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An inclusive approach to Digital Heritage: preliminary achievements within the INCEPTION project

F. Maietti[1], M. Medici[1], E. Piaia[1]

[1]Department of Architecture, University of Ferrara, Italy

Abstract

At the end of the second year of activity and after having completed the first steps in the development of its main goals, the project "INCEPTION - Inclusive Cultural Heritage in Europe through 3D Semantic Modelling" is now facing different challenging actions starting from already developed advancement in 3D data capturing. Semantic modelling for Cultural Heritage buildings in H-BIM environment and the development of the INCEPTION platform for deployment and valorisation of enriched 3D models will allow accomplishing the main objectives of accessing, understanding and strengthening European cultural heritage. In this direction, the approach and the methodology for semantic organization and data management toward H-BIM modelling will be presented, as well as a preliminary nomenclature for semantic enrichment of heritage 3D models. According to the overall INCEPTION workflow, the H-BIM modelling procedure starts with documenting user needs, including experts and non-experts. The identification of the Cultural Heritage buildings semantic ontology and data structure for information catalogue will allow the integration of semantic attributes with hierarchically and mutually aggregated 3D digital geometric models for management of heritage information.

CCS Concepts

•***Computing methodologies*** → ***Graphics systems and interfaces;*** •***Applied computing*** → ***Architecture (buildings);*** •***Software and its engineering*** → *Software libraries and repositories;*

1. Introduction

Nowadays, we are witnessing to a more and more growing dichotomy between engaging and rewarding user experiences and the enrichment of the scientific knowledge. Bridging the gap is the significant request that dissemination activities should try to achieve. Within this framework, the INCEPTION project goals are consistently aligned while accomplishing the main objectives of accessing, understanding and strengthening European cultural heritage by means of enriched 3D models.

The INCEPTION project [DGMP16], started in June 2015 and lasting four years led by the Department of Architecture of the University of Ferrara, aims at developing advanced 3D modelling for accessing and understanding European cultural assets. The main innovations proposed by the project are related to innovative technologies for creating 3D models with an inclusive approach to Cultural Heritage; the possibility to achieve interoperable models able to enrich the interdisciplinary knowledge of European cultural identity by different users; the development of an open standard platform to "contain", implement and share the digital models.

Within this overall structure, the project is divided into five main steps: setting up of a common framework and knowledge management; advancement into the integrated 3D data capturing methodology; semantic modelling for Cultural Heritage buildings in H-BIM environment; development of the INCEPTION platform; deployment and valorisation through different on-site and off-site applications for a wide range of users.

1.1. Main contents and paper purposes

The already developed Data Acquisition Protocol sets up a common and shared procedure to collect data, allowing to make the data reliable and comparable. Furthermore, once the reality is digitized, the choice of the right ICT standard is a necessity in order to aggregate data in compliance with needs predetermined within the project. Since buildings, sites and complex architectures are the main topic of the INCEPTION project, the BIM IFC standard seemed to be the most suitable choice. Nevertheless, making a standard, born for new buildings, suitable for historical ones, asked for a further development and enrichment by the use of semantic technologies, that led to the definition of the new INCEPTION ontology.

Only on this ground, it was possible to design a platform that could meet the main aim of realise innovation in 3D models "forever", "for everybody", "from everywhere", by developing, collecting and sharing inter-operable 3D semantic models. This short paper wants to briefly describe these mains steps in order to deepen

and focus on the data flow, as well as the interdependencies of the different components, that has been needed to achieve the work-in-progress results by the mid-term of the EU research project.

2. Data capturing

The 3D data capturing process is the first step of the overall INCEPTION procedure [MDGB*17]; optimized data acquisition and processing allow managing data toward the most possible interoperability.

Among the main challenges achieved by the Optimized Data Acquisition Protocol (DAP), there are the setting up of a common procedure to collect data, and to manage issues related to the 3D survey of complex architectures and to the large amount of captured data. The purpose is to guide the processes of digitization of cultural heritage, respecting needs, requirements and specificities of cultural assets [DGBPZ12]. The protocol has been developed within a more wide-ranging methodological procedure of heritage documentation [RS16], considering semantics and metadata in addition to geometries and morphologies in order to start working on model enrichment since the data acquisition phase. This set of flexible guidelines considers site specifications and the uniqueness of Cultural Heritage, according to many different characteristics and to the main purposes of survey and documentation procedures, defining a common background for the use of 3D models across multiple building types and for a wide range of expert and non-expert users [PBDMDM13].

The DAP is intended to ensure uniformity in 3D digital survey aimed at 3D H-BIM semantic models creation and their implementation for the INCEPTION platform. Under the DAP, the survey workflow is split into eight main steps that define specific requirements and their related activity indicators (Scan Plan, Health and safety, Resolution Requirements, Registration mode, Control network, Quality control, Data control and verification, Data storage and archive) and four evaluation categories (B, A, A+, A++). From the minimum evaluation category to be compliant with the INCEPTION Platform up to the A++ category, the DAP relates type of building and survey and deployment purposes. This classification ranges from very simple buildings for the creation of low-detailed BIM model for digital reconstruction aimed at VR, AR and visualization purposes, to very complex buildings, where the capturing process need to be documented and traced. Survey procedures under "A" category, where metric and morphologic data are relevant, are suitable for restoration projects, for survey integrations, etc. [DGMP*17]. The DAP is now under application within 3D data capturing and documentation of the INCEPTION Demonstration Cases, nine significant heritage sites in six European countries, practical applications and analytic potential of 3D models for research, interpretation, scholarship and innovation in curation and dissemination, related to multimedia process, application tools, accessible databases and the INCEPTION platform [IFM*16].

In order to understand the impact of the INCEPTION DAP, a specific evaluation grid has been arranged considering three features [EG15]: reliability, usability, effectiveness of the survey, considering the point of view of end-users and the capability of a 3D survey to be compliant with standards and ensure a long-term support [BBM04].

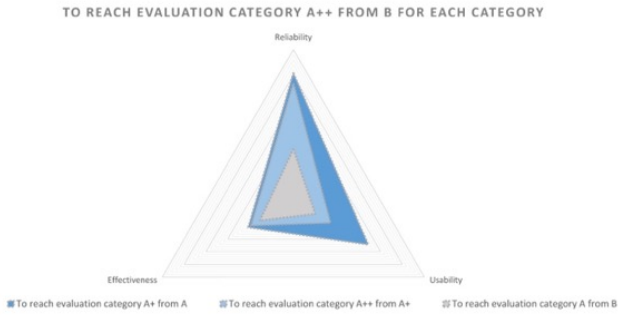

Figure 1: *Aggregation of evaluation features into ternary plots.*

3. Semantic enrichment

Once data are captured and stored, they should be processed in order to make them usable and understandable. One of the most widespread approach for historical buildings is related to a 3D digital semantic model, based on BIM technologies. Since several researches have already deepened and stressed the creation of geometrical models by survey data [Rem11], we'll not further discuss the topic in this essay. Anyway, we should consider that successful results have been already achieved, even if a univocal workflow is still far away to be identified. Instead, the semantic enrichment is a more challenging topic. The expectations on this are quite broad, but the architectural differences make the task quite difficult. Furthermore, what is the added value of applying a linguistic resource to the architectural problem is still an open question, as well as how to identify an effective BIM approach for cultural heritage knowledge [ACM17] semantic enrichment and model management.

We can state that the first step in creating semantic BIM for cultural heritage is defining the ontology, a formal representation of knowledge as a hierarchy of concepts within the cultural heritage domain, using a shared vocabulary to denote the types, properties and interrelationships of cultural heritage aspects [ALT16]. Nevertheless, naming each architectural element that composes a building is not an easy task. For this reason, aiming at the standardization in heritage documentation data handling and management, the INCEPTION project has developed common parameters setting a nomenclature or "glossary of names" as a starting point to semantic enrichment and modelling in BIM environment. A specific hierarchical organization of European Cultural Heritage information about buildings is under development, based on sematic approach to prevent a restricted access to the knowledge. With a top-down approach, information about the target of the model will be organized in a semantic structure, adding to geometric information attributes such as architectural style, time frame, author, location, etc.

Semantic 3D reconstruction of heritage buildings and sites needs a multidisciplinary approach based on the collaboration of various experts towards the development of 3D models integrating semantic data [MKK*13]. The first step requires the identification of the Cultural Heritage buildings semantic ontology and data structure for information catalogue in order to integrate semantic attributes with 3D digital geometric models for management of heritage information. The ultimate goal of this process is the development of

semantic 3D reconstructions of heritage buildings and sites, integrated with intangible information and social environment, to create models more accessible and implementable. Collection of semantic data associated to the models enables the semantic information enrichment by users, sharing knowledge and allowing new interpretation and understanding of European cultural assets.

The issue of semantic enrichment has been split into "how to retrieve the data" and "how to aggregate the data". If 3D data can be captured following a more commonly shared procedure, terminology and interpretation have a large variety when looking at semantics, due to different competencies, skills and languages. On the other hand, making data aggregable asks for a Semantic Web structure [LAN*17] in order to give back to different users a new way to look at the information in a Heritage context. A semantic web structure means also that the relations, properties and composition of the "nodes" of the information give a new insight different from a list of the same concepts or a database structure. Since now, consistent structured data are missing in for cultural heritage architectures. The INCEPTION approach in the selection of the nomenclature for Cultural Heritage starts from classical architectural sources: the project is focused on historical architectures and sites, and the activities accomplished during the first year of project defined the common framework for catalogue methodology. The outcomes from this work led to comprehensively considerations related to possible classifications of individual buildings and sites [MPHKI16] according to international Charts, Recommendations and Conventions.

The work done so far regarding the "taxonomy of monuments" according to holistic e-documentation needs is the base to understand the approach on "names" to start a classification in Semantic Web in order to connect terms with H-BIM ontology. Additional future steps will allow adding further terms, definitions and different translations by means of automatic procedures. Therefore, the common glossary of names crossing all demonstration cases under development. Names have been organized following a structure that could ensure the linking between elements and could be reused in the IT development phase. Analysing the state of the art of CH data dictionary, the Getty Vocabularies were chosen as starting point. The Getty vocabularies (AAT - Art & Architecture Thesaurus, TGN - Getty Thesaurus of Geographic Names, and ULAN - Union List of Artist Names) contain structured terminology for art, architecture, decorative arts, archival materials, visual surrogates, conservation, and bibliographic materials. Compliant with international IT standards, they provide authoritative information for cataloguers, researchers, and data providers. A work started in the late 1970s, the vocabularies grow through contributions. Furthermore, the publishing of Getty vocabularies is based on SKOS (Simple Knowledge Organization System) allowing a great accessibility and re-usability of the contents. Indeed, more vocabularies could be connected in future, without the need for several and significant changes to the structure.

The current work is to create an ontology as a valuable base for possible upgrading about what is expected/required in H-BIM [BBM*16]. However, it is important to understand the difference between BIM standards and the Semantic Web technologies. Indeed, the ifcOWL is defined as serialization of an IFC schema definition [LS16], in order to enable the use of contents semantically managed. For this reason, within INCEPTION, H-BIM is meant to be an ontology to support storage of semantic knowledge available for Cultural Heritage buildings and architectural complexes, as well as their related information [CYY15]. The integration of Getty vocabularies and ifcOWL is a complex but feasible task, focusing on the actual queries, communications and current H-BIM work. Furthermore, within INCEPTION, we had the chance to test such integration, achieving positive results as well as beginning an implementation thanks to the use of a "glossary of names" gathered by the Demonstration Cases analysis.

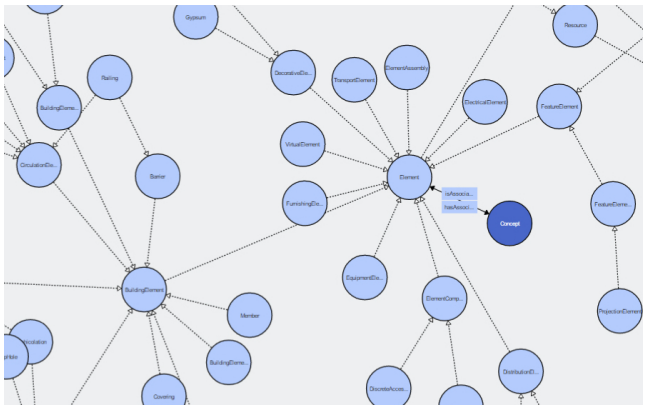

Figure 2: *Graphical representation of the INCEPTION HBIM ontology*

4. An overview on the INCEPTION platform

Once data are collected and aggregated thanks to the use of semantic technologies, the most valuable goal is strictly related to dissemination capabilities. Indeed, the richness of the INCEPTION project is represented by accessibility to a crowdsourced database of both scans and reconstructions, with different level of confidence by their source data. Therefore, the INCEPTION platform [BBZ*16] will have to contain, visualize, manage, update, and exchange technical and divulgative information regarding historical heritage, through the use of 3D BIM models. Any form of digital or digitized content, stored or linked into a 3D H-BIM model, as well as semantically indexed by the use of the INCEPTION ontology, will allow the use of different navigation systems.

From one side, the search feature within the INCEPTION platform will be implemented by semantic query of 3D models as well as their metadata and paradata [AG15], connected to the geometry of BIM models. In this way, humans and computers are able to speak a common language, achieving a great enhancement regarding the possibility of navigating through data, that will be progressively updated during the evolvement of the platform. More and more historical building models will enrich the INCEPTION database, from difference sources, and every additional piece of information will create a new knowledge, that could be easily explored.

On the other side, the INCEPTION Time Machine will represent

the possibility of navigating nonlinearly over time and therefore in the history of a building [Kap15]. Above all, the "Time machine" is a metaphor that allows to define one of the main features of the INCEPTION User Experience. It makes the platform more meaningful [DLBS*11] and engaging while navigating and searching within the database. Its effectiveness is mainly determined by the enhanced perception and comprehension of available contents. But, in order to get the highest level of user involvement, it is necessary to refer to a widely shared and well-known typology of interface for the navigation objects trough time. For instance, all available models should be automatically organized, by the platform, into coherent series, homogeneously oriented, placed and scaled, in a sort of navigable timeline by the use of the scroll command or searching by date. Thus, the effectiveness of this metaphor will directly proportional to the number of time-snapshots available. By the way, from a computer perspective, Time Machine will represent only a different navigation / search and display system of already indexed and archived digital content and a specific way to use the content versioning of some 3D models. Indeed, any media (historical photos or plans, reconstructive 3D model, documentary material, etc.) that allow the user to perceive the suggestion of a place in another time, past or future (as in projects, renderings, etc.) will be aggregated [IHD*13]. Then, thanks to the use of already existing graphic engines, several outputs will be possible, including immersive experience by the use of virtual and augmented reality tools, devices and apps.

In the next steps of the project, each INCEPTION demonstration case will produce data that will be hosted by the platform, allowing to test the validity of the platform itself (3D models and versioning, animations, images, etc.) and further developments (immersive environments, VR, AR, etc.

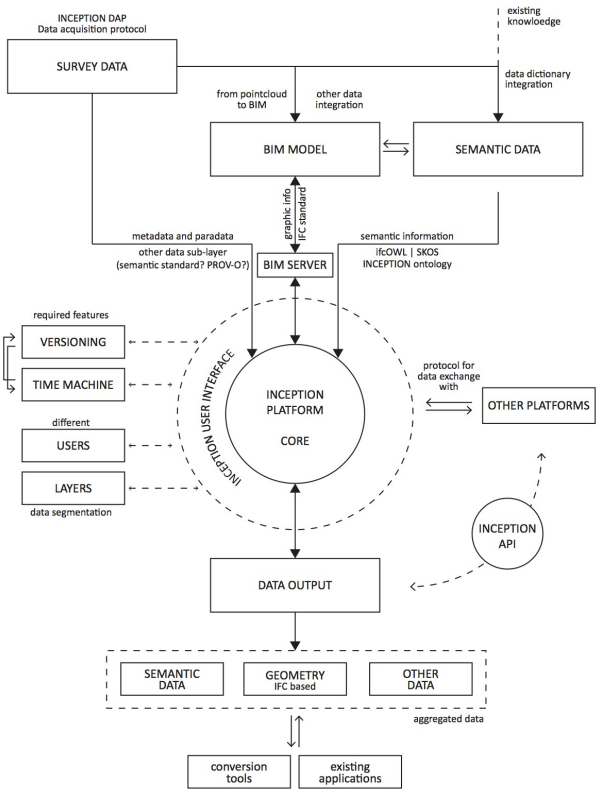

Figure 3: *Links and data flow between the platform's components and between INCEPTION and external tools.*

5. Conclusions: achieved results and further developments

So far, the INCEPTION project has defined the approach and the methodology for semantic organization and data management toward H-BIM modelling, as well as a preliminary nomenclature for semantic enrichment of heritage 3D models has been set up. The organization of consolidated knowledge is performed following a specific workflow in order to get them suitable for their reuse into H-BIM semantic model, accordingly to digital documentation and capturing protocols that has been developed.

Nevertheless, developing an H-BIM is a complicated "reverse engineering" process. According to the INCEPTION workflow, it starts with documenting user needs, including and engaging not only experts but also non-experts. The demand has been leading us to "how" and "what" surveying information we should include in H-BIM. The surveying procedure produces a variety of different data, formats and outputs. It is essential to process that data without losing important information like metadata and paradata while editing and developing the digital elements of the H-BIM. A methodology of archiving digital data and linking them to the final product is one of the main outcomes. Before and during the creation of H-BIM, the nomenclature (vocabularies, thesaurus, etc.) is critical to maintain a common typology and to support interoperability.

Starting from the standardization for H-BIM modelling, the methodology for merging IFC models and semantic data has been defined. The identification of the Cultural Heritage buildings semantic ontology and data structure for information catalogue will allow the integration of semantic attributes with hierarchically and mutually aggregated 3D digital geometric models for management of heritage information. The development of a semantic 3D reconstructions, integrated with intangible information and social environment [DDI*17], structuring digital representation of buildings and sites will lead to the creation of models more accessible and implementable in a Heritage-BIM environment, based on Open BIM standard (IFC, IFD, etc.).

Thanks to the use of data collected by Demonstration Cases, the identified methodological workflow and the technical tools and procedures will be further tested and stressed by end of the project. This will allow, from one side, to check the real validity of what has been developed until now and, on the other side, to upload several contents to the platform, bringing it into life and make it a significant dissemination tool.

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