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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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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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Digital Documentation: Sustainable Strategies for Cultural Heritage Assessment and Inspection

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Abstract. As part of 3D integrated survey applied to Cultural Heritage, digital documentation is gradually emerging as effective support of many different information (photos, texts, non-destructive diagnostic analysis, multi-resolution images, historical data, etc.) in addition to the shape, morphology and dimensional data. Sustainable strategies in heritage documentation can be achieved through the implementation of effective data collection processes and the development of semantically enriched 3D models. Advanced 3D documentation methodologies identifying different layers of data to be recorded for heritage applications is one of the main outcome of the European Project "INCEPTION - Inclusive Cultural Heritage in Europe through 3D semantic modelling", funded by EC within the Programme Horizon 2020. Technical information will be processed in order to contribute to the creation of a documentation and data acquisition protocol, aimed at identifying sustainable strategies for conservation, refurbishment, reuse and enhancement of heritage buildings and sites. The contribution will deepen in particular the integration of different documentation techniques to enable understanding, interpretation and sharing of collected data.

1. INTRODUCTION

Heritage documentation is basic for understanding our legacy and our cultural identity. The building inspection as well as the documentation processes are becoming more and more relevant and effective in order to collect data and information allowing knowledge, understanding, assessment, preservation and manage intervention on cultural heritage.

While traditional methods and tools of "direct" survey and documentation remain an essential approach to analyze and investigate the main features regarding heritage sites, new technologies and instruments now available allow to create integrated digital databases able to collect dimensional data, information related to structures and materials, state of conservation, diagnostic analysis and historical data, making the data capturing an overall integrated process in supporting sustainable decision strategies for conservation, restoration, refurbishment and enhancement of cultural heritage.

Methods and processes for data collection are continuously developing and today are characterized by an effective interdisciplinarity.

Skills on 3D laser scanner survey, diagnostic procedures and historical researches, as well as about environmental condition assessment or management of metric and dimensional data support the vision of integrated digital documentation for cultural heritage assessment.

Our generation is not able to preserve efficiently cultural heritage and sites due to urban sprawl, pollution, global warming, mass tourism, extreme weather events, etc. We are not able to preserve what we discover and to maintain existing heritage assets and this requires cataloguing and documentation procedures.

The main international and national organizations (UNESCO, CyArk, ICCD, ICOMOS, etc.) that deal with cultural heritage conservation, preservation and enhancement, are increasingly engaged in promoting and spreading processes of cataloguing and documentation. UNESCO

recommendations on *Reporting and Monitoring* encourages site managers and local authorities to work towards managing, monitoring and preserving the World Heritage properties.

In this frameworkdigital technologies are very relevant becausethey are able to survey very rapidly heritage building and sites by collecting millions of spatial coordinates. These 3D acquired data can be used not only for documentation and monitoring purposes but also for digital application (such as virtual tours, virtual tourism, digital reconstructions, etc.) and to create integrated 3D database for preservation, diagnostics, restoration, and management procedures.

"Heritage information − the activity and products of recording, documenting, and managing the information of cultural heritage places − should be not only an integral part of every conservation project but also an activity that continues long after the intervention is completed. It is the basis for the monitoring, management, and routine maintenance of a site and provides a way to transmit knowledge about heritage places to future generations".

Heritage recording to capture information is relevant to understand the physical configuration, evolution and condition of heritage sites and objects, and it is the basis for decisions regarding conservative strategies for sites and objects.

Documentation allows to collect information acquired over time through heritage recording and other researches in order to constitute the knowledge base for particular sites and objects.

Information management is the process of acquiring, storing and sharing site documentation to ensure its accessibility, security and reliability.

Different methodologies, instruments, techniques and processes can be used on the basis of the characteristics and features of the object to be surveyed and, above all, on the basis of the different purposes of the building inspection. Moreover, there is a strong relation among data capturing and collection of information and the ability to make decision about interventions or management strategies.

Based on the size, complexity and volumetric articulation of the areas to be surveyed as well as the surface's characteristics or specific environmental conditions addressed, the survey project can be supported by the integration of different methods:

1) 3D laser scanner in order to obtain a 3D metric model;
2) topographic method for the recording of the different scans and for the definition of the overall network;
3) photographic survey for the overall documentation of the monument and the state of conservation;
4) direct survey when a specific check is required;
5) diagnostic macroscopic investigations for the analysis of the state of conservation of the surfaces.

The overall process allowed to obtain a "capital" of metric data, democratic in its use over time: the 3D survey follows an organization able to highlight the steps of its achievement and to retrace the registration process and data fusion. The obtained 3D model, certificate with a certain degree of accuracy and precision related to the performance specifications of the instrument and the complexity of acquisition, is a set of coordinates x, y and z that can be queried by everyone even after the measurement phase.

The degree of flexibility allows to transfer in laboratory processes of organization and interpretation, freeing the acquisition procedure from the metric data representation and making the "capital" of measures exportable, upgradeable and able to be implemented over time. Starting from this "geometric memory" it is possible to extract both geometric aspects for the enhancement of documentation and information for conservation, diagnostics, monitoring and restoration project.

The 3D morphometric survey based on time-of-flight technology (used for large buildings or complexes) can be integrated with topographic survey and optical triangulation scanners (used to survey decorative details, small objects or archaeological remains). High-resolution photographic survey and documentation on materials and structures can be added to the 3D database, while the analysis of the state of conservation (by means, for example, of spectrophotometric survey or thermal camera) allow diagnostic investigation by processing reflectivity index acquired during laser scanning survey.

Via a server, local network or the Internet, it is possible to query the integrated database from PCs and extract different measurement data, surface specifications, two-dimensional CAD drawings, up to three-dimensional printable models.

2. THE CULTURAL HERITAGE INSPECTION

The Cultural Heritage inspection and monitoring could be considered the first step of the maintenance and restoration process.

The main aims of the Cultural Heritage analysis and investigation process are oriented:

- to collect technical information;
- to define the conservation and decay conditions;
- to describe the risk conditions;
- to propose several types of building interventions (maintenance, rehabilitation, re-use and restoration);
- to set-up a detailed maintenance plans and programmes.

The constant inspection and survey activities are necessary to prevent more important decay conditions and are strictly related to prevent damage of the cultural heritage. In fact, one of the most important advantages of the periodic inspection activities is related to the technical information collected in different periods.

Considering that the Cultural Heritage inspection requires relevant historical and technical knowledge as well as the ability to use of specific methods, tools or techniques, only qualified operators should be involve in this task under the supervision of the Project Manager.

Furthermore, it is suggested that a team of expert accomplishes the building analysis (inspection and survey) to reduce the risk of non-conforming interpretations.

In the last years several European countries have developed specific Cultural Heritage inspection activities oriented to collect technical information on the state of historical buildings or sites and subsequent proposed of preventive interventions.

The most important European Cultural Heritage inspection method is the *Monumentenwacht*. This method proposed a visual non-destructive inspection without the employing of innovative technologies. The outcome of this inspection method consists in an "observation report" that presents:

- macroscopic decay,
- recommendation to improve the building qualities and,
- additional investigation by using innovative technologies and tools (instrumental inspection).

Usually, the information collected during the inspection are describe in the Final report and could be recorded and shared in an implementable digital database.

Despite this, today several sustainable technologies and instruments aimed at Cultural Heritage non-destructive inspection are able to collect, at the same time, several digital data.

3. THE 3D LASER SCANNER TECHNOLOGIES AND THE DIGITAL DOCUMENTATION

The collecting information to preventive conservation, monitoring and maintenance of European cultural historical heritage is undeniably connected with the use of specific methods, tools and techniques that in recent years have become technologically advanced and diffuse in all countries.

The innovations of these digital technologies to analyse the Cultural Heritage have been improved and updated in the last decade. The main potential use is related to the rapid analysis of the heritage building and sites.

In this framework the 3D laser scanner technologies allow digital surveys obtaining high definition databases established on even more detailed three-dimensional morphometric scans. The technological evolution of the automatic survey systems represent an important innovation that allows the introduction of the morphology-metric system as an essential support for the setting-up of the three-dimensional databases. The integration of other non-destructive

procedures as thermal imaging, index of reflectivity, integrated sensors, spectrophotometry, sonic surveys, etc. allows the collection and addition of other significant digital data.

This typology of database represents the basis of "geometric memory archive" of heritage buildings and sites that can be used for research goals by art and architecture historians, professionals, heritage sites managers, etc., but can also be used for preservation, restoration and environmental protection of heritage assets.

In fact, thanks to the use of laser scanner technology it is possible to obtain a large number of information that can be collected in a "digital archive".

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 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. Also the outcome of digital reconstructions is frequently provided in non-interoperable formats, and not easily accessible too.

Despite this, it is important to consider the problematic related with the use of the 3D laser scanner. The level of difficulty of 3D laser scanner tool is very high if measured using the following indicators: 1) time, 2) economic cost and 3) required degree of knowledge. This method has to be systematic and efficient in order to avoid inaccuracy, inconsistency and human error. The main problems connected with the efficiency of this survey method are:

- access to all areas to be surveyed;
- target position;
- availability of the hardware storage capacity for large amount of information acquired during the survey;
- post-processing of the acquired data;
- establishment of a database organized by individual architectural elements integrated with a description of additional data;
- concept of "open data packet";
- management of the outgoing flow of information (byserver infrastructure);
- management of the flow of feedback information(completed with the CAD drawings);
- editing of the final drawings delivered.

For this reason establishing an European standard for the use of the 3D laser scanner in heritage filed could be very relevant and effective. Protocol and standard use could be shared to all European Countries and applicable during the survey and inspection of different typologies of cultural heritage.

The INCEPTION project works in order to implement a common protocol for data capturing, especially in consideration of the use of 3D data capturing technologies.

The protocol will take into consideration the importance of the "digital information" and will be developed analysing the functionalities, capabilities and cost-effectiveness as well as to improve the interoperability and the accessibility of the data.

Another relevant feature regarding the use of the 3D laser scanner technologies concerns the development of 3D semantic models of cultural heritage. Indeed, the data capturing and heritage documentation are strongly related to 3D models exploitation (geometry - metadata - semantic enrichment) and to the optimisation of 3D data acquisition tools.

The 3D semantic models of cultural heritage will also be directly applicable for practical purposes through:

- multilevel organisation of databases applicable for conservation and restoration work, enhancement, promotion, management, and exposition of cultural heritage;
- enhanced point cloud data with highly descriptive quality in terms of material characteristics and morphology (complex geometries and shapes) of cultural heritage;
- inherent indicators for risk assessment of cultural heritage (i.e. environmental risks indicators, safety and security monitoring, unpredictable events management);
- integrated functional distinction of data, shape-related analysis, and semantic information for in-depth studies by researchers and common understanding for end-users at large.

4. THE INCEPTION RESEARCH AVENUES

The European Project "INCEPTION - Inclusive Cultural Heritage in Europe through 3D semantic modelling", funded by EC within the Programme Horizon 2020, is focused on:

- 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 scholars, researchers and non-expert;
- the development of an open standard platform to "contain", implement and share the digital models.

The project has been selected within 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 INCEPTION project, started the last June 2015, will be developed by a consortium of fourteen partners[1] from ten European countries led by the Department of Architecture of the University of Ferrara.

One of the main project' objective is to develop cost-effective procedures and enhancements for on-site 3D survey and reconstruction of cultural heritage artefacts, buildings, sites and social environments.

This research section 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 as cultural heritage sites, historical architectures, archaeological sites and artefacts that are characterized by smart handling of non-conventional characteristics, location and geometries.

New methods for condition assessment survey of cultural heritage based on predictive analysis (diagnostic, conservative, morphometric), non-destructive procedures (thermal imaging, level of reflectivity, integrated sensors, spectrophotometry, sonic surveys, etc.) will be developed and will be supported by economically sustainable technologies and devices.

Moreover, the project will propose an essential optimisation 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.

Innovation in documentation of cultural heritage will not involve only data acquisition procedures and hardware and software applications, but the project will set a protocol (guidelines or common methodology) for documenting Cultural Heritage relating to results accuracy and reliability, different sites specifications, historical phases, etc.

INCEPTION equips all actors and stakeholders to cope with the changing roles of reconstruction, preservation and conservation of cultural heritage by:

- closing the gaps between technical fieldwork and modelling in 3D data capturing and the model exploitation for social sciences purposes;
- optimization of 3D data acquisition tools through special set of firmware for cultural heritage, which is able to handle point clouds as well as photo-based data, in order to generate input for H-BIM modelling;
- semantic ontology to identification, recognition and analysis of non-typical geometries, materials, textures, spaces and landscapes of cultural heritage in modelling.

[1] 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).

5. CONCLUSION

The integration of digital data and the possibilities of re-use of digital resources is an important challenge for a sustainable protection and conservation (decision-making process) of the historic buildings as well as for an efficient management in the long term.

The digital data alone are not enough to improve the quality of cultural heritage management. It is necessary to consider the elaboration of "digital models and platform" allowing data integration, data accessibility and data updating.

Digital models and platform bring positive effect to the policies addressed to the digitally preserving and sharing the world's cultural heritage in danger and can help the implementation of social initiatives aimed to save specific site in danger.

Integrated digital models, digital archives and "geometric memory" repository can support initiatives aimed to save cultural heritage sites digitally before more are ravaged by war, terrorism, arson, urban sprawl, climate change, earthquakes, floods, and other threats. There isn't enough money or enough time to physically save every site, but digital documentation can contribute with the 3D technology to digitally save these sites to make them available for generations to come.

Last but not least, the creation of integrated documentation platforms is important:

- to provide new documentation procedures for the building preservation;
- to correlate different criteria and indicators that suggest the building decay state;
- to propose advanced diagnostic and data management;
- to take in consideration the building risk assessment.

The aims and the outcomes proposed by the INCEPTION project are very innovative and could create an important impact to preserve, to manage and to study our European Cultural Heritage.

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See the UNESCO commitment on cataloguing and documetation on whc.unesco.org. CyArk was founded in 2003 to ensure heritage sites are available to future generations, while making them uniquely accessible today. CyArk operates internationally as a non-profit organization with the mission of using new technologies to create a free, 3D online library of the world's cultural heritage sites before they are lost to natural disasters, destroyed by human aggression or ravaged by the passage of time (www.cyark.org).The Italian ICCD (Istituto Centrale per il Catalogo e la Documentazione) is an Institute created to manage the national catalog of archaeological, architectural, historical, artistic and ethno-anthropological heritage; it processes the methods of cataloging and coordinates operational activities of technical bodies; it realizes campaigns of documentation of cultural heritage; it protects, preserves and enhances its collections of historical photography and aerial photography. ICOMOS (International Council on Monuments ans Sites) is a non-governmental international organisation dedicated to the conservation of the world's monuments and sites. ICOMOS Documentation Centre is the primary repository for the original documentation of the cultural and mixed (natural and cultural) properties that have been inscribed on the UNESCO World Heritage List since 1978(www.icomos.org).

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