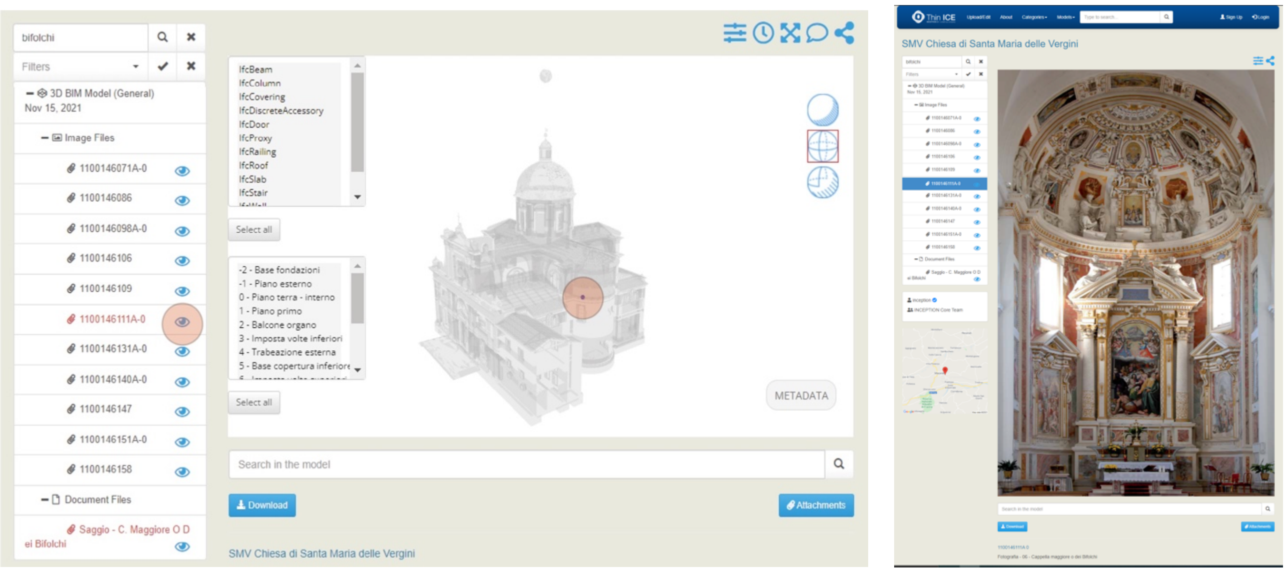

Figure 5: 3D textured visualization of the overall H-BIM model processed by the ICE services (left) and visualization of the high resolution photo of one of the chapels (right) retrieved from the ICCD Digital Catalogue.

3.2 The new 3D web viewer

The 3D web viewer has been re-designed and re-developed as a WebAssembly solution. WebAssembly (abbreviated WASM) is a binary instruction format for a stack-based virtual machine. WASM is designed as a portable compilation target for programming languages, enabling deployment on the web for client and server applications. The basic difference here is also that all processing is now done on the client side and the files don’t have to be transferred to another location to process them, making the viewer working also in case of bad internet connections.

However, the WASM solution still works in combination with parsing all data for geometry through a Fuseki server. However, the geometry is for now not stored as an ontology (although it is valid content against the GEOM ontology) but stored as BASE64 strings.
JSON strings as results of a SPARQL query can be accepted by the WASM component, working very similarly to our WebGL solution, however much faster (and for visualization with everything done on the client).
At the current development the main developments have been:

- All geometries are stored as a matrix + set of vertices (x, y, z, Nx, Ny, Nz, [u, v]) with per color (i.e. ambient, diffuse, emissive, specular + transparency) a set of triangles, lines and points (i.e. technically supporting mapped items, assemblies, point clouds etc.);
- A modular setup, both in non-geometrical semantics as well as in geometrical semantics, i.e. it is cleanly decidable what processing should be executed in the Web Assembly (WASM) component and what should be pre-processed (into both extremes, i.e. full IFC / STEP parsing in WASM or delivering a pure mesh as input);
- In the developed WASM component the following file types are supported:
    - IFC (IFC 20 LF, IFC2x, IFC2x2, IFC2x3 TC1, IFC4 Add2 TC1, IFC4x1, IFC4x2, IFC4.3 Add1 and IFC4.4)
    - STEP (CIS/2, AP203, AP214 and AP242(ed2))
    - DXF
    - DAE (Collada without textures as .ZAE)
    - OBJ
    - JSON with geometry embedded geometry serialized as BIN/X in BASE64 format.
- Furthermore, the support for meshing of E57 files has been implemented in the Geometry Kernel. E57 files can be loaded directly within the viewer and automatically a meshing algorithm will be applied.

Based on the developed solution and new features introduce, there are 3 main benefits:

- Faster processing and capabilities for visualizing larger (IFC) files
- Reduction of data transfer, for example compare the zipped version of the JSON for a complete IFC file with current traffic
- Tighter integration with Semantic Web; as each individual geometrical object is encoded as a single BASE64 string processing of even high volume (less semantic rich) geometry instances can be integrated in Fuseki / JENA without losing performance. [on request each BASE64 string can be extended in a triple file serialized as turtle]

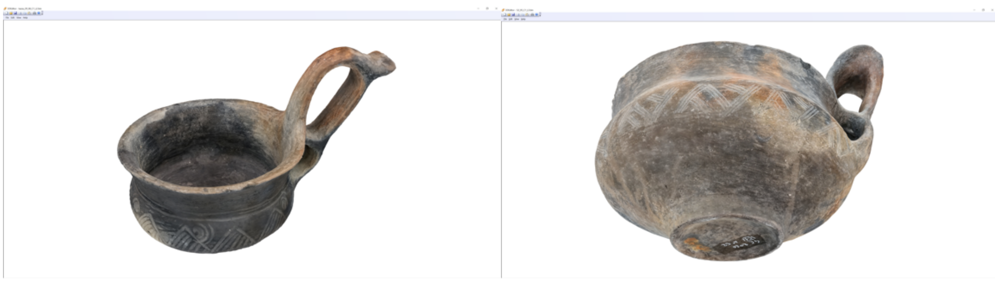

Figure 6: Testing small 3D objects on the new 3D web viewer developed as a WebAssembly solution: Collada textured models of archaeological finds form the Bolsena Lake.

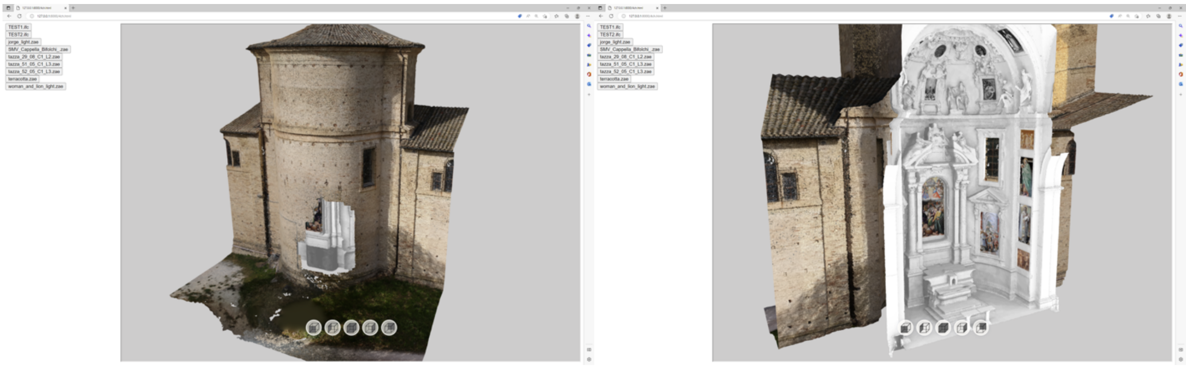

Figure 7: Testing big 3D objects on the new 3D web viewer developed as a WebAssembly solution: Collada textured models of the Church of Santa Maria delle Vergini in Macerata.

4. Joining the 4CH Cloud Platform as hybrid solution

This section reports on the specific actions for integrating or federating the different INCEPTION services in the 4CH Cloud platform, making it a hybrid solution of integrated and federated services as already foreseen in D3.1 – Design of the CH Cloud and 4CH platform.

The INCEPTON platform already exposes REST APIs and a reachable endpoint for interacting with it and retrieving the data, making it compliant with the first requirements of both integration and federation.

4.1 Service integration: the Fuseki Triple Store

A main service that composes the current INCEPTION platform/application will be integrated into the 4CH Cloud Platform: the Fuseki Triple Store for the semantic triples.

The Apache Jena Fuseki is a SPARQL server. It can run as an operating system service, as a Java web application (WAR file), and as a standalone server. Fuseki comes in two forms, a single system "webapp", combined with a UI for admin and query, and as "main", a server suitable to run as part of a larger deployment, including with Docker or running embedded. Both forms use the same core protocol engine and same configuration file format.
Fuseki provides the SPARQL 1.1 protocols for query and update as well as the SPARQL Graph Store protocol. Fuseki is tightly integrated with TDB to provide a robust, transactional persistent storage layer, and incorporates Jena text query.

INCEPTION Core Engine technologies uses the the Apache Jena Fuseki for managing all the data. The resources exposed by this service can be labelled as free-access or authentication protected depending on the data type, ownership and/or other specific requirements. The labelling, however, will be managed by the backend web service that can't be integrated (Web application for uploading new 3D and H-BIM models).

Currently, this service and the related ones exploiting it are undergoing a re-development. The Fuseki Triple Store will be containerized and make available in the common image repository offered by the 4CH Cloud Platform. The images will respect the common security aspects and will be compliant with the security best practices.

Furthermore, the data managed by the Fuseki Triple Store (such as 3D models and all the documents classified as attachments) will be stored in the data storage infrastructure of the 4CH Cloud Platform.

4.2 Service federation: the web applications and the 3D web viewer

Three services that composes INCEPTION platform/application will be federated:

- Web application (front-end) for navigating the 3D H-BIM models and their attachments and performing SPRQL queries.
- Web application (back-end) for uploading new 3D and H-BIM models and their attachments, modifying and updating the existing ones, as well as adding knowledge in the form of metadata.
- 3D web viewer supporting 3D and H-BIM models.

As already mentioned, REST APIs are already exposed. All three service exposes resource manged by the Apache Jena Fuseki that, as previously managed, will be labelled as free-access or authentication protected. Authentication and authorization mechanism will be compliant with the requirements of service federation. Thus, these 3 services will comply with the federation requirements.

Nevertheless, must be noticed that also these three services can be also containerized but the integration can't be achieved since they are running under a Microsoft Windows Server environment and exploiting Microsoft Internet Information Services. Indeed, among the requirements for service integration there is the use, within the container, of an Open-source Operating System. However, the main development was performed under the INCEPTION project and the re-development under an Open-source Operating System is out of the scope of the 4CH project.

4.3 Under evaluation: services for converting the 3D H-BIM models into semantic triples

As in the previous case, the set of services for converting the 3D H-BIM models into semantic triples have been developed under a Microsoft Windows Server environment but can potentially be re-compiled for running under an Open-source Operating System. Currently, this possibility is under evaluation since requires a limited amount of time for re-compiling, but they could present unexpected behaviours, errors or crashes. Nevertheless, the complete re-organization of dataflows between services located on different servers can lead to Cross-Origin Resource Sharing (CORS) issues for functions not covered by REST APIs requiring a further development.

Thus, for this set of services is still under evaluation the feasibility of the integration. If this won't be technically possible or if too many issues will raise in this phase, these services will be federated complying with all the related requirements.

5. Next steps

The present document described the activities carried out until now, explaining what has been already developed and what is still ongoing.
In order to conclude the integration and federation of the different services by the end of the project and delivering a complete hybrid solution, the following steps are needed:

- Finalizing and testing the integration of the Fuseki Triple Store.
- Making the front-end and back-end web application compliant with the authentication and authorization mechanism.
- Finalizing and testing the federation of both the web applications and the new 3D web viewer.
- Concluding the evaluation of integration or federation of the set of services for converting the 3D H-BIM models into semantic triples and finalization and testing of the identified solution.
- Overall testing of the hybrid application in specific case studies.

Furthermore, it must be noticed that the concurring actions that will provide web services on Cultural Heritage (and 3D Cultural Heritage in particular) may need to use some or all the services composing this hybrid application based on INCEPTION technologies. Some of these services have been already included in the work plan of other EU project such as 5Dculture[4], a project that aims to enrich the offer of 3D digital cultural heritage assets in the common European data space for cultural heritage and foster their reuse in domains such as education, tourism and the wider cultural and creative sector.

Nevertheless, the 4CH project will continue to proactively explore in the next month any possible synergy with the deployment of Data Space on Cultural Heritage (DS4CH) or other new initiatives such as the European Collaborative Cloud for Cultural Heritage[5].

[4] https://pro.europeana.eu/project/5dculture-deploying-and-demonstrating-a-3d-cultural-heritage-space
[5] HORIZON-CL2-2023-HERITAGE-ECCCH-01-02(HORIZON-RIA), HORIZON-CL2-2023-HERITAGE-ECCCH-01-01(HORIZON-IA)

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