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Published Version:
Bonsma, P., Bonsma, I., Ziri, A.E., Parenti, S., Lerones, P.M., Hernández, J.L., et al. (2016). INCEPTION Standard for Heritage BIM Models. Cham : Springer International Publishing [10.1007/978-3-319-48496-9_47].

Availability:
This version is available at: https://hdl.handle.net/11585/659707 since: 2019-03-04

Published:

DOI: http://doi.org/10.1007/978-3-319-48496-9_47

(Article begins on next page)

This is the accepted manuscript of a conference paper published in:

Bonsma P., Bonsma I., Ziri A.E., Parenti S., Lerones P.M., Hernández J.L., Maietti F., Medici M., Turillazzi B., Iadanza E. (2016) INCEPTION Standard for Heritage BIM Models. In: Ioannides M. et al. (eds) Digital Heritage. Progress in Cultural Heritage: Documentation, Preservation, and Protection. EuroMed 2016. Lecture Notes in Computer Science, vol 10058. Springer, Cham.

The final authenticated version is available online at: https://doi.org/10.1007/978-3-319-48496-9_47

INCEPTION Standard for Heritage BIM Models

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Abstract. The EU Project INCEPTION will create a platform that is able to exchange content according to state-of-the-art available open BIM standards. This INCEPTION open Heritage BIM platform is not only exchanging data according to existing state-of-the-art standards, but it is based on a new Heritage BIM model using Semantic Web technology. This allows applications to retrieve content according to modern query languages like SPARQL and allows user defined 'on-the-fly' extensions of the standard. This paper describes the structure and development of this new Heritage BIM standard. The Heritage BIM standard is developed by several Semantic Web and BIM standardization specialists in combination with top experts in the field of Cultural Heritage, all of them partners within the INCEPTION project.

Keywords: 3D, BIM, IFC, ifcOWL, GIS, H57, H-BIM, OWL, OWL2, Semantic Web, RDF, RDFS.

1 Introduction

The European Project "INCEPTION - Inclusive Cultural Heritage in Europe through 3D semantic modelling"[1], funded by EC within the Programme Horizon 2020, focuses on three main objectives: to create an inclusive understanding of European cultural identity and diversity by stimulating and facilitating collaborations across disciplines, technologies and sectors; to develop cost-effective procedures and enhancements for on-site 3D survey and reconstructions of cultural heritage buildings and sites; to develop an open-standard Semantic Web platform for accessing, processing and sharing interoperable digital models resulting from 3D survey and data capturing.

This inclusive approach includes open-standard format for cultural Heritage Building Information Modelling (H-BIM) as part of the overall procedure aimed at enriching and enhancing the changing role of 3D representations for knowledge, reconstruction, preservation and exploitation of Cultural Heritage.

The integration of semantic attributes with hierarchically and mutually aggregated 3D digital geometric models is essential for management of heritage information. The development of tools for 3D automatic delineation depending on acquisition technologies, from point clouds to photo-based data, allows to achieve a common standard interoperable output for BIM environment. Therefore, starting from advanced procedures aimed at handling multi-data point clouds and triangle meshes into BIM software, the INCEPTION procedure advances BIM approach for Heritage knowledge, going a step forward the usual procedure to locate/define 2D or 3D primitive shapes onto the point clouds. INCEPTION develops methodologies and algorithms to recognize these shapes. Results will be constructed in BIM software avoiding the oversimplification of the shapes. When used in models of Cultural Heritage, semantic BIM will be able to be connected to different users (e.g. scholars, technicians, citizens, etc.) in support of the user's needs for interpretation of the cultural heritage model, in addition to the common BIM features of 3D visualization, technical specifications and dataset.

The recent earthquake in central Italy (23 August 2016), causing about 300 victims, almost destroyed the beautiful towns of Accumoli and Amatrice. The last one was inserted in 2015 among the "most beautiful villages of Italy". Both the towns date back to XI-XII centuries and are home to beautiful churches and sanctuaries, heavily damaged by the earthquake. The same fate has befallen many houses of historical interest. Similarly, in 2009, the same region was hit by a big earthquake that fatally wounded the wonderful ancient city of L'Aquila, still undergoing a slow process of architectural recovery, causing 309 victims.

One of the aims of the INCEPTION procedure is protecting the cultural heritage of seismic areas with scopes of classification, prevention and reconstruction.

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[1] The INCEPTION project, Grand Agreement no.: 665220 started the last June 2015, is developed by a consortium of fourteen partners from ten European countries led by the Department of Architecture of the University of Ferrara. More information can be found on [http://www.inception-project.eu/].

The paper starts exploring the state of the art within existing open standards, focusing on available H-BIM solutions up to explaining INCEPTION implementations.

2 Existing Open Standards

In the area of BIM, GIS, Cultural Heritage and Semantic Web, a lot of valuable work is already done. INCEPTION has taken existing state-of-the-art open standards and technology as a starting point. In this chapter we will just name a few relevant open standards in the area of BIM and Point Clouds, without being complete in number of standards nor in the areas (for example GIS was removed completely keeping the paper size reasonable). A complete reference can be found in D4.1 from the INCEPTION project.

2.1 Existing BIM Standards

This paragraph will explain the main open BIM standards expected to be used for data providers of BIM.

IFC (ifcXML, ifcOWL, ifczip).

The first developments for the IFC format dates back to 1985. The name IFC (Industry Foundation Classes) was first introduced in 1994 led by Autodesk. In 1995 it became a vendor independent standard and had several releases, IFC 151 and IFC 20LF (Long Form) were popular releases for the academic world. Since IFC 2x3 released in 2006 (and later improvements IFC 2x3 Final and IFC 2x3 TC1) it was also becoming more popular for use in real life projects. Nowadays IFC 2x3 TC1 is still the most popular version although for INCEPTION the new version IFC4 (formally known as IFC 2x4) has some important improvements for both 3D representation and scheduling.

IFC is meant to be used by all the disciplines in the Building & Construction industry and the only widely used open standard supporting so many different disciplines. All major CAD vendors and a wide variety of other applications offer support for IFC. Most of the applications supporting IFC are not certified, although most CAD systems with IFC support have a certification from buildingSMART. IFC carries an object-based view of the model, including geometry in 3D (and 2D) as well as properties and interrelationships between objects. It is a well thought through standard with relatively high complexity for software vendors to support. IFC support includes schedule data, quantities and many other construction related data.

The standard exchange format for IFC is STEP/EXPRESS. As serialization support for this format is limited the past few years other serializations are defined also. It started with support for ifcXML, with an alternative ‘simple’ ifcXML format. More recently also ifcOWL serialization is created, this last format is compatible with Semantic Web RDF, RDFS and OWL2 standards. Although there is a small data loss the fast majority of knowledge is kept in these alternative serializations. A different format is ifczip and is nothing more than the zipped version of an original IFC file.

bSDD.
Building Smart Data Dictionary is like the semantic extension of the IFC schema. Although IFC in combination with its property sets (and about 3000 properties) has already a lot of semantics in it, to cover the complete Building & Construction industry the semantic definition has to be far larger (numbers differ but we could expect that 100.000 object definitions are required where even the latest IFC schema has less than 1000 entities). bsDD is the standard from Building Smart defining how such extensions of the semantics can be stored and defined.

2.2 Existing Point-Cloud Standards

E57.
Most 3D imaging systems for data exchange today takes place using one of three types of file formats: proprietary formats (not an efficient approach to data exchange in the long term), ad-hoc formats (not space or time efficient and no widespread usage), or the LAS format (limited file size and features). The E57 format is intended to overcome these issues, being a more general format that is well-suited for storing data across a variety of application domains. It is able to store point clouds and also other information from 3D scanners like images. The file format is specified by the ASTM, an international standards organization, and it is documented in the ASTM E2807 standard [Huber-2011].

Next to the standard a 'reference implementation' is created to make more attractive and easy the use of the standard. The reference implementation is called libE57 and is written in C++ and sources are available [http://www.libe57.org/]. The libE57 application contains an API that can be used by parties that like to import or export files in E57 format.

2.3 Available H-BIM Solutions.

Several H-BIM Solutions are already available. One thing we can notice in many of these solutions is use of Semantic Web techniques or use of BIM related standards. For example the vendor specific standard Graphisoft GDL language (Graphical Description Language) allows parametric modelling of components, something very useful in the area of geometry for Cultural Heritage content.

One typical behavior of most currently available H-BIM solutions is that they are clearly focused on one or two areas of the core of a Semantic Web based solution:

- Cultural Heritage
- Semantic Web technology
- BIM / 3D / Point Cloud knowledge

3 Semantic Web

3.1 RDF

RDF (Resource Description Framework) supports creating and processing metadata by defining a default structure. This structure can be used for any data, independent of their character. Thus, the application areas of RDF are numerous, e.g., web-based services, peer-to-peer networks, and semantic caching models; they all have in common that huge amounts of data have to be processed when querying RDF data. RDF data can be represented using XML, a triple structure or a graph. Only the graph representation enables the semantic interpretation of the RDF schema.

All of the elements of the triple are resources with the exception of the last element, object, that can be also a literal. Literal, in the RDF sense, is a constant string value such as string or number. Literals can be either plain literals (without type) or typed literals typed using XML Datatypes. These triples together form RDF graph. A normative syntax for serializing RDF is RDF/XML.

3.2 RDF Schema (RDFS)

RDFS extends RDF vocabulary to allow describing taxonomies of classes and properties. It also extends definitions for some of the elements of RDF; for example it sets the domain and range of properties and relates the RDF classes and properties into taxonomies using the RDFS vocabulary.

The RDF schema statements are valid RDF statements because their structure follows the structure of the RDF data model. The only difference to a pure "resource - property - value" - triple is that an agreement about the specific meaning for reserved terms and statements has been made. Next to that, the RDF schema provides a vocabulary for defining the semantics of RDF statements

3.3 Web Ontology Language (OWL)

OWL is a W3C standard. The abbreviation stands for Web Ontology Language and is a language for processing information on the web. It is built on top of RDF and RDFS. OWL was designed to be interpreted by computers and parsed by applications. It is not meant for being read by people. OWL is written in XML and has three sub-languages - OWL Lite, OWL DL (includes OWL Lite) and OWL Full (includes OWL DL). The Ontology is about the exact description of things and their relationships. For the web, ontology is about the exact description of web information and relationships between web information. The standard OWL is a part of the "Semantic Web Vision", a future web where:

- Web information has exact meaning
- Web information can be processed by computers
- Computers can integrate information from the web

3.4 **Web Ontology Language 2 (OWL2)**.

OWL 2 adds new functionalities with respect to OWL 1. Some of the new features are syntactic sugar (e.g., disjoint union of classes) while others offer new expressivity, including keys, property chains, richer data types, data ranges, qualified cardinality restrictions, asymmetric, reflexive, and disjoint properties, and enhanced annotation capabilities. OWL 2 also defines three new profiles and a new syntax. Some of the restrictions applicable to OWL DL have been relaxed resulting in a slightly larger set of RDF Graphs that can be handled by Description Logics reasoners.

3.5 Reasoning

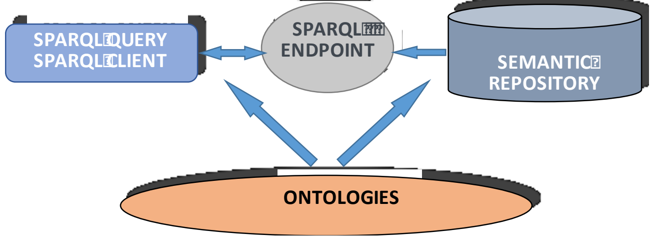
OWL enables "reasoning", as mentioned above. That means it gives the possibility to check the logical correctness of statements and add statements that are implied by other statements

A "semantic reasoner", "reasoning engine", "rules engine", or simply a "reasoner", is a piece of software able to infer logical consequences from a set of asserted facts or axioms. The notion of semantic reasoner generalizes that concept of inference engine, by providing a richer set of mechanisms to work with. The inference rules are commonly specified by means of an ontology language, and often a description language. Many reasoners use first-order predicate logic to perform reasoning; inference commonly proceeds by forward chaining and backward chaining. There are also examples of probabilistic reasoners, including Pei Wang's non-axiomatic reasoning system, and Novamente's probabilistic logic network.

3.6 SPARQL

SPARQL is the reasoning language for Semantic Web. Servers support in many cases out-of-the-box SPARQL queries.

The gate for the access to the Inception ontology will be a SPARQL endpoint. SPARQL 1.1 is a semantic query language and a recommendation of W3C. Its adoption in Inception project is important to access to the CH semantic storage. Multiple programming languages, libraries and semantic repositories implement SPARQL queries. The 1.1 standard also allows to write queries which directly update the RDF graph. Being SPARQL syntax based on graph traversal, it is also easy to visualize SPARQL results graphically. Although repositories could be navigated and examined with different tools, a SPARQL endpoint is one of the powerful tools to open semantic data to main exploitation.



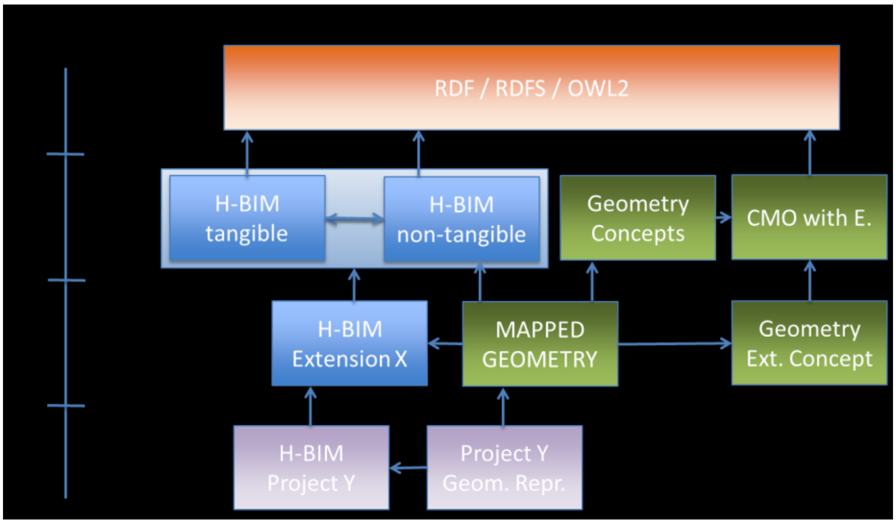
4 H-BIM Ontology

This chapter describes the architecture of the H-BIM Ontology as well as some examples of the content. The H-BIM Ontology is the core of the INCEPTION Platform. The content of the Ontology will be developed together with the specialists that are partners within INCEPTION. By definition the content will however be incomplete; the architecture therefore allows users to extend the H-BIM Ontology either for projects or for larger aggregations, like countries, styles etc.

4.1 Background

The architecture of the H-BIM Ontology is defined to enable storage of semantic information from any cultural heritage object. A clear distinction between tangible and non-tangible content is defined and, in line with the base concepts behind Semantic Web technology, it allows layered extension of the ontology itself. Typical for the H-BIM Ontology is the close connection with existing state-of-the-art BIM standards like IFC/ifcOWL and the link with 3D content defined in Semantic Web (i.e. open standard CMO with Extensions).

4.2 Architecture Overview



4.3 Technology Layer

Within this layer we use the Semantic Web technology as described in chapter 3. This means use of the RDF, RDFS and OWL2 as top layers of the H-BIM Ontology.

4.4 INCEPTION Layer

The INCEPTION layer of the H-BIM model contains the real knowledge from the specialists within the INCEPTION project. This is knowledge about Cultural Heritage but also knowledge from existing state-of-the-art open BIM and open GIS standards.

One important part of the INCEPTION layer is the difference between tangible and non-tangible results. Since this is a known term in the area of Cultural Heritage and distinction is not always clear, much time and effort is put in defining what is covered by the terms.

4.5 Extensions Layer

As soon as new concepts within the extension layer are defined the queries can be used. Extension could concern new relations between existing content and therefore applied on all existing content, but extensions can also be specific for dedicated content. Some examples:

Example of extensions applicable on existing content.

The INCEPTION H-BIM standard has embedded parts of the semantic structure of IFC (and therefore ifcOWL). This means classes Wall, WallStandardCase and CurtainWall exist. Adding a super class Walls and the knowledge that above named classes inherit from this new class Wall is an extension that works on all available content. A SPARQL query can be created to get all instances of new class Walls and it will directly have content for the majority of the Cultural Heritage H-BIM models stored in the INCEPTION platform.

Example of extensions applicable on new content.

It is allowed to add a class to the H-BIM model in the extension layer with a new name and no relation to any existing part of the H-BIM model. A query on this class is only relevant for new content incorporating the knowledge that this new class is existing.

4.6 Project layer

Within the project layer the real content is defined, this content is arranged according to the layers above. All content can be queried according to the SPARQL queries defined on top of the INCEPTION layer. It is also possible to create solution specific queries as well as queries dedicated to certain extensions as defined in the extension layer.

5 Implementation

The INCEPTION standard is the base for the platform that will be developed within INCEPTION. As the INCEPTION standard is developed

5.1 Server Solutions

The core of the INCEPTION platform will be a server that is able to handle the INCEPTION standard and offer basic functionality like support for SPARQL. During writing of this paper the selection of the server handling this Semantic Web data is not finalized yet, there are several options and the most promising solutions at this moment seem to be RDF4J and Fuseki 2.

As not only Semantic Web data needs to be stored, but many different file formats including open standard BIM formats as well as point cloud data a file server will be part of the INCEPTION platform also.

Sesame / RDF4J 2.0.
The official name is RDF4J and its current release is 2.0, however this solution is best known under its former name OpenRDF Sesame framework. It became part of the Eclipse Foundation and has no official first version at this moment after this important change.

Fuseki 2.
Fuseki server is already existing for a while and although especially Fuseki 2 would be of interest for INCEPTION also Fuseki 1 is still actively maintaine. Fuseiki 2 is a server solution on top of Apache and Jena and also called Apache Jena Fuseki. It is a SPARQL server and an open source project.

5.2 SPARQL Queries

Technology choices and implementation will be driven by the accessibility of data through SPARQL queries addressed to a SPARQL endpoint. This means that a running REST web service should respond to data queries and produce as results a set of triples serialized on one of the most used RDF serialization (RDF/XML, Turtle, N3) or an RDF graph. This should include queries both on tangible and non-tangible data and their specific relations.

SPARQL queries are "data-oriented" so there is no inference in the query language itself, all the data manipulation and inferencing has to be done by a layer on storage or on in memory RDF data. Thanks to its structure and many converters present in the market SPARQL queries can be applied not only to native RDF data but also on any data that could be mapped to RDF, like other kind of well-formed relational data.

6 Conclusion

The use of BIM for Cultural Heritage is becoming more and more an effective tool to manage 3D representations at different layers and for multiple purposes, pursuing the common vision, at European level, to apply research, technology and innovation in innovative media to expand understanding and access of the heritage assets.

One of the main challenges is how to manage the complexity of heritage buildings and sites, fostering the collaboration across disciplines through semantic-aware representations, able to solve interoperability issues and avoiding the segmentation of knowledge. The technology of Semantic Web and integration with 3D and BIM are the drivers behind H-BIM Ontology. The H-BIM Ontology in its turn is the core of the INCEPTION H-BIM Platform.

The INCEPTION procedure could be conveniently exploited for protecting the cultural heritage of seismic areas with scopes of classification, prevention and reconstruction.

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