Massimiliano Lo Turco
Elisabetta Caterina Giovannini and Noemi Mafrici
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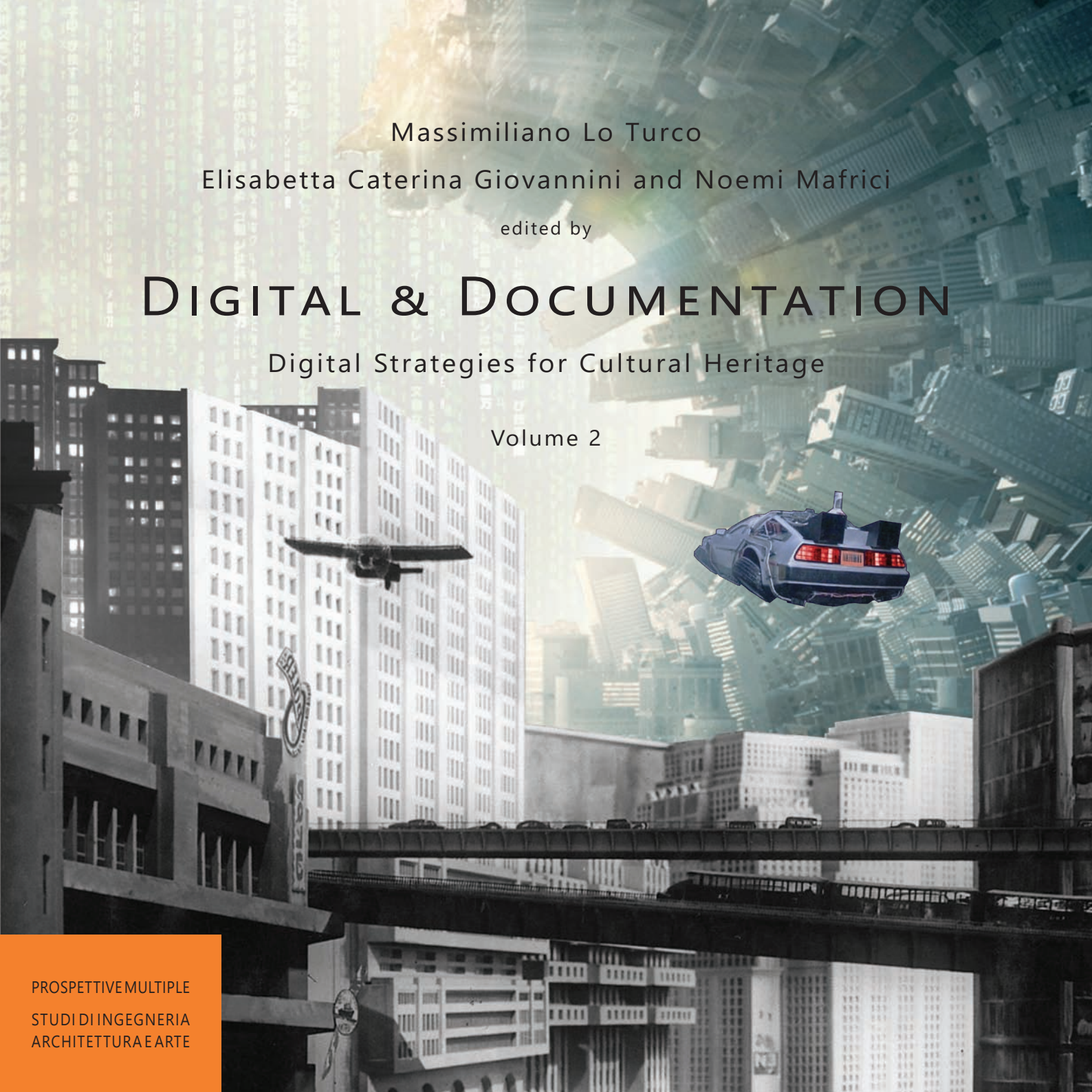
Digital & Documentation

Digital Strategies for Cultural Heritage

Volume 2



PROSPETTIVE MULTIPLE
STUDI DI INGEGNERIA
ARCHITETTURA E ARTE

Massimiliano Lo Turco
Elisabetta Caterina Giovannini and Noemi Mafrici
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Digital & Documentation

Digital strategies for Cultural Heritage

Volume 2

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The volume consists of a collection of contributions from the seminar "Digital & Documentation: Digital Strategies fo Cultural Heritage", realised at the Politecnico di Torino on June 14th, 2019. The event, organized by the "BIM Acquisition as Cultural Key TO Transfer Heritage of ancient Egypt For many Uses To many Users REplayed" - B.A.C.K. TO T.H.E. F.U.T.U.RE. Project - team of DAD - Department of Architecture and Design of Politecnico di Torino, promotes the themes of digital modeling and virtual environments applied to the documentation of architectural scenarios and the implementation of museum complexes through communication programs of immersive fruition.
The event has provide the contribution of external experts and lecturers in the field of digital documentation for Cultural Heritage. The scientific responsible for the organization of the event is Prof. Massimiliano Lo Turco, Politecnico di Torino.

This publication is made with the contribution of DAD, Department of Architecture and Design of Politecnico di Torino, through the “BIM Acquisition as Cultural Key TO Transfer Heritage of ancient Egypt For many Uses To many Users REplayed” - B.A.C.K. TO T.H.E. F.U.T.U.RE. Project, in collaboration with Fondazione Museo delle Antichità Egizie di Torino. The project is one the winner of the call “Metti in rete la tua idea di Ricerca” partially financed by Compagnia di San Paolo.

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The event “Digital & Documentation - Vol. 2” has seen the participation of professors, researchers, scholars and private institutions

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Fondazione Museo delle Antichità Egizie di Torino

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Institute for Heritage Sciences of the National Research Council

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PART II

DATABASES, SEMANTICS & INTEROPERABILITY

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05 DATA ACQUISITION PROTOCOLS AND SEMANTIC MODELLING OF THE HISTORICAL-ARCHITECTURAL HERITAGE: THE INCEPTION PROJECT

Federica Maietti, Marcello Balzani

Abstract

Advanced and integrated digitization of heritage artefacts, monuments and sites is one of the priorities stated at European level during recent events focused on next research avenues to record, document and preserve Europe's cultural heritage and foster its accessibility.
In this scenario, it is possible to identify different research approaches, addressing several aspects related to the development of databases and digital models; the state of the art at international level is articulated, complex and inter-sectoral, but it is possible to point out some common directions towards digitization strategies and data management. Parametric modelling, semantic enrichment and applications aimed at the immersive fruition of cultural heritage are some of the main research fields fostering new approaches to innovation of methodologies and tools.
New technologies, devices and digital environments are influencing the ways in which heritage contents are explored, used, managed and shared, also in citizens everyday life. In this framework, the project INCEPTION - Inclusive Cultural Heritage in Europe through 3D semantic modelling, funded by the European Commission within the Horizon 2020 programme, develops key-targeted innovations in efficient 3D digitization methods, post-processing modelling tools, semantic web-based solutions and applications to foster a wide and aware access to digital Cultural Heritage.
The overall methodology is focused on Architectural Heritage, deepening the potential that the "architectural space" has in creating new connections and awareness in the field of cultural heritage.

La digitalizzazione avanzata e integrata di manufatti, monumenti e siti del patrimonio culturale è una delle priorità a livello internazionale, come dichiarato durante i recenti eventi della Commissione Europea incentrati sui prossimi percorsi di ricerca per rilevare, documentare e preservare il patrimonio culturale e promuoverne l'accessibilità. In questo scenario, è possibile individuare diversi approcci di ricerca che affrontano molteplici aspetti correlati alla messa a punto di banche dati e modelli digitali; lo stato dell'arte a livello internazionale si configura come articolato, complesso e intersettoriale, ma è possibile individuare alcuni orientamenti comuni nei confronti delle strategie di digitalizzazione e di utilizzo dei dati. La modellazione parametrica, l'arricchimento semantico e la fruizione immersiva del patrimonio culturale sono alcuni dei principali settori di ricerca che promuovono nuovi approcci all'innovazione di metodologie e strumenti. Nuove tecnologie, dispositivi e ambienti digitali stanno influenzando il modo in cui i contenuti correlati al patrimonio culturale vengono esplorati, utilizzati, gestiti e condivisi, anche nella vita quotidiana. In questo contesto, il progetto INCEPTION - Inclusive Cultural Heritage in Europe through 3D semantic modelling, finanziato dalla Commissione Europea nell'ambito del programma Horizon 2020, sviluppa innovazioni mirate a un avanzamento nella digitalizzazione 3D, strumenti di modellazione e processamento dei dati, soluzioni basate sul web semantico e applicazioni per favorire un accesso inclusivo e consapevole al patrimonio culturale digitale. La metodologia complessiva è incentrata sul patrimonio architettonico, approfondendo il potenziale insito nello "spazio" nell'innescare nuove connessioni e nuove consapevolezze nel campo del patrimonio culturale.

Introduction

Nowadays, interest and commitment in the field of 3D digitisation of cultural heritage artefacts, monuments and sites is becoming ever increasing and crucial. Widespread threats due to natural deterioration, pollution, disasters, mass tourism, terrorism and vandalism, create an urgent need to make the most of digital technologies to record, document and preserve Europe's cultural heritage and foster their accessibility to European citizens[1].

A significant emerging trend at European level shows an increasing digitisation of immovable cultural heritage as well as initiatives to enhance cross-border cooperation and digital capacity in the cultural heritage sector.

Moreover, among most relevant needs in the field of heritage documentation, the importance of linked open data has emerged as a relevant topic to be further addressed along with technologies that can improve the quality of digitized material presented online.

In this context, standards or guidelines in 3D data capturing, documentation and data management are also seen as goals to be reached and further developed.

ICT standards, visualisation of and access to digital objects (metadata, graphical materials, etc.), interoperability, storage, use and long-term digital preservation to copyright, business models, findability, 3D digitisation and web statistics are additional research avenues to be implemented in the very near future[2].

In the above mentioned report on digitisation, online accessibility and digital preservation of Cultural Heritage, it is stated that library and archival materials are the main digitized resources together with museum collections, while an increasingly widespread digitalization of heritage buildings and sites is beginning (under EU initiatives and funding programmes) through 3D digitization activities.

This scenario, in addition to highlighting the need to apply digitization to the cultural heritage in an increasingly focused way, makes it possible to identify different research approaches, addressing several aspects related to data acquisition, documentation, modelling and management.

The state of the art at international level is articulated, complex and inter-sectoral, but it is possible to point out some common directions towards digitization strategies and data handling. Parametric modelling, semantic enrichment and applications aimed at the immersive fruition of cultural heritage are some of the main research fields fostering new approaches to innovation of methodologies and tools[3].

In this framework, the project INCEPTION - *Inclusive Cultural Heritage in Europe through 3D semantic modelling*, funded by the European Commission under the Horizon 2020 programme, aimed at developing 3D digitization methods, post-processing modelling tools, semantic web-based solutions and applications to foster a wide and aware access to digital Cultural Heritage.

The four-year project started in June 2015 and was completed at the end of May 2019. During the project development, the objective of carrying out simultaneously an approach based on knowledge and data interpretation, the needs of access to digital data by different types of users, and the implementation of specific tools were pursued.

INCEPTION overall methodology

The overall project development was set according to the following objectives:

Fostering collaborations across disciplines and technologies in Cultural Heritage field;

Proposing innovation in 3D data capturing procedures and 3D modelling (at heritage building and site scale);

Connecting to the geometric 3D model the necessary semantic information for in-depth studies and different uses;

Fostering the use of interoperable formats, making models interoperable, easily accessed, used and reused;

Developing an open-standard Semantic Web platform for accessing, processing and sharing interoperable digital models[4].

In order to reach the above-mentioned goals, three main research fields were faced: 3D data capturing, 3D modelling, data sharing.

After having set the project methodology or framework definition, the involvement of the Stakeholder panel and the identification of user needs were the starting point for starting activities related to documentation and data capturing. This section of the project led to the definition of the Data Acquisition Protocol and the development of a specific concept of an optimized 3D laser scanner firmware for 3D data acquisition. The concept is based on the general requirements of the workflow developed in the Data Acquisition Protocol for survey procedures of tangible cultural heritage.

In addition to provide a workflow for a consistent development of survey procedures, the definition of the Protocol allowed a consistent 3D digital data management toward modelling in BIM environment. Focusing on open standards (such as E57) for point clouds and open standard IFC for semantic BIM data managed by Semantic Web-based technology, the project foresees a long-term open access and interrelation of all available data.

BIM modelling and semantic modelling were developed simultaneously to the definition of the platform architecture. The platform aims at establishing a close connection between state-of-the-art architectural modelling technologies (BIM) and the latest cutting-edge web technologies. It is grounded on semantic web technologies and makes use of WebGL and RESTful APIs, in order to enrich heritage 3D models by using Semantic Web standards; this structure allows interlinking the platform with external available linked data and makes it gradually enhanced by further ontologies.

The main outcomes of the project, listed above, have been gradually applied and tested during the four years of development on nine Demonstration Cases in six European countries. These pilots have been selected in order to have a sample of different typologies of heritage buildings, covering different historical periods, a wide range of sizes and morphologies, different states of conservation, environmental conditions and different needs and requirements by Stakeholders.

The final step was related to the setting up of user-oriented tools based on data collected on the platform. Starting from existing systems, platform functionalities and external apps are indeed aimed at immersive experiences for accessing and understanding heritage sites.

The applied activities on Demonstration Cases allowed figuring out the practical application and analytic potential of resulting 3D multi-information models for research, interpretation, analysis and additional uses according to different purposes and users.

The digitalization of the selected Demonstration Cases was planned from the beginning in order to provide new approaches in studying, documenting, preserving, managing and communicating the architecture and its contents starting from the geometric knowledge obtained by 3D data capturing. The output 3D models allow data managing for scholar, professional, academic uses, up to multimedia visualisations and applications for site enhancement and for creating innovative ways to explore the architectural heritage and new forms of accessibility.

Starting from the survey and documentation, up to the data modelling, aggregation and uploading on the Platform, the INCEPTION procedure has been applied to all Demonstration Cases through the following activities:

Meetings and exchanges with the Stakeholders, to identify users, requirements and needs.

Development of overall survey and documentation process.

Application of the Data Acquisition Protocol by setting up a specific data management procedure.

Semantic enrichment of the 3D model in BIM environment[5].

Uploading and management of models, data and

information on the INCEPTION Platform, by setting a specific heritage workflow to be performed through the platform according to target users, needs and requirements. Development of user-oriented applications.

Data Acquisition Protocol

As already mentioned, the Data Acquisition Protocol[6] has been developed jointly to enhanced laser scanner. While the Protocol set up the guidelines for documenting Heritage sites, one of the main aims of the enhanced firmware was integrating metadata and paradata, developing 3D point cloud models linked to additional information and providing useful information for successive processing steps, such as H-BIM modelling, in a common and easy manner.

The Protocol[7] is a set of flexible guidelines ensuring data homogenization between surveys tailored on different requirements.

The initial assumption to the Protocol development was considering both site specifications and the uniqueness of each Cultural Heritage, and significances that can be documented on site or revealed in the available sources. The significances have been divided in nine categories (Spatial/metric-morphologic analysis, geometric significance; Aesthetic significance; Cultural-symbolic significance; Economic significance; Environmental significance; Historic significance; Risks; Social significance; State of conservation).

Specific activity indicators related to survey planning, performing and managing were then set up (Scan Plan; Health and safety; Resolution Requirements; Registration mode; Control network; Quality control; Data control and verification; Data storage and archive).

The Data Acquisition Protocol was the main source for the feature collections to be applied to the concept of the enhanced 3D laser scanner firmware. Most of the activity indicators were directly transcribed into functions to be covered by the firmware. Therefore, in addition to functions are already present in the existing firmware, a number of functions were identified as additional features to be developed and implemented as enhancements specifically for heritage sites survey[8].

In order to manage data capturing according to pursue a data capturing consistent to the aims of the survey, specific evaluation categories were set up. Starting to B up to A++ category, this classification includes four ranges of actions. From simple buildings or buildings for the creation of low-detailed BIM model, the category is "B". For complex

Fig. 1 - Exterior and internal views of the Istituto degli Innocenti in Florence, the Italian Demonstration Case developed under INCEPTION

Fig. 2 - Internal views of the Istituto degli Innocenti in Florence

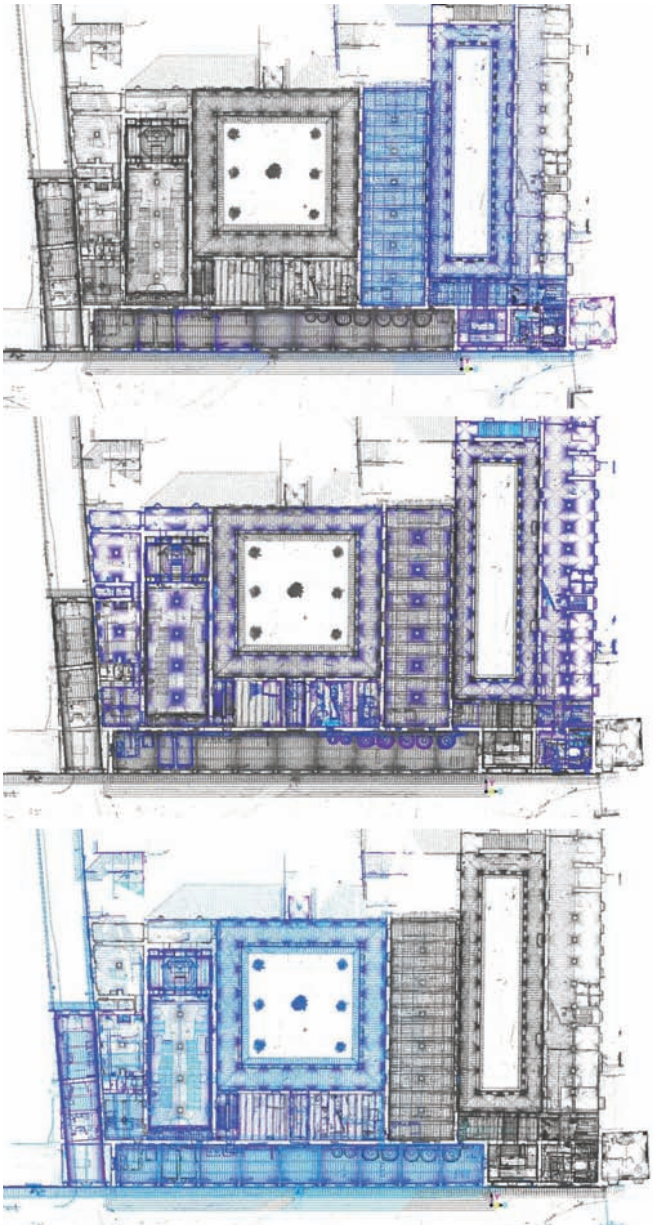
buildings or for surveys where the capturing process needs to be documented and traced, or for documentation that are the base for restoration projects, the category is "A++". For instance, the survey of the Istituto degli Innocenti in Florence, the Italian Demonstration Case, reaches the highest level (A++). This level achievement is due to the complexity of the building, to the set of significances embedded by the building by Brunelleschi[9], to the several technologies and techniques used during different survey campaigns and to integrated surveys in different times[10].
The digitalization of the Istituto degli Innocenti[11] and the development of specific applications within the INCEPTION project, can provide new approaches in studying, documenting, preserving, managing and communicating the architecture and its contents, not least the art collections and historical archive. According

to the Stakeholder requirements, since the Istituto has many tourist visits, main outcomes from INCEPTION are related to dissemination and enhancement of the three sections of the Istituto: history, architecture and arts. Future applications are not focused only on tourists but also on improved accessibility of history, architecture and arts contents for new studies of Renaissance architecture.

Data modelling and sharing under INCEPTION

Modelling procedures from 3D survey to BIM were implemented under INCEPTION. The definition of an open-standard format and semantic ontology to generate high quality, reliable and interoperable models of so-called H-BIM[12]. The starting point was the setting up of a procedure focused on the aggregation of geometries, significances, data and information into a BIM environment. An H-BIM ontology to model Heritage sites merging BIM and Semantic Web Standards into the INCEPTION Platform was developed. The H-BIM ontology allows identifying each building part through semantic concepts, allowing the connections to other Semantic Web entities and opening the building model to holistic enrichments. Using ontologies[13] opens up the opportunity to "layering" other ontologies, which means adding levels of machine-readable knowledge, and linking each component to external media files.

Connecting BIM environment and Heritage domain was faced by working with available tools and functionalities offered by W3C and where possible open source solutions. Semantic non-geometrical knowledge and semantic geometrical knowledge are split but interconnected, starting from IFC and IfcOWL[14]. BIM and Heritage are linked by adding a layer of mappings as typically applied with Semantic Web technology. The H-BIM is furthermore able to be enhanced by third parties extending, improving and adjusting the H-BIM over time and for different aggregations levels, allowing the INCEPTION platform to be



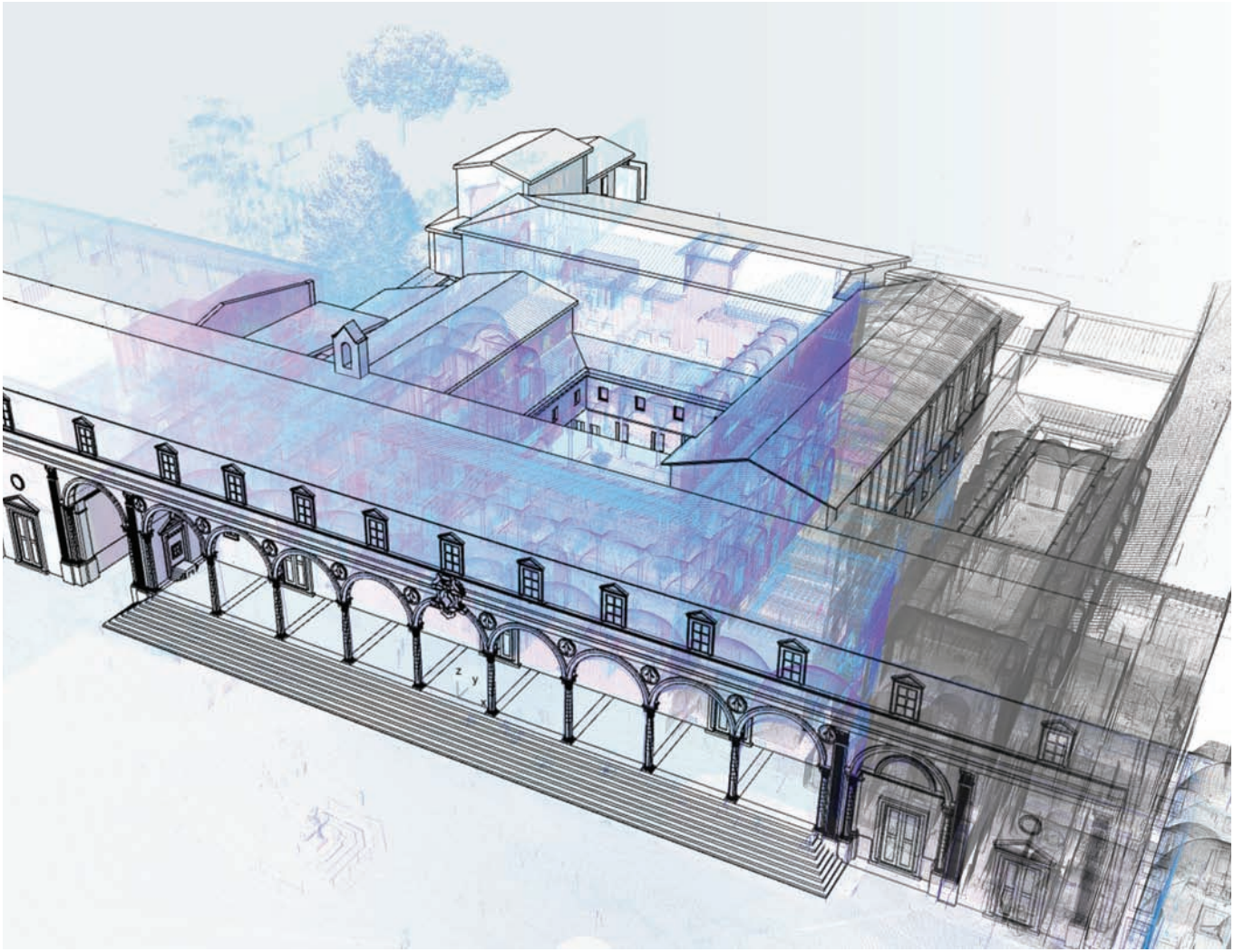
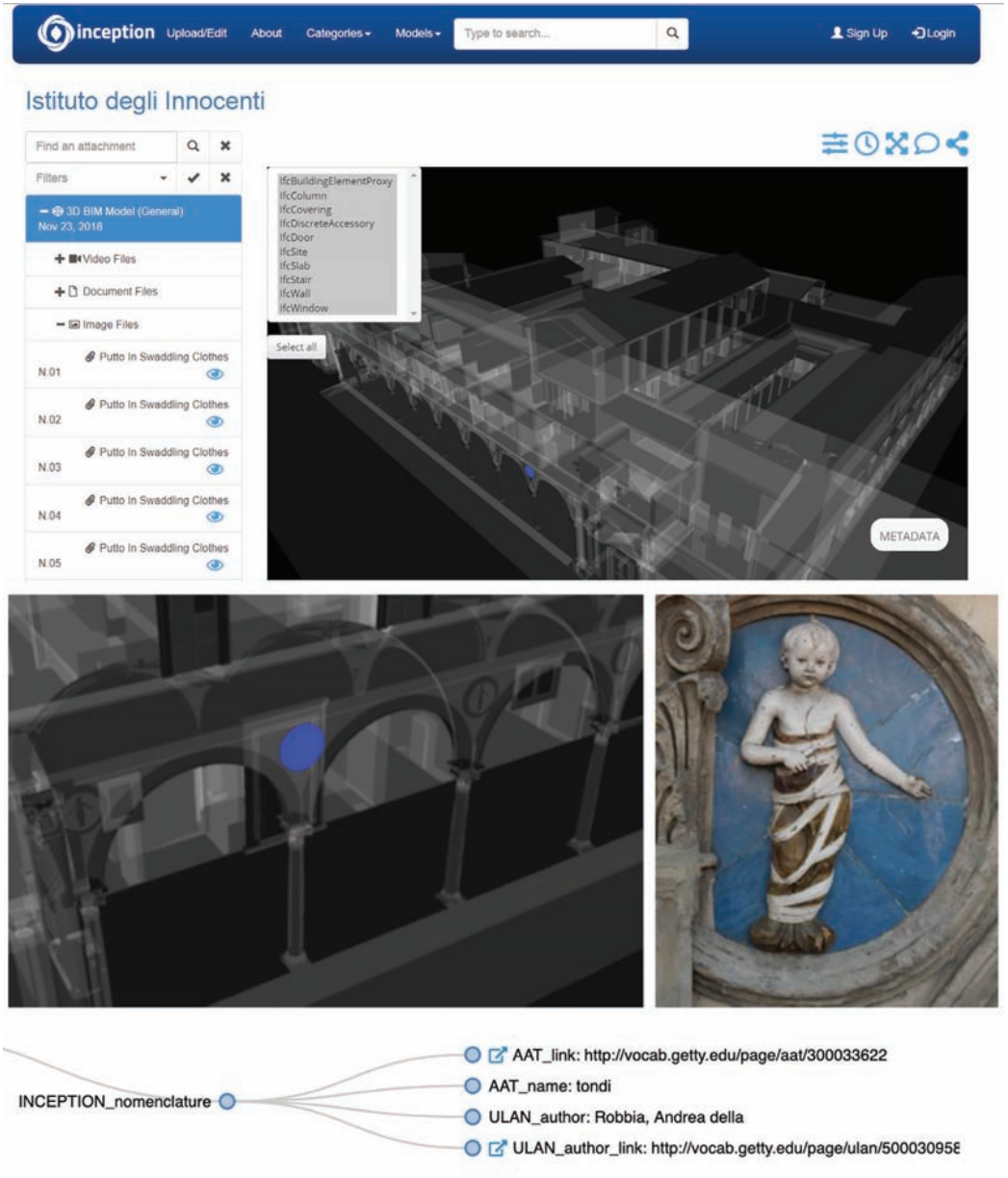


Fig. 3 - Planimetric views from the 3D database of three survey campaigns of the Istituto degli Innocenti in Florence

Fig. 4 - BIM model overlaying the 3D point cloud of the Istutito degli Innocenti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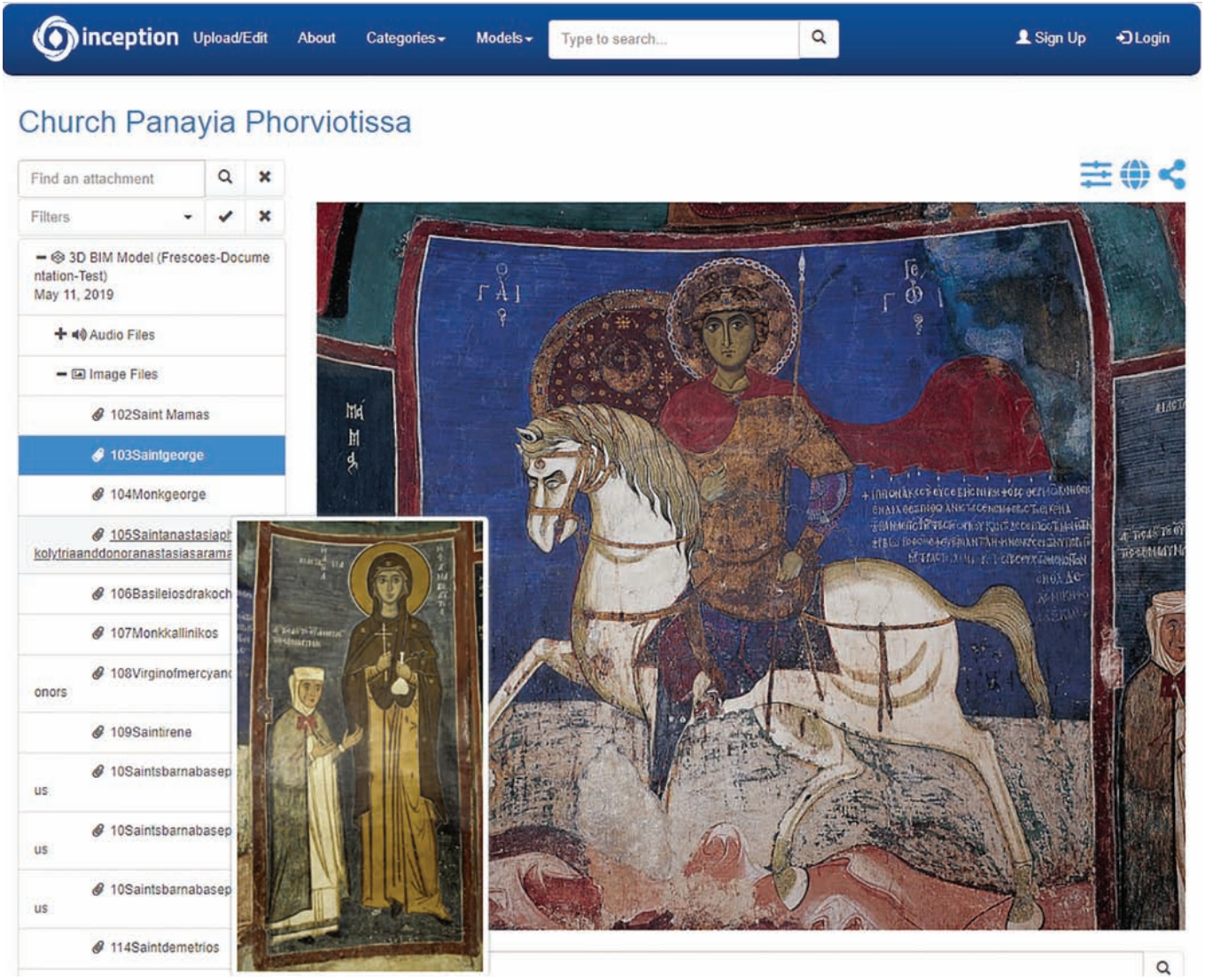

Fig. 5 - Screenshots of the INCEPTION platform. Decorations on the façade of the Istituto degli Innocenti. The metadata for a single 3D element span from physical properties (material, dimensions, etc.) to nomenclature

Fig. 6 - View of the platform functionalities applied to the Cypriot Demonstration Case. Image files related to the 3D model are displayed

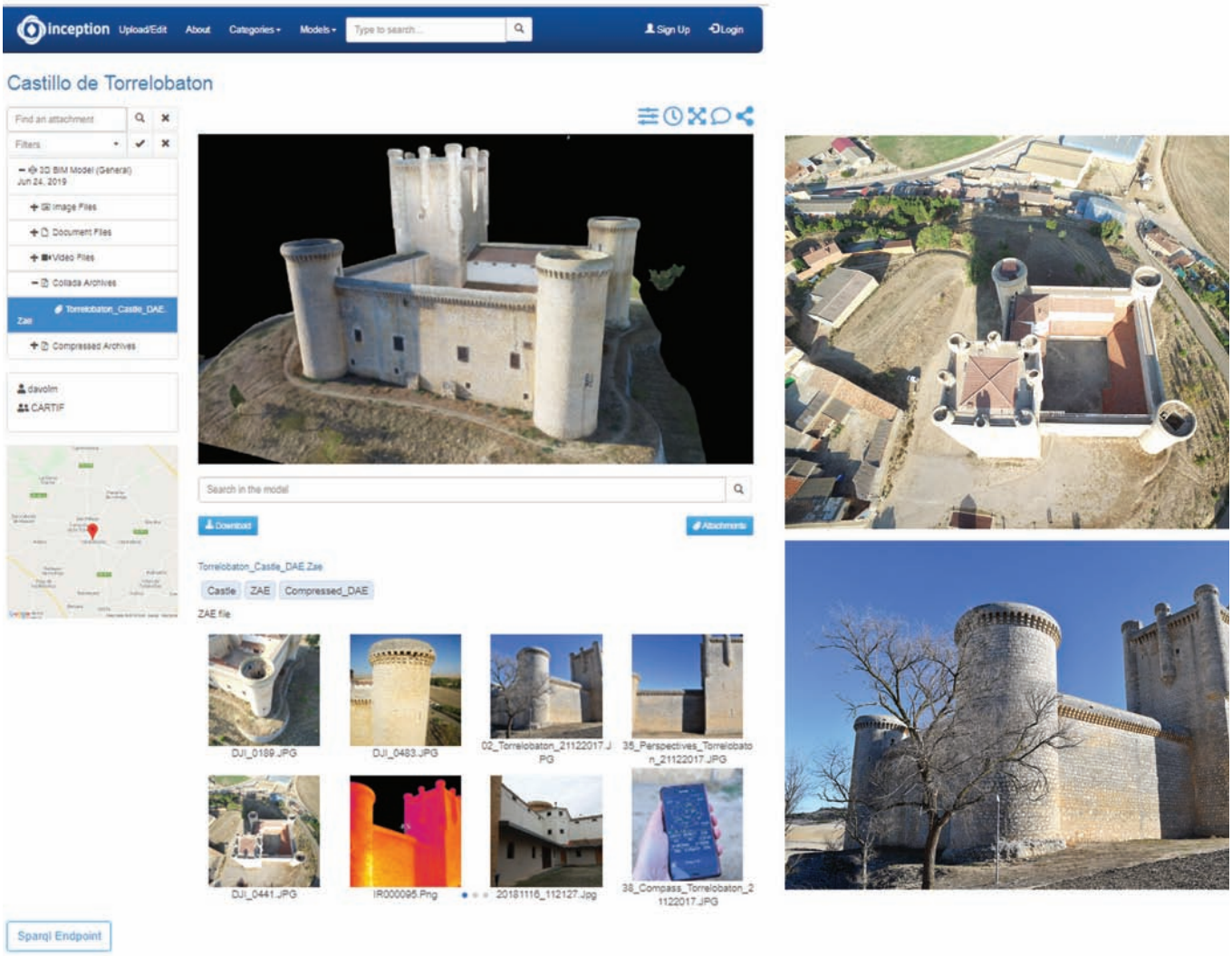

Fig. 7 - View of the platform functionalities applied to the Spanish Demonstration Case. One of the 3D model uploaded on the platform is a textured DAE model

flexible towards different views on how information should be stored according to the H-BIM ontology[15]. Therefore, the aim of the H-BIM ontology for the INCEPTION project is the capability to create, exchange and reuse information.
In the cloud-based architecture, the main input is a BIM model of a Heritage site[16]. The development of an interoperable ontology allows aggregating information into the parametric model. The capability of the ontology to be linked with external open data or other ontologies is one of the main achievements. Therefore, the advancement proposed in model sharing under INCEPTION is based on core functionalities tailored on end-user needs, including developers and solution providers for interacting with external mobile devices and applications.
This orientation towards the end-users has been carefully verified during the development of the project thanks to the involvement of the stakeholders, who have actively contributed, from the third year onwards, also in identifying platform contents, user experience and interface. This helped focusing the main actions in browsing 3D digital models and interacting with specific information (according to different user categories) and developing platform functionalities.
Feedback from Stakeholders allowed stressing the current changing role of 3D digital models in representation of heritage and its analysis and collaboration across disciplines, providing semantic information for in-depth studies by researchers and users[17].

Conclusion and future developments

At the end of the project it is possible to emphasise that the main results, both at methodological and application level, have been achieved, putting together essential steps and workflows that can contribute to improving the documentation, survey, modelling, use and reuse of digital data applied to Cultural Heritage.
There is of course room for further developments and improvements, starting from the population of the platform following the INCEPTION procedure. Therefore, the conclusion of the project is not an end but a starting point.
The next steps, in the very near future, concern the application of the procedural protocols developed, in order to verify and test platform functionalities over a wide range of heritage digital models.
Following also the research directions expected in the coming EU programmes, next actions and follow-ups will be focused on fostering high quality, interoperable and open access to digital data to create higher digital engagement for different heritage fields.
Next steps will also connect project outcomes with emerging technologies such as big data, artificial intelligence and extended reality, by exploring new ways of advancing scientific understanding and new engagements for citizens.
Moreover, "*The Commission Recommendation on digitisation and online accessibility and digital preservation of cultural material (2011/711/EU) has helped Member States to develop strategies and improve conditions for the entire digitisation lifecycle. Europeana, Europe's digital platform for cultural heritage, embodies the continuous effort of the European Commission and the Members States to democratise access to cultural heritage, foster pan-European collaboration between heritage institutions, and promote interoperability and open access, while respecting copyright*"[18].
The direction traced through the development of the platform will be therefore further strengthened. A common standard, methodologies and guidelines to model data and knowledge aiming at a comprehensive, holistic documentation of European 3D cultural heritage assets; and the definition of framework conditions for an open European repository for storing, managing and re-using interoperable 3D models are indeed among the main EU aims for the coming years.

Notes

[1] Declaration: Cooperation on advancing digitisation of cultural heritage 2019.

[2] Cultural Heritage: Digitisation, online accessibility and digital preservation, 2019.

[3] Cf. Bianchini et al. 2016.

[4] Cf. Iadanza et al. 2019.

[5] Cf. Maietti et al. 2018.

[6] Cf. Balzani, Maietti 2017.

[7] Cf. Di Giulio et al. 2017.

[8] Cf. Maietti et al. 2017.

[9] Cf. Balzani, Maietti 2015.

[10] Cf. Balzani 2016.

[11] Cf. Di Giulio et al. 2014.

[12] Cf. Dore, Murphy 2017.

[13] Cf. Tiano, Martins 2018.

[14] Cf. Bonsma et al. 2016.

[15] Cf. Iadanza et al. 2019.

[16] Cf. Brusaporci et al. 2018.

[17] Cf. Parisi et al. 2019.

[18] Declaration: Cooperation op. cit.

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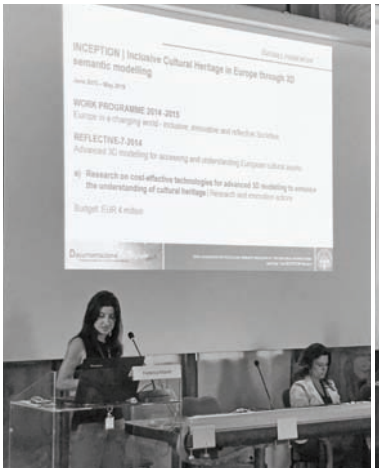
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Cultural Heritage is as rich as complex and its documentation is an increasing challenge. The digital solutions are numerous and their potential is a topic of constant investigation by the scientific community, that is requested to deliver digital strategies to make heritage permanently open and shared. The volume collects the contributions to the second conference of the 'Digital & Documentation' series, extending the debate to a multidisciplinary network of experts. It presents a frame of strategies for the documentation of Cultural Heritage in a wider perspective, stimulating reflections on: the relationships between physical and digital assets; the consistence of digital data and its management; digital representation as a mean to the transfer of cultural heritage. It comprehends theoretical studies and best practices on tangible and intangible heritage, taking into account applications for the research and the communications of Cultural Heritage as 3D representations, digital anastylosis, Augmented and Virtual Reality, Artificial Intelligence, semantics and databases. Aiming to give a comprehensive view on digital and documentation, the volume involves multiple perspectives from cultural institutions and universities, from experts in representation, geomatics, history, architecture, archaeology and ICTs for a multidisciplinary outcome.

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