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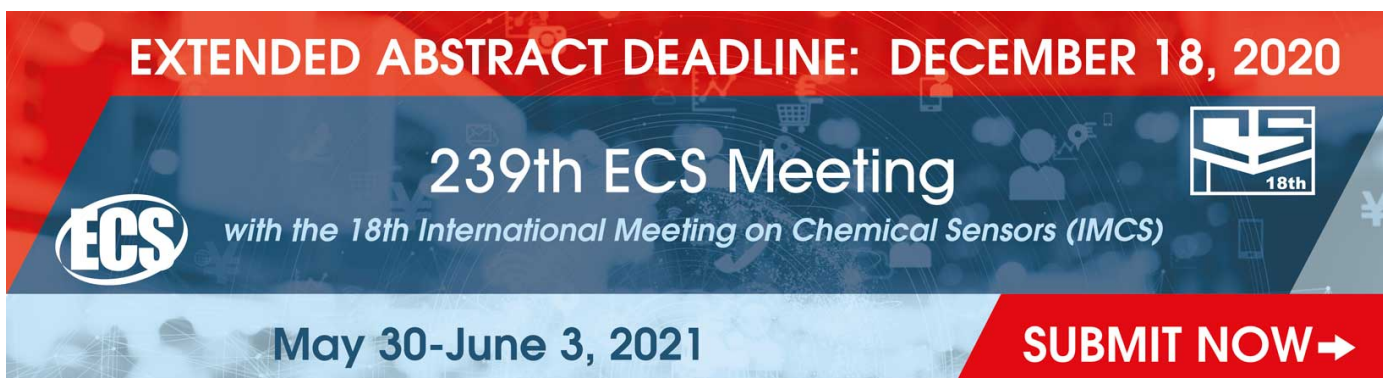
Bridging the Gap between 3D Navigation and Semantic Search. The INCEPTION platform

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Bridging the Gap between 3D Navigation and Semantic Search. The INCEPTION platform

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Abstract. The paper presents the main outcomes and future development of the INCEPTION project, "Inclusive Cultural Heritage in Europe through 3D semantic modelling", funded by the European Commission under the Horizon 2020 Work Programme *Europe in a changing world – inclusive, innovative and reflective Societies* (Call Reflective-7-2014, *Advanced 3D modelling for accessing and understanding European cultural assets*) and completed in May 2019. In particular, the key-targeted project achievement will be presented: a specific cloud-based platform conceived to accomplish the main objectives of accessing, understanding and strengthening European Cultural Heritage by means of enriched 3D models. The need for digital data interpretation, in addition to documentation, guided the overall process of the cross-disciplinary work methodology, based on new methods and tools for 3D surveying and H-BIM modelling, new approaches and methodologies for Cultural Heritage 3D data inclusive access and exploitation by means of the Platform.

1. Introduction

The main results of the INCEPTION project are effective 3D digitization techniques, post-processing tools for enriched semantic modeling, web-based solutions and applications to ensure broad access to heritage material to experts and non-experts [1]. INCEPTION, acronym for *Inclusive Cultural Heritage in Europe through 3D semantic modeling*, was financed by the European Commission (Horizon 2020, Call Reflective-7-2014, *Advanced 3D modeling for accessing and understanding European cultural assets*).

Project implementation has been divided into several steps to address all of the major challenges and criteria for changing the role of digital models in Cultural Heritage (CH): semantic enrichment, interoperable formats, disciplinary partnerships, and the exploitation of digital sources.

In order to undertake holistic and critical analysis and an inclusive interdisciplinary approach, the first action establishes a shared structure for the convergence of many areas of expertise, allowing real coordinated data collection in the second action. When data is obtained, semantic processing makes it possible to efficiently aggregate data. It is possible to create a forum for storing, archiving and exchanging semantically enriched models through the adoption of Building Information Modeling (BIM) standards. Ultimately, the implementation of such information is carried out through a user-oriented program, beginning with the interoperability of existing data [2].

The project was developed over a period of four years, from June 2015 to May 2019. The final presentation of results, during the last Consortium Meeting held in Zagreb (Croatia), highlighted the achievement of remarkable solutions for the scientific community. The post-project follow-up was also considered essential in order to make full use of the opportunities that have been developed during the funding period, in Digital CH and also for applications in other areas. The laser scanning firmware for optimized 3D data acquisition (as part of the first deliverables concerning data collection) and the web platform for exchange and collaboration of Heritage data in BIM format are the most relevant innovations of the project. Now the platform is under improvement in order to provide solutions to market-needs such as restoration and other applications.
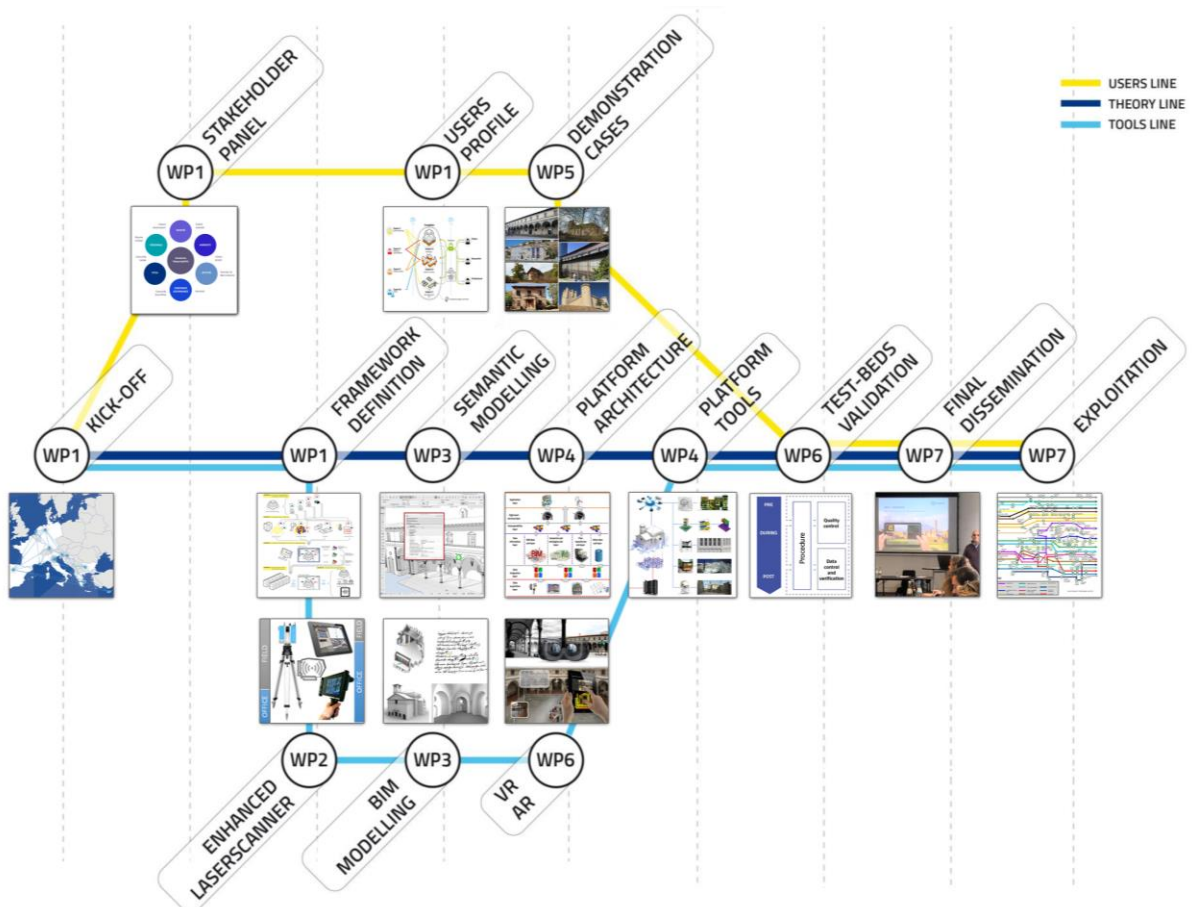

Fig. 1 Schema of the INCEPTION overall procedure split in different actions.

This paper is mainly focused on models sharing, 3D navigation and semantic search. The assumption from which this project section was developed is that there is an increasing amount of 3D data on Cultural Heritage buildings in Europe, and a wide variety of innovations and user-oriented applications, but there has been a lack of tools for sharing digital models of heritage buildings. The State of the Art research from which INCEPTION began to structure a methodological proposal for the integrated documentation and inclusive use of 3D models has revealed that many projects and initiatives have been undertaken to digitize heritage [3]. Nevertheless, many of them concentrated on movable heritage, not on a building scale. Furthermore, since one of the key results of INCEPTION is the implementation of a semantic BIM framework for Cultural Heritage buildings and sites, the features included in the framework were compared with several web-based platforms [4][5] that

provide downloading and exchange of 3D models. Platforms dedicated to CH are typically dedicated to document and/or enhance a particular documentation project [6] or to providing interactive fruition of 3D models [7][8].

INCEPTION, building up on previous experiences from different domains [9][10], developed a RESTful suite for accessing and understanding digital Cultural Heritage sites, offering the chance to collect and explore time-upgradable 3D models.

2. Semantic modeling and data management

The key preliminary action for the development of the platform deals with the BIM modeling, which allows for the linking of data and information to geometries through semantics.

In order to collect and link additional data and knowledge to the BIM model, a layer-based and sharable ontology has been set up, connecting each part of the building to its construction or style category [11][12][13]. The need to also establish links between the BIM model and external information has led to the development of an extension of the ontology, to be able to connect documents or other data either to the entire model or to specific parts. The starting point is the ifcOWL, an open format of the semantic web specific for parametric modeling, adapted to the specificities of Cultural Heritage, integrating it with an appropriate nomenclature. This integration was initially implemented on a set of digital models developed during the project as pilot and use cases:

- A Museum, to connect the building with the collection of artworks located inside it by applications of data enrichment and Virtual and Augmented Reality (Hydra, Greece);
- A Museum building to analyse the peculiar structure and its behaviour from a technical (construction technology) and loading point of view (Zagreb, Croatia);
- A church in need of enhancement and connection with the intangible heritage (Mirlovic Zagora, Croatia);
- A very renowned renaissance complex to aggregate historical documentation to the digital model and increase knowledge (Florence, Italy);
- A Chapel, to test the use of the BIM model for asset management requirements (Groningen, The Netherlands);
- An historic building to develop ICT tools in order to perform multispectral analysis and enhance cultural and educational activities, improving experiences of citizens and visitors (Athens, Greece);
- A small Church with wall paintings inside to which to connect information for knowledge and enhancement and to assess the state of conservation of frescos and materials' quality and performance (Nikitari, Cyprus);
- A Castle, to study the state of conservation and digitally monitor cracks and humidity (Valladolid, Spain);
- Archaeological remains of an acropolis to study the parametric modelling of unique and irregular elements (Erimokastro, Rhodes, Greece).

Heritage pilot cases were pointed out in order to provide the most possible variety of conditions and features to apply efficiently and assess the INCEPTION procedure; these heritage buildings and complexes have dissimilar features to be digitally surveyed and modelled by data enrichment, in order to cover various assessment condition and meet different needs by sites owners or managers, ranging from diagnostic up to improvement.

Therefore, after the documentation stage, following a specific procedure set up according to the Data Acquisition Protocol [14] developed under INCEPTION, 3D modeling and data aggregation in BIM environment started. During the project development, the Protocol provided a set of actions aimed at optimizing digital documentation and data capturing, allowing to manage a shared framework for the development of parametric models (H-BIM).

3. Navigation and semantic search: the INCEPTION platform

The platform developed within the project is something very different from an archive or database: it is a tool that allows to expand and adapt the standards available nowadays. By applying specific IT solutions, when the 3D parametric model is uploaded on the platform each geometric element is connected to an URI (Unique Reference Identifier) through an HTML interface that uses the capabilities of the semantic web. Thanks to this code, it is possible to link and aggregate different information (documents, pictures, different file formats as text, video, audio, etc.) to specific parts of the model accordingly.

This step, in which the INCEPTION platform embeds data and information clustering and connection, has created the conditions for a wider use of the IFC format in modeling. When an IFC (Industry Foundation Classes or ISO 16739:2013) [15] model is developed with new property sets, the platform is able to manage these proprieties by an automatic process, converting data and features in semantic triples. In addition, if these property sets are generated to meet particular requirements or actions related to Heritage data management and foreseen within the platform tools, merged data can be processed beyond.

A feature particularly relevant for 3D models navigation and use of related data semantically aggregated is the ability to allow links to external databases or repositories, mainly significant in model browsing and for the widest possible use of data gathered through semantic technologies. When setting up the platform's functionalities, the question was raised as to not only uploading parametric models but other 3D model formats of Heritage sites, including the DAE. This ability has been undertaken for a number of reasons:

- sometimes BIM Authoring file formats are not conceived to export applied textures into the IFC (as can happen for instance for painted or decorated surfaces, where the colour and texture data is crucial for the documentation of architectural surfaces);
- very often it becomes particularly relevant to be able to aggregate to the BIM model of the heritage building or site additional 3D models of parts of the building or decorative elements or artworks included in the heritage building itself;
- the ability to reuse different (non-parametric) 3D models previously developed is a great advantage since it allows to upload on the platform potential unexploited data and reconnect these data to the semantic structure;
- the platform can become a means to increase the shared use of different 3D models [16] [17].

The platform architecture is therefore structured to manage data in a targeted and flexible way, and to create specific media and software solutions effectively usable for Heritage documentation and data sharing.

The platform is currently being further implemented in order to be user-friendly to as many people as possible thanks to targeted functionalities and to increase the possibilities for exploring different contents and to reach a deeper knowledge of heritage sites and buildings, not only through visualization but also through interaction with these structured data and information. Indeed, the different heritage 3D models that can be uploaded on the platform in different file formats, once loaded are processed and connected to each other. By activating a specific platform functionality, it is possible to swap between models while keeping the same angle or view. In addition, it is possible to use the transparency visualization tool to select geometric elements between models. For instance, it is possible then to select a surface with specific features such as decorative or frescoed elements in the DAE model and explore information about that geometry by switching to the BIM model.

The platform can then be used in so-called static mode, exploiting the different contents (3D models, pictures, documents, ontologies, etc.) downloading the information to be used in external applications, or in dynamic mode, through the INCEPTION APIs to get information directly from the platform on external applications.

Fig. 2 The INCEPTION semantic approach. In addition to the IFC model management, the platform allows browsing different contents by selecting geometric elements through the "transparency" tool.

The so-called "Time Machine" functionality is an example of data processing and management that can be developed within the INCEPTION platform. The Time Machine tool allows to view and analyze the BIM model by selecting the historical period associated with parts of the model of the architectural complex, which correspond to specific time frames. A time line is thus processed and displayed in the platform, allowing dynamic views, i.e., the model representing what the building looked like in the selected historical period or specific year. This function, which requires in-depth historical investigations and consultation of documentation that can be uploaded to the platform and associated with the model, can be of support in the analysis, knowledge and interpretation of buildings or historical sites. The Time Machine functionality provides a wide range of users with the ability to browse and analyze the modeled heritage according to spatial and multi-temporal criteria, leading to new dimensions for the enjoyment and experience of the historical environment.

On the case studies listed above in paragraph 2 and on other 3D models of cultural heritage sites and buildings, different ways to use the multiple outcomes and results of the digitization process and data semantic organization within the platform have been tested, in order to validate the documentation methodology, experimented tools, uses and exploitation. Among the main applications targeted to the Heritage community in a broad sense to interact with 3D models and the platform, Virtual and Augmented Reality (VR and AR) applications are mainly focused for touristic or ludic purposes, or the so-called edutainment, therefore also with educational purposes for the knowledge of the heritage. Pursuing these aims, the already mentioned "static" and "dynamic" methods that the platform allows have been tested.

The choice to adopt AR or VR applications clearly depends on the different ways to enjoy digital contents. Indeed these applications allow to explore heritage contents synchronously or asynchronously, and on site or remotely. Both the experiences and the devices used are therefore different. The models are delivered through the platform in already existing Apps for several purposes (research, tourism, building maintenance, specific studies, etc.) also using mobile devices (for AR applications) or headsets.
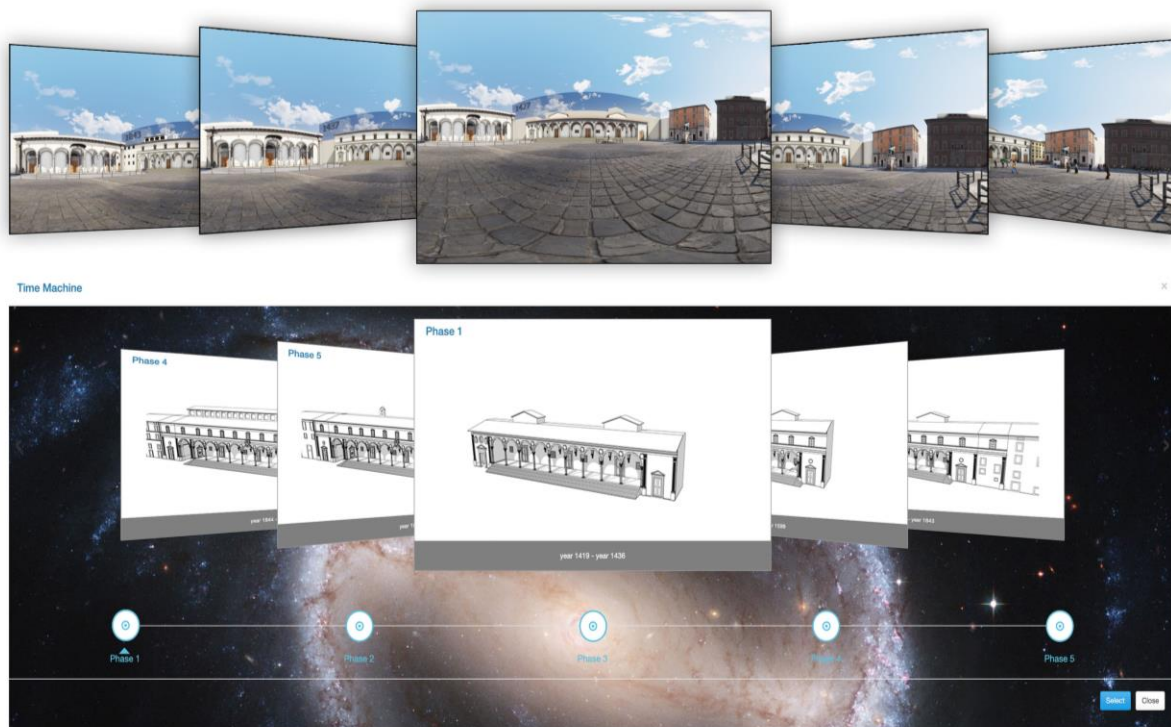
Fig. 3 Visualization of applications for Virtual/Augmented Reality and, below, the application developed to browse BIM models according to the time dimension. The time line is visible as well the different phases and corresponding configurations of the building over the centuries.

4. Future developments

Leveraging on technologies and approaches typical of semantic web for organizing H-BIM modelling and management of data [18], the INCEPTION Platform enables the deployment and valuation of enriched 3D models, achieving the key purposes of information retrieval and enhancing CH in Europe. Thus, users are increasingly able to access knowledge of various sites and artifacts, share knowledge among themselves and enrich the understanding by means of digital platforms and social media with their observations and additional insights. In addition, digital models and aggregated platform data enable the deployment of models for various purposes through Virtual and Augmented Reality applications.

The trends, results and follow-ups of INCEPTION will shift in the direction indicated in the recent Declaration "Cooperation on advancing digitization of cultural heritage" signed by Member States during the Digital Day 2019. This Declaration confirmed the commitment by the European Council, the European Parliament and the European Commission in fostering digital technologies to record, document and preserve Europe's cultural heritage and their accessibility to European citizens.

In order to meet documentation and security needs in the face of growing threats to cultural heritage causable by natural disasters, pollution, mass tourism, destruction over the period, terrorism and vandalism, future research will also require documenting and digitization, therefore growing the accessibility for European citizens' to heritage sites at risk. The efficient use of digital content, increased digital participation and promotion of sectors like tourism, education and creative industries needs high-quality 3D models, interoperable formats and open access to digital heritage properties.
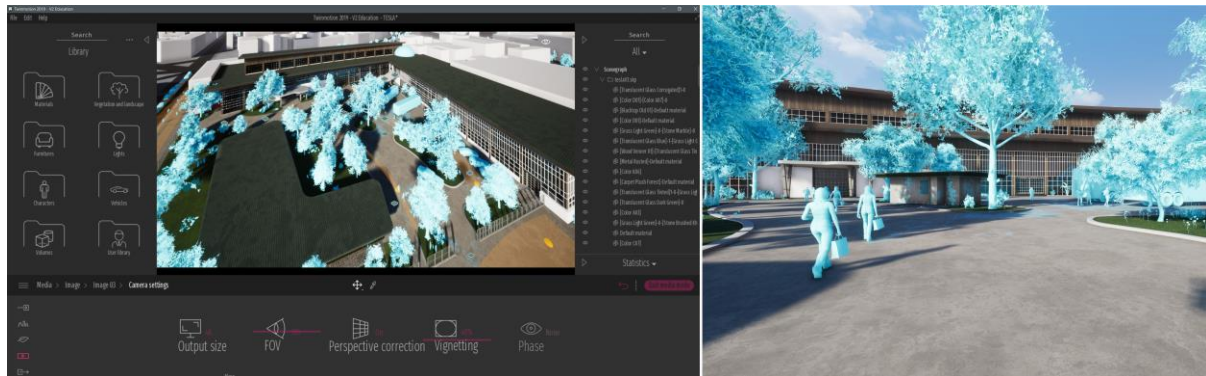
Fig. 4 Development of a Virtual Reality immersive environment for one of the INCEPTION Demonstration Cases: the Technical Museum Nikola Tesla in Zagreb, Croatia.

Additional steps in the area of the digitization of heritage will be introduced through the implementation of the Protocol and the population network. These acts would follow criteria relating to common data modeling principles, methodologies and guidelines; platform conditions for open repositories for the storage, management and re-use of interoperable 3D models; and best practices for the development of 3D digitization knowledge and skills.

Future progress will also require the use of the data obtained for on-site and off-site applications on the platform. Big data, artificial intelligence, natural language processing, augmented-virtual-mixed reality and 5 G to make creative use of digitized cultural resources, the extraction of information and a more immersive experience of heritage material are potential research avenues that can benefit from what has been developed already.

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