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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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# SBE 16 Malta

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# Towards a Sustainable Built Environment

International Conference

16th March – 18th March 2016

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Sustainable Built Environment Malta

SBE Malta (Sustainable Built Environment Malta) is an organisation committed to Sustainable Development, education and research in green buildings and sustainable built environment. SBE Malta acts as the National Chapter of iiSBE, the International Initiative for a Sustainable Built Environment (www.iisbe.org). SBE Malta was set up in 2012 and registered as a voluntary organisation with the Commissioner for Voluntary Organisations in Malta. It is also registered as a legal entity with the Government of Malta. The primary objective of SBE Malta is the advancement of environmental protection and improvement by promoting Principles of Sustainable Development and Sustainability in the Built Environment. SBE Malta was set up as the Green Building and Sustainable Built Environment organisation in Malta, to establish relationships with professionals, public and private organisations at the local and the international level; to participate in international organisations; to promote the advancement of education; to conduct and promote research (www.sbemalta.org).

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# Contents

# 3D Integrated Laser Scanner Survey and Modelling for Accessing and Understanding European Cultural Assets

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**Abstract**. 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: the "geometric memory" is essential for knowledge, protection and sustainable conservation of Cultural Heritage, although there are still some limits to the exploitation of 3D models obtained by laser scanner survey. The growing numbers of un-exploited and "un-interpreted" 3D models points out the remarkable 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. The European Project "INCEPTION - Inclusive Cultural Heritage in Europe through 3D semantic modelling", funded by EC within the Programme Horizon 2020, proposes the enhancement of efficiency in 3D data capturing procedures and devices.

## 1. INTRODUCTION

The greatly stimulating effect of technological innovation as the speed of the digital image processing could mislead and it is easy to make confusion between purposes and actions while dealing with enhancement and promotion of cultural heritage. This phenomenon threatens to generate substantial disaffection among specialists and technicians who seek to give some useful validity to their subject matter through description.

The nearly ten years of research and experimentation have been characterized by an attempt to focus efforts and contribute to the enrichment of representational knowledge of existing elements. The chosen research field, which nevertheless remains open to interdisciplinary approaches, is surveying, representing and preserving our cultural heritage. The newly developed technologies for the automatic acquisition of geometrical data are innovative elements that allow us to create databases of high definition, three-dimensional morphometric data.

These archives of architectural and archaeological data are a valuable research tool for archaeologists, architects, and historians of art and architecture, but also, and above all, they serve the purpose of protecting and preserving cultural heritage sites and provide support to restoration processes and training programmes.

The development of criteria for multilevel organization of databases are mainly oriented to preservation and restoration work, but also contributes to the enhancement, promotion, management, and enjoyment of cultural heritage sites. The database contains 3D models obtained by the use of laser scanner and all the topographic, photographic, diagnostic, and structural data associated with them. Databases allow users to consult and update all data, providing an important foundation for the management, preservation, maintenance, and enhancement of heritage sites.

The European Project “INCEPTION - Inclusive Cultural Heritage in Europe through 3D semantic modelling”, funded by EC within the Programme Horizon 2020,aims to solve the shortcomings of state-of-the-art 3D reconstruction by significantly enhancing the functionalities, capabilities and cost-effectiveness of instruments and deployment procedures for 3D laser survey, data acquisition and processing. It solves the accuracy and efficiency of 3D capturing by integrating Geospatial Information, Global and Indoor Positioning Systems both through hardware interfaces as well as software algorithms.

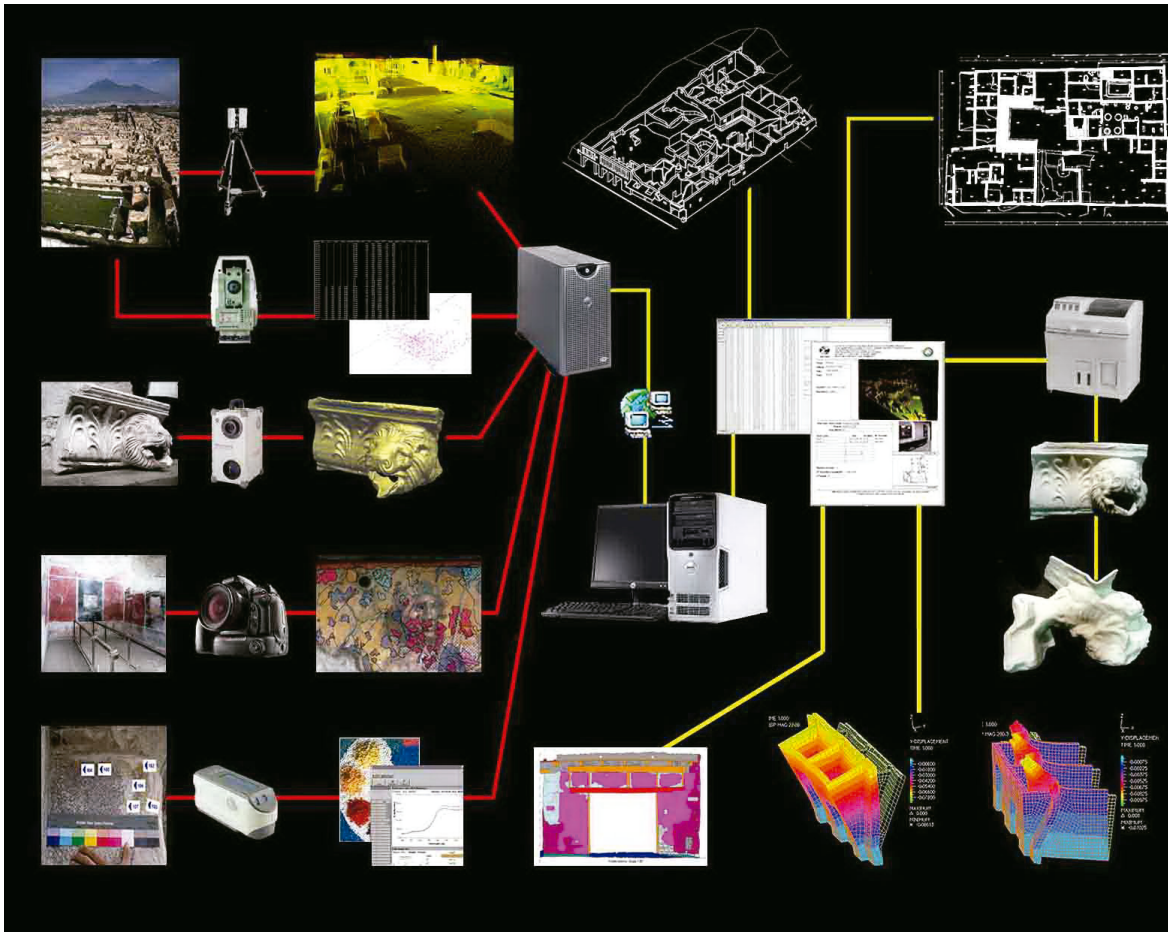

Fig1. 3D integrated survey methodologies applied to the Pompeii archaeological site: 3D time of flight laser scanner survey, topographic survey, 3D optical triangulation laser scanner, digital photographic surveyare integrated to analysis of conservative specifications by spectrophotometric surveyandreflectivity index. It is possible to obtain CAD representations, solid models by 3D printer, structural analysisand conservative specifications.

## 2. STATE OF THE ART

Nowadays a wide range of devices and technologies for 3D data capturing are available, and these technologies are more and more accurate and fast. High quality 3D acquisitions are now possible even with low-cost devices and freeware tools, but every 3D measurement device present different limitations and potentialities, requirements and specifications, characteristics that must be carefully assessed in order to correctly carry out a survey.

An integrated tridimensional survey, aimed at metric, morphological and diagnostic measurement, has a complex and hierarchical data structure, in which every registered value contributes, by its specific properties and different capturing processes and techniques, to the creation of a metric descriptive model. The most accurate survey methodologies and processes involves several phases and devices in order to perform on-site data acquisition, data processing

(scan registration, data cleaning, surface reconstruction, texturing, etc.), outcomes and drawings production based on specific purposes.

By this, multi-scale and multi-purposes analysis of an artefact, based on its context, could be carried out.

Moreover, some gaps in the procedure of 3D acquisition and data management still occur due to the lack of technological integration between different kind of devices and instruments and because the huge amount of acquired data very often requires time consuming processes.

Fig 2. Cross section directly obtained from the point cloud model generated by the 3D integrated survey. The amount of information acquired, opportunely normalized (such as density and reflectivity index) allows analysis and direct interaction with the architecture, avoiding additional representation procedures. This acquisition-visualization method allows a high level of knowledge and usability of two-dimensional drawings reducing time and cost.

The INCEPTION project[1] will face the changing role of 3D digital models in heritage representationand theircollaborative use across disciplines.Breakingdownthe barriers caused by

[1] The project, started in June 2015, will be developed by a consortium of fourteen partners from ten European countries led by the Department of Architecture of the University of Ferrara (scientific coordinator Prof. Roberto Di Giulio) which makes use of the facilities and researchers of the Laboratory TekneHub, Ferrara Technopole, belonging to the Construction Platform of the Emilia-Romagna High Technology Network. Academic partners of the Consortium, in addition to the Department of Architecture of the University of Ferrara, include the University of Ljubljana (Slovenia), the National Technical University of Athens (Greece), the Cyprus University of Technology (Cyprus), the University of Zagreb (Croatia), the research centersConsorzioFuturo in Ricerca (Italy) and Cartif (Spain). The clustering of small medium enterprises includes: DEMO Consultants BV (The Netherlands), 3L Architects (Germany), Nemoris (Italy), RDF (Bulgaria), 13BIS Consulting (France), Z + F (Germany), Vision and Business Consultants (Greece).

The project has been applied for the Work Programme Europe in a changing world – inclusive, innovative and reflective Societies (Call - Reflective Societies: Cultural Heritage and European Identities, Reflective-7-2014, Advanced 3D modelling for accessing and understanding European cultural assets).

the sector segmentation, a ‘common framework’ for the interpretation of European cultural identity and diversity through 3D documentation of cultural heritage sites and buildings will be established.

## 3. THE INCEPTION METHODOLOGY

The INCEPTION main aim is focused on innovation in 3D modelling of cultural heritage through an inclusive approach for time-dynamic 3D reconstruction of heritage sites and on the possibility to create an inclusive understanding of European cultural identity and diversity by stimulating and facilitating collaborations across disciplines, technologies and sectors.

Within this overall framework, the project will develop cost-effective procedures and enhancements for on-site 3D survey and reconstruction of cultural heritage artefacts, buildings, sites and social environments.

This objective will be achieved by:

- Enhancing 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 artefacts that are characterized by smart handling of non-conventional characteristics, location and geometries.
- Developing new methods for condition assessment survey of cultural heritage which are based on predictive analysis (diagnostic, conservative, morphometric), non-destructive procedures and supported by economically sustainable technologies and devices.
- Optimization of hardware and software instruments for easy scan system, rapid capture of main features/geometric data, and automated data output in an H-BIM environment.

The integrated data capturing methodology will be accomplished by the implementation of a common protocol for data capturing and related enhancement of functionalities, capabilities and cost-effectiveness of data-capturing technologies and documentation instruments. The protocol will consider quality indicators, time-consumption, cost-effectiveness, results accuracy and reliability, useful data to be recorded for heritage applications.

In order to maximize the impact, the INCEPTION project will adopt a broad and a dedicated Stakeholder Panel, in order to provide a significant panel discussion with experts in the field of Cultural Heritage not only scientifically but also directing research toward those strategies needed by "end users" and institutions to increase knowledge, enhancement and dissemination through digital models in order to promote the inclusiveness and accessibility of European cultural heritage. The members of the dedicated Stakeholder Panel will provide demonstration cases, support the consortium in data collection, and exhibit the preliminary results of the project through either on-site or off-site demonstration activities.

An innovative concept for an enhanced 3D data capturing system, addressed to an easier and more accessible data processing and modelling, will be developed: experimentation for an enhanced 3D data capturing system equipped with a new firmware optimized for cultural heritage application, addressed to an easier and more accessible data processing and modelling, will be accomplished putting in action the protocol during the survey procedures of the demonstration cases.

The development of tools for 3D automatic delineation depending on acquisition technologies, from point clouds to photo-based data, will allow to achieve a common standard interoperable output for BIM environment.

Fig 3.Tempio di San Sebastiano, Leon Battista Alberti, Mantua. Overlap between the point cloud obtained by means of 3D morphometric acquisition and its graphic rendering through BIM parametric modelling, and, in particular, Heritage-BIM environment

### *3.1. Optimization of 3D data acquisition protocol*

Starting from the state-of-the-art concerning main 3D survey methodologies and documentation systems and recording 3D (data capturing mobile devices, drones and aerial survey devices, mobile robots) the project will develop an integrated methodology and protocol for Cultural Heritage acquisition. The main purposes of data acquisition protocol are:

- close the gap between specialist technicians and non-technical users involved in heritage documentation, in order to facilitate non-technical users;
- provides a guide to the user and the supplier of metric survey data, explaining expected features in order to achieve the main goals in cultural heritage documentation and data capturing;
- definition of common procedure for historical data retrieval and possible previous survey; cataloguing and digitization; knowledge of geometric, surface and structural features; analysis of the state of conservation; maintenance of programmatic interventions in the short and long term;
- list of performance indicators to ensure the effective management of metric survey projects, focusing on the needs and requirements of non-technical users of heritage documentation;
- examines issues such as quality, accuracy, time, costs and specific skills required - focus on needs to be developed regarding data precision and 3D accuracy, visualization production systems, etc.

The project will develop a framework for LIDAR data capturing with very high documental value, based on the enhancement of current systems, by specific adaption of the firmware to optimized 3D data acquisition protocols and standards for Cultural Heritage documentation.

The enhancements will focus on firmware level and consider such as selection modes, basic data segmentation (e.g. object from context), filtering (e.g. moving objects as site visitors), data preview functions (e.g. integrity check), data density control (e.g. thresholds for meshing), registration assistance (e.g. overlap indications). The data communication workflow will be adapted to analysis results and dedicated processing routines in the Cultural Heritage context.

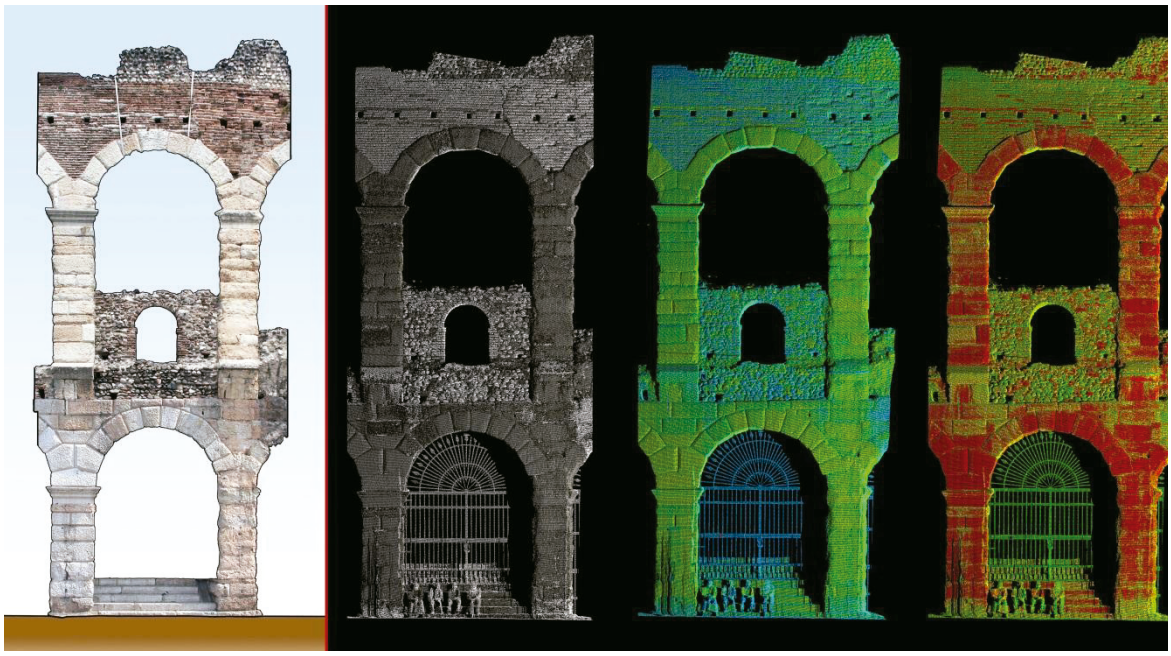

Fig 4. Arena di Verona. Digital image process starting from the data obtained by the 3D laser scanner survey, time-of-flight technology. The processing of the reflectivity index for the identification and analysis of the homogeneous surface' areas (in order to analyze the state of conservation of historical surfaces) and the orthogonal elevation obtained by photos colorimetrically calibrated are useful tools for the analysis of surfaces' conditions and historical materials

## 4. 3D DATA MODELLING: FROM THE POINT CLOUD TO THE BIM ENVIRONMENT

As well as three-dimensional scanners are a technology now widely used in the field of cultural heritage survey and the field of restoration and conservation, the Building Information Modelling systems, starting from the development of CAD, are becoming tools more and more used for the documentation of cultural heritage, as well as semantic web technologies.

The integration between BIM environments and three-dimensional acquisition technologies is one of the challenge to be faced in order to guarantee a truly collaborative process in the heritage preservation sector.

Starting from the implementation of the 3D data capturing protocol for heritage applications and the identification of the Cultural Heritage buildings semantic ontology and data structure for information catalogue, the project will develop guidelines for 3D parametric and semantic modelling in an Heritage-BIM environment, based on Open BIM standard, improving a "BIM approach" for Cultural Heritage.

3D models generated through INCEPTION methods and tools will be accessible for many different users. Semantic enrichment will generate 3D models for multiple purposes depending on the needs and level of knowledge of the end-users. The semantic enrichment will link geometric information for 3D visualisation, historical information, and geo-technical data as well as structural information for material conservation, maintenance and refurbishment.

An open-standard format and semantic ontology to generate high-quality, reliable and interoperable models of H-BIM will be used in order to manage point clouds in the overall

process to generate 3D models without compromising the high quality and accuracy of surveyed data.

Semantic H-BIM allows users not only to access but also to interact with the models, allowing spatial and multi-criteria queries in a virtual 3D environment. The end-users will be able to access information utilising a standard browser, and they will be able to query the database using keywords and an easy search method.

INCEPTION semantic modelling approach will resolve the existing barriers between data collection and documentation, as well as between model creation and analysis / interpretation.

## 5. CONCLUSION

The need of a future re-use of such broad and descriptive source of measurement data demands new applications to facilitate information accessing collected in three-dimensional database without compromising the quality and amount of information captured in the survey.

Databases allow users to understand how each survey-phase was carried out (scans, topographic support, images acquisition, etc.) and thus to obtain the maximum possible amount of morphological information; this procedure means to work with complex interfaces that are based on the programming languages of the software used to complete the survey itself.

Currently, efforts in developing the user interface are concentrated on providing direct or partially controlled access to the large three-dimensional scale models, also by means of immersive navigation. The creation of large digital spaces properly set up in terms of both form and dimensions, will make possible to navigate, enter, and extract its qualities and specifications (measurements, colors, materials, historical documentation, conservation records) in real time.

However, the user's needs and desire for knowledge might be somewhat stymied by such complicated interfaces that could be hard to understand.

Current efforts are focused on creating immersive and easy-to-use 3D visualizations that can be accessed from a wide range of user.

The field of experimentation underlying the integrated, interdisciplinary research effort shares many aspects (dimension and complexity of the data) with heritage surveys, and the results obtained so far give us reason to hope that these optimization processes can be exported.

New simplified navigation interfaces are also being developed for users with lower levels of expertise to facilitate access to and navigation of the three-dimensional models.

It is thus clear that new visualization and communication modes for the geometrical and measurement information have to be conceived and developed in step with the development and application of three-dimensional surveys.

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