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Europe and the Mediterranean:
Towards a Sustainable Built Environment

Edited by Ruben Paul Borg, Paul Gauci, Cyril Spiteri Staines

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International Conference

16th March – 18th March 2016

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Sustainable Built Environment Malta

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Abstract. Within the EU research project titled INCEPTION, a Heritage-BIM Interoperable Platform will be developed and used to store all cultural heritage-related data. This platform will strongly depend on Semantic Web and Building Information Modelling (BIM) technologies that drive the 'INCEPTION Time Machine' where a time dimension will show how the cultural heritage evolves in association with its built and social environments. This paper describes the technical research challenges associated with this platform. An initial research activity is dedicated to review the state-of-the-art in BIM, H-BIM, H-GIS, as well as the utilization of Semantic Web for enabling semantic search and enrichment of Cultural Heritage information by the end-users. The subsequent research activity will focus on the integration of 3D point-clouds and sensor data with the H-BIM. Various data will be stored on the H-BIM platform and made available via APIs and web interfaces. The platform itself will contain services for geometric shape recognition and semantic query. Finally, the AR and VR applications as well as semantic searches, the Time Machine / 4D Viewer component, and a semantic enrichment application will be made available for the end-users and third-party developers alike.

1. INTRODUCTION

The documentation of cultural assets is inherently a multimedia process, addressed through digital representation of the shape, appearance and conservation condition of the heritage architectures and sites. Digital models are expected to become the representation (forever, for

everybody, from everywhere) and research needs to acknowledge the changing role that reconstruction, preservation and conservation now play in the representation of heritage and its analysis.

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; the development of an open standard platform to "contain", implement and share the digital models are among the main innovations proposed by the INCEPTION project, funded by the European Commission within the Work Programme *Europe in a changing world – inclusive, innovative and reflective Societies*.

INCEPTION methods and tools will result in 3D models that are easily accessible for a wide range of users, and interoperable for use by different hardware and software. It develops an open-standard Semantic Web platform for: Building Information Models for Cultural Heritage (H-BIM) to be implemented in user-friendly Augmented Reality (VR and AR) operable on mobile devices.

2. STATE-OF-THE-ART

The INCEPTION project will start from the current state-of-the-art developments in the area of BIM and semantic modeling in the context of Heritage BIM, knowledge management, Cultural Heritage asset management software and 3D data capturing.

2.1. BIM semantic modelling in the context of Heritage BIM

A BIM open standard is required to allow managing 3D models supporting the storing of cultural heritage information. Recent scientific and technical works clearly show this demand by means of a cross-disciplinary approach to enhance the analysis and understanding of heritage sites.

This goal is based on the following challenges to achieve an inclusive 3D virtual cultural heritage (Fig.1):

- In practice, is not solved how to handle the large amount of data provided by 2D/3D acquisition devices, or how to extract all possible information from them.
- It is not solved, but demanded, the combination of different information to achieve a useful multipurpose and multiuser 3D model as unique digital representation comprising graphic & semantic information.
- The process involving the generation and management of digital representations is not so usual as expected. Even less involving physical and functional characteristics of heritage according to BIM. These aspects are necessary for the proper standardization of processes, ensuring interoperability and interdisciplinary.

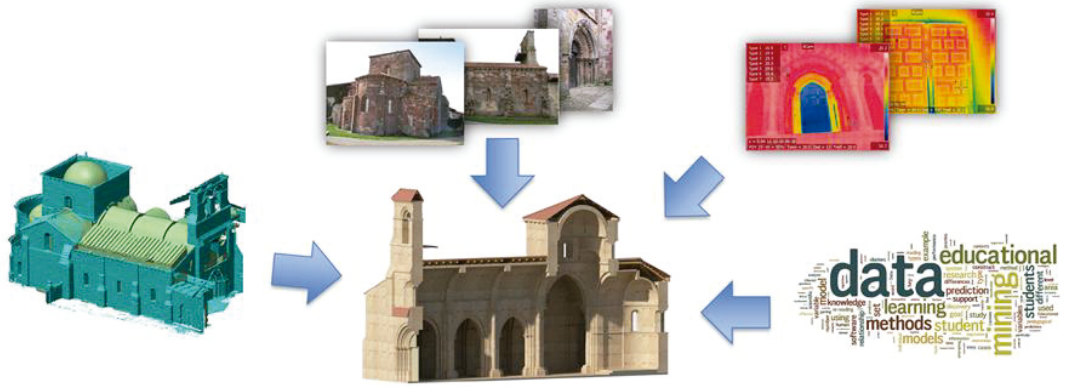


Fig 1: Inclusive 3D virtual cultural heritage approach

Three IT research needs should be addressed on this regard:

- An integrated software for documenting, planning, tracking of interventions and managing of heritage immovable assets (local or remotely) needs to be developed. The software should simultaneously incorporate graphics (plans/layouts, high-res photographs, blueprints, thermal images, etc) and semantic information (meaningful data related to structures, finishes, installations, remote monitoring, historical data, relational databases, textual information, etc). Hence, a well-defined specification on the type of graphical and semantic information required is the first challenge to tackle, taking into account: utility; type (2D/3D); formats; supplier; acquisition technologies; acquisition and processing techniques; directives and references to be applied; usability (citizen, technician, scholars or literature).
- A specific hierarchical organization of European cultural heritage information about buildings based on sematic approach needs to be developed as well. It is a different approach from the geometric information: adding attributes like architectural style, time frame, author and location, or related to physical structure but knowledge cannot be assumed by the geometric data.
- Combining content information on heritage buildings with data derived from the use of survey technologies (i.e. laser-scanner point clouds, photo-based scanning, and monitoring data) into a 3D model is obliged. Specific tools (shape recognition and photographic and thermal image blending) should be developed to allow obtaining BIM-compatible useful information from initially non-parametric 3D models.

The resulting models require to be manipulated into BIM packages (H-BIM) and also to be uploaded onto Internet in order to be handled in mobile devices to ensure maximum usability.

2.2. Knowledge Modelling

The in Knowledge modeling plays a key role in built heritage field due to incremental learning and different user involvement segmentation and scope. Different actors need a different range of information related to the model to enhance knowledge and interact with the physical representation of the building. In cultural heritage cross domain data are available to guarantee a deep understanding of the building history, useful also for maintenance and exploitation.

Knowledge layering starts from the physical description of geometrical entity (e.g. Cylinder cv Column) and refines the understanding of the model with every kind of content that is somehow related to it, like documents, surroundings, historical data and structured representation. Even on modern construction industry narrowing building reconstruction to geometrical modeling is limiting and new libraries have been developed to add additional data for semantic representation of intangible relations.

On historical buildings the very definition of the cultural heritage asset requires that knowledge layers and evolves in time. In this case the lack of documentation linked to the model could be the cause of the loss of part of the research data or restoration issues or even irreparable damages. With the rise of virtual museum and augmented reality citizen and tourists also need to easily find interesting information in digitally represented model, with a knowledge driven approach that requires that data are accessible also by semantic information retrieval techniques.

Interesting attempts to build a semantic knowledge associated to historical building has been made and there are some successful projects which allow the exploitment of historical linked data. Different approaches have been selected due to the focus on different information and the variety of users. One main focus of those projects is how to solve the link between intangible and tangible data context by the integration of a BIM environment with an ontology based system. The W3C standards ontologies already recognized as global reference with a coherent and interesting approach to cultural heritage sharing has been analyzed with a focus on conversion and references between geometrical data, time representation, ontology based knowledge and general textual documentation.

Then standardized ontologies and formalized system like Dublin Core, CIDOC-CRM, SAPO, Geonames, ESE (Europeana) are taken in to account to be analyzed as a starting point to develop an integrated historical linked data system to model cultural heritage buildings.

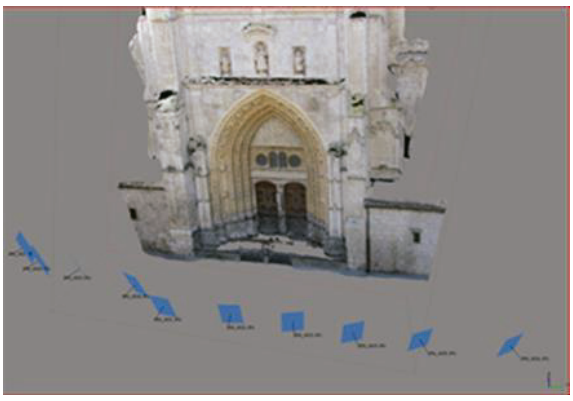
2.3. Software CH Asset management

One of the goals of the INCEPTION project is oriented towards the development of cost-effective procedures and tools for survey, condition assessment and maintenance of cultural heritage assets. Because CH asset management requires non-conventional inspection methods, it is of outermost importance to develop a new method for condition assessment, which is based on predictive analysis (diagnostic, conservative, morphometric), non-destructive procedures (thermal imaging, level of reflectivity, integrated sensors, spectrophotometry, ultrasonic surveys), supported by economically sustainable tools and devices.

Outside the domain of cultural heritage, asset management has been developed as an important knowledge field both in science and practice. Standardised methods are also available, for instance ISO 55000 (PAS 55) on asset management and Dutch NEN2767 on technical condition assessment. These methods are used in combination of performance-based maintenance contracting. The INCEPTION project has analysed the existing software tools for condition assessment, and selected a state-of-the-art solution for further advancements and implementation for CH asset management. The solution is based on the innovative software RE SUITE –a complete software package that allows various components to be easily automated. Using RE SUITE, all types of users can collect, structure, analyse and disclose the asset information. The solution is able to centralize all the information / results from various software applications in order to cost-effectively manage all project information and key business processes across the building's or system's lifecycle.

CH asset management in INCEPTION aims to progress beyond the state-of-the-art by progressing from a "cure" (responsive) to a "care" (preventive) approach. The innovative "care" approach comprises proactive and integrated management of CH assets whereby regular maintenance and periodic monitoring substantially anticipate, prevent and minimize damages and losses. For this purpose, INCEPTION approach towards CH asset management focuses on quality assurance, starting from a profound preliminary analysis; followed by a well-founded diagnosis; and completed with the inspection of the efficiency of executed interventions and a system of periodic monitoring.

2.4. 3D data capturing



The increasing development of 3D laser scanner technologies allows to create high definition databases based on even more detailed three-dimensional morphometric data. These "digital archives" are an extremely valuable research tool in cultural heritage field, although there are still some limits to the exploitation of 3D models obtained by laser scanner survey. The growing numbers of un-exploited 3D models points out the need for innovative methods that could benefit from the informative value provided by new systems for surveying and representations as well as data management tools. The development of high quality 3D models in specific conditions, such as in Cultural Heritage field, is still time-consuming and expensive, and generates too large data. Furthermore the outcome of digital reconstructions is frequently provided in non-interoperable formats, and not easily accessible too.

INCEPTION proposes a substantial enhancement in the efficiency of three-dimensional data capturing procedures and devices, especially their suitability and aptitude for the physical cultural resources and assets: cultural heritage sites, historical architectures, archaeological sites and artifacts that are characterized by smart handling of non-conventional characteristics, location and geometries.

Moreover, research challenges aim to break through the barriers caused by segmentation in collecting documentation data, closing the gap regarding the absence of a common protocol based on survey methodologies and technological integration.

3. FOCUS ON R&D IDEAS OF THE H-BIM PLATFORM

The INCEPTION project and specifically the H-BIM platform will face many challenges. One of the base and unique ideas of INSITER is the Time Machine, a more detailed description can be found in 3.1. The H-BIM Platform itself and technical challenges that have to be tackled developing it can be found in the next paragraph 3.2. Important end-user results as the front-end applications about Virtual Reality & Augmented Reality will be discussed in 3.3.

3.1 Time Machine

One of the main challenges of the INCEPTION project is to realise innovation in 3D modelling of cultural heritage through an inclusive approach for time-dynamic 3D reconstruction of artefacts, built and social environments. The so-called INCEPTION "Time Machine" will be developed as an open-standard Semantic Web platform for creation, visualisation and analysis of 3D H-BIM models of cultural heritage over time, with emphasis on how the modelled cultural heritage evolves over time in association with its built and social environments.

The implementation of the dynamic structure of the platform through models and reconstructions/simulations related to specific historical periods, allows to "move across time and space" enabling features like time-machines, and it is connected also with time planning of interventions. Users will be provided with a dash board for accessing survey data, i.e. cloud of points, and building 3D historical simulations.

A possible data model to manage the "time dimension" in cultural heritage 3D models is through ontologies. Semantic data model has been applied and exploited in several ways in virtual museum and cultural heritage artefacts but time representations have always been a critical point: time as a measure is a mathematical entity but it is also descriptive and in this domain events are closely interlaced with non-tangible properties like architectural styles, environment description, authors and usage which often have not a strictly defined time span. Time definition is also used by related documentations about the building, so in the Time Machine tool properties linked to the model should be available for a specific period of time. Another issue is that in cultural heritage domain time is not always known or perfectly indicated on specific events or could be defined in relation with other events.

Having a consistent time data model (from geometrical modelling to physical properties, and linked to related information and documentation) gives clear advantages for a global integrated paradigm but this application has to be efficient by all possible access points: it has to have an effective interface to serve the Time Machine tool, it has to be integrated in the semantic search engine and eventually it has to be exposed as linked data without any conversion.

The use of semantic data model is a bottom-up solution that could take care of most of those domain distinctive features, because ontology models are by definition inclusive and flexible.

The choice of an ontology related to an event or a time span is also related to the fact that semantic ontologies are not only knowledge representation that gives a logical framework through the use of mathematical properties to harmonize data sources, but they are related to two very important features: the capacity of enriching the domain knowledge by automated reasoning (the ability to logically infer new data from formal properties) and a formal query language (SPARQL) that could be integrated in different IT frameworks.

Different references mean different meanings and applications, so that define a time span for a physical entity could imply an evolution, transforming it in another entity, or its replacement; physical properties related to the style description should deal with their relation with the model changes through time, some not precise phrasal indication (e.g. in the mid of seventeenth century) in related documentation has to be taken in account and granularity of time measure could affect performance and usability.

3.2 H-BIM Platform

The H-BIM platform makes use of Semantic Web technology to store semantic knowledge from the Cultural Heritage. However the platform needs to deal with several data sources and data formats, many of them in first instance likely hard to cover with Semantic Web Technology.

One of the other important formats are point clouds. Point clouds are large amounts of data; even with current modern systems it is hard to handle the amount of data generated by scanners. State-of-the-art professional CAD applications are often not able to visualize complete point clouds scans. Dedicated applications are used to visualize these results before included within CAD applications. As the point clouds are becoming more important and availability of scanners increases availability of content and usefulness it is an important area for CAD applications also.

On the other side while semantic web is becoming mature and standards like OWL2 and SPARQL are accepted and used in more use cases as well as its underlying structures are supported by large software companies like HP and ORACLE. The semantic web however has important issues when the original content is scaled. Even moderate sized models can reduce the speed of high-end systems that work perfectly on small toy models into unacceptable slow solutions.

Bringing both worlds of large sized point clouds and hard o scale semantic web together will for sure introduce interesting challenges. Shape recognition will both reduce the size of relevant information as well as increase the computer understandable semantic meaning of point clouds. The boundaries of what is possible over here and in what way this can be automated and make use of advanced semantic web functionality will become an important technical result of INCEPTION in the context of the H-BIM platform.

Another important technical challenge can be found in the availability of open Heritage BIM standards. Current open standards that both support semantics and geometry are not always easy and complete enough to cover the requirements for Cultural Heritage information. Current Cultural heritage standards are often based on existing open or closed standards, use a limited subset of them and cover only a limited subset of what is needed for the H-BIM platform.

Non-professional users as well as experts will need to be able to add information and knowledge inside the H-BIM platform. Still the data stored within the H-BIM platform needs to be consistent and trustworthy. As similar questions also exists outside the Cultural Heritage domain, especially in the context of semantic meaning of knowledge the expectation is that state-of-the-art solutions from other domains can be applied.

3.3 Heritage Virtual Reality /Augmented Reality

The first applications of Virtual Reality (VR) date back to the late sixties, when the first rudimental systems tried to replicate an idea coming from literature and cinema. Fifty years later the gap between the user experience in a real environment and a virtual one is still quite wide, mainly because today technologies are still focused only on two out of our five senses.

Nevertheless, combining real environments with virtual objects and information and vice-versa (real objects and persons in virtual spaces) is leading the way to new important business applications based on the relatively new concept of Augmented Reality (AR).

Milgram and Kishino (1994) helped clarifying the panorama by defining four environments: the real environment, the virtual environments (computer generated and unrelated to real world), AR (the real world is the backdrop for computer-generated contents) and Augmented Virtuality (real-world data and objects immersed in a virtual environment).

Yuen et al. (2011) gave a good overview of the main application fields where AR is taking a growing role in redefining the way of working, such as advertising and marketing, architecture and construction, entertainment, medicine, military applications, travels and education.

For the end-users, the purpose of VR and AR deployment in INCEPTION is to allow 3D semantic model utilisation for queries, visits, uploads and downloads and access through apps that facilitate an analysis of needs, behaviours, expectations of CH customers and operators.

The models will be delivered through INCEPTION Platform in already existing Apps for a myriad of purposes. With this feature, the models will be utilised for research, tourism, building maintenance, specific studies, etc. It will be tested also using Virtual and Augmented realities applications on tablets and smart phones.

INCEPTION investigates the possible use of the standard format for Augmented Reality, i.e. ARML, developed within the Open Geospatial Consortium (http://www.opengeospatial.org/projects/groups/arml2.0swg). Whenever relevant, INCEPTION will also employ knowledge and guidelines from the EuroVR – European Association for Virtual Reality and Augmented Reality (http://www.eurovr-association.org/), the European Project International Augmented Med (http://www.iam-project.eu/), and from certain EU research projects, like Archaeoguide and Veritas.

Moreover, the digital model generated will be readily exported to VRML, X3D or equivalent formats which are appropriate for: VR/AR applications; multimedia edition; conceptualization in a computer scenario; and historical recreations.

4. CONCLUSION

The INCEPTION project has just started and within this project we are just starting to find the context, state-of-the-art and possible solutions for a Heritage-BIM Interoperable Platform.

Nevertheless the team with an unique combination of knowledge and background available within BIM, Semantic Web, Server/Platform solutions and Cultural Heritage solution enables the potential to deliver an interoperable platform that serves CH inan unique way. Making use of Semantic Web techniques and open BIM standards the H-BIM Platform can become the intermediate for Cultural Heritage information forever, for everybody, from everywhere.

The first prototypes, platform architecture and solutions to the challenges named will be available in spring of 2017. The following year more detailed beta applications and developments will become available including a beta version of the H-BIM Platform. Within the last year of the INCEPTION project the prototypes and beta developments are tested and further improved.

Within INCEPTION the solutions and developments towards the technical challenges are backed by 6 project demonstrations from Italy, The Netherlands, Spain, Cyprus, Croatia and Greece. These project demonstrations concern real use-cases that will show the potential and possibilities of the solutions and are expected to be followed by many more in order to store, understand and make available Cultural Heritage information and its contexts to both professionals as non-professional users.

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