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A BIM for the identity of historic urban landscapes. Integrated applications of survey for the Certosa di Bologna architectural heritage

Un BIM per l'identità dei paesaggi urbani storici. Applicazioni integrate di rilievo per il patrimonio architettonico della Certosa di Bologna

The research proposes a methodological advancement of 3D modeling techniques in relation to an integrated process of architectural survey and representation. The BIM proposal develops representation models and augmented fruition of the site and their tangible and intangible meanings for the valorization of diffuse heritage. At the monumental complex of the Certosa di Bologna, the original headquarters of the Carthusian monastery built in 1334 and suppressed in 1796 by Napoleon, the study is developing a BIM application for the architectural and artistic heritage. The integrated survey methodologies are dedicated to the modeling of architectural components from active sensors data sets. The project aims, on the one hand, to introduce an almost unknown historical and artistic heritage, through multimedia visualization, and on the other, to set up an information tool for the restoration, maintenance and valorization.

La ricerca propone un avanzamento metodologico delle tecniche di modellazione 3D in relazione ad un processo integrato di rilievo. La proposta di BIM sviluppa modelli di rappresentazione e fruizione dei luoghi e dei loro significati materiali ed immateriali per la valorizzazione del patrimonio diffuso. Presso il complesso monumentale della Certosa di Bologna, originaria sede del convento certosino edificato a partire dal 1334 e soppresso nel 1796 da Napoleone, è in corso di sviluppo una applicazione BIM per i beni architettonici e artistici. Le metodologie di rilevamento integrato sono dedicate alla modellazione delle componenti architettoniche a partire da data sets provenienti da sensori attivi. Il progetto ha l'obiettivo, da un lato, di far conoscere un patrimonio storico-artistico pressoché sconosciuto, attraverso visualizzazioni multimediali, e dall'altro di impostare uno strumento informativo per il restauro, la manutenzione e la valorizzazione.

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Keywords: Heritage BIM, Historic Urban Landscape, Survey systems, 3D modelling, Certosa di Bologna

Parole Chiave: *Heritage BIM, Paesaggi Urbani Storici, Sistemi di rilievo, Modelli 3D, Certosa di Bologna*

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INTRODUCTION

The methodological advancement of 3D modeling techniques intended as a simple visualization and subsequent graphic transcription on the orthogonal planes of the built environment, today poses new ways for knowledge and management of historic urban landscapes and diffuse heritage, as cited by the recent UNESCO document *Recommendations on the Historic Urban Landscapes* (UNESCO, 2011); the "historic urban landscape" is defined as a portion of the urban pattern as result of a historic layering of values and cultural and natural attributes, by extending the concept of "historic center" to include the urban environment in its broadest sense, its geographical position and environmental features.
The historic urban landscapes are recognized as a shared cultural heritage, material expression of the local culture, but also systems which, through their image and identity, need specific strategies for their documentation and use. Unesco document states that: "Knowledge and planning tools should help protect the integrity and authenticity of the urban heritage attributes. ... These tools should include documentation and mapping of cultural and natural features of landscape". In addition, the recommendations call for the integrated use of both traditional and innovative instruments, always adapted to the local context and needs analysis. These tools have the task of facilitating intercultural dialogue from local intelligence and must represent the stories, traditions, values, needs and aspirations of communities. In this regard, UNESCO refers explicitly to the knowledge and planning tools that need to protect the integrity and authenticity of the characteristics of cultural landscapes.
In the essay it is described an applied research on knowledge and diffused heritage valorization based on survey integrated methodologies, representation and fruition of places and their tangible and intangible values. The investigation is developing a BIM application for the monumental complex of the Certosa di Bologna, original settlement of the Carthusian monastery then dismissed as a result of the Napoleonic campaigns: the analysis methodologies of the architectural lexicon and the classification of typological elements (places of worship, cloisters, common areas, burial fields) are introducing an almost unknown historical and artistic heritage and also to develop an information tool to aid the restoration, maintenance and valorization design.
In the visual transcription process, based on the use of digital tools, drawing moves away from its traditional vocation that is linked to the expression graphics and direct consciousness of the sign; the package content goes beyond the graphic the field also incorporating algorithms and graphics libraries of objects, defined through categories and parametric data. In the digital drawing the model becomes multi-scalar namely contains all possible views and can be represented in a single view.
The introduction of semantic digital models binds even more drawing to representation of construction types, testing it first in the virtual environment and allowing operator to make the necessary technical evaluations; in this way digital drawing combines the experimental synthesis from imagination process up to the formation of images.
Model since the Renaissance is the crux of any design process for the construction; technologies to make it happen and ideas to improve the perceptual rendering not only support its fruition but make it more easily settled in the form of prototype simulating effectively its characters.
Filippo Brunelleschi did make masonry models (finite element model) to make static control anticipating in fact the structural experiments of the eighteenth century; He built them even without the detailed elements to enhance the work's formal definition and then implementing a primordial 3D drafting (rapid prototyping). In addition, the model built for the extraordinary construction site of Santa Maria del Fiore constituted an element of standardization and unification of the construction activities, combining the needs of architect, contractor and builders (information model).
Antonio da Sangallo the Younger devoted seven years to build an expensive but very refined model which measured about 50 square meters with a height of 5 meters; the interiors were treated to increase the texture reality (photorealistic rendering), providing for adjustments to improve the perception and use (navigation walk through), creating colored paper layers similar to the modern digital textures (texture mapping) and finally enriching interiors with three-dimensional figures made of wax (cutouts).
Michelangelo ordered the construction of several models of wood and clay for the dome of St. Peter's Basilica in fact materializing his ideas and leaving them as a testament to continue and complete the building after his death (BIM model and management of the project life cycle); the Michelangelo models gave an overall view but also refer to construction details, constructed in scale to obtain a symbolic representation but also realized in real-scale; that way he created an "immersive environment" in analogy to the navigation procedures that today virtual reality techniques allow (multi-scale models and virtual navigation).
The need to anticipate the cutting operation of the stone and to forecast geometric codified procedures to design structural elements in cut stone led to the birth of stereotomy by Philibert de l'Orme who proposed a stereotomic system based on "*traits*": a series of parallel sections as he did in the masterful example of *trompe* in Anet castle.
This technique included the need to determine in advance the conformation of the individual building blocks and the possibility to verify in this way the stability in relations to key sections of the artifact as well as today it is applied to structural and architectural modules that make up the building organisms.
The virtual reconstruction of stereotomic models constitutes today a front of very advanced and progressive research being able to integrate different digital technologies for representation, visual computing and prototyping.
The parametric modeling systems allow to modify the digital model in a similar way to the actual building themselves becoming prefabrication methods. Therefore, the representation of the model coincides with the model itself and is limited or defined only by working interfaces and visualization and often tends to be confused with the built object.
The stereotomic method introduced by Philibert de l'Orme, in particular according to his *trait* method, supports the research on the generation of models and on the use of parametric design systems that provide the geometric description (with graphic primitives) and also build relationships and geometric and functional coherences. A *trait geometrique* includes the overall model of the object and also effectively allows to describe it with multiple sections and even to build directly the physical model, despite how complex its implementation or its representation.

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INFORMATIVE SURVEY METHODOLOGY FOR INTEGRATED BIM HERITAGE

The process of analysis and mapping of diffuse heritage is a cognitive-oriented action of its fruition (and possible changes), and also includes the emotional and perceptual dimension of senses involvement aimed at the representation of space through visual thinking and production of materials graphics.
This concept is associated with the increasing use of digital images in architectural survey 3D modeling which has favored the production of perceptual products validating processes and then producing technical representations.
The mapping process consists in the sequential formation of "images", that are born before as mental concepts that are then processed as graphics transcripts in relation to a more or less sophisticated code. The images "build" a form, give a level of iconicity, reproduce themselves by means of their geometrical structure, typological, artistic and highlight the structural and functional relationships between the components; perform the main purpose, according to the neuro cognitive sciences, that it is to identify and classify objects.
As reminds us Marco Gaiani, we are experiencing a new era in the field of computing date because today "the development of digital technologies such as real-time rendering (RTR) of 3D models and Web 3.0 (such as the semantic web, and 3D geospatial) have opened up new scenarios of reading and interpretation of historical architecture, the introduction of new broadcasting methods and information not only about the textual research, but also based on geo-spatial navigation methods and space-time "(Gaiani, 2015).
The most advanced research in the field is referring to tools and processes that are changing the understanding of the architectural heritage, as well documented in the *Handbook of Research on Emerging Digital Tools for Architectural Surveying, Modeling, and Representation* edited by Stefano Brusaporci (Brusaporci, 2015). Recent applications related to representation are creating rapidly new fields of study such as visual computing, digital documentation of cultural heritage and diffuse fruition of cultural heritage through interactive tools (Handbook of Research on Visual Computing and Emerging Geometrical Design Tools, Giuseppe Amoruso, 2016). The application of the information surveying allows new data fruition following logical alternatives: (i) the definition of a continuous system through an interpolation algorithm that simulates an immersive observation; (ii) the description using similar fixed scenes to shots; (iii) the thematic representation in line with the overall description of objects that is separated from the concept of identical reality.
In addition, the digital representation has allowed to extend the drawing concept, containing within itself all the three-dimensional constructions and visualizations (3D models) but also the potential of hypertexts and interactivity.
For this purpose were used modeling softwares, image or range based, integrated with segmentation tools and semantic modeling, BIM environments oriented to the definition of a 3D object database, geo-referenced and logically related to the cost-effective management of the cognitive process.
The project integrates various detection techniques directed to an innovative approach, technologically advanced and cost-effective, 3D modeling, semantic representation, management, conservation and protection of monuments and urban systems.
Data from the various sensors and platforms and at different temporal geometric and radiometric resolutions, have been appropriately integrated to allow the generation of parametric libraries of 3D representation of the key architectural elements and develop a cognitive system type Heritage Building Information Modeling (Dore & Murphy, 2012).
The goal is to create multi-scale 3D models that will later be detailed, segmented and semantically enriched so that they can represent the overall historic urban landscape values. They are also used for the interpretation, analysis and visualization generating creative applications for the dissemination of cultural contents and understanding of the transformations that the site has undergone.
Their transfer on user-friendly platforms or image-

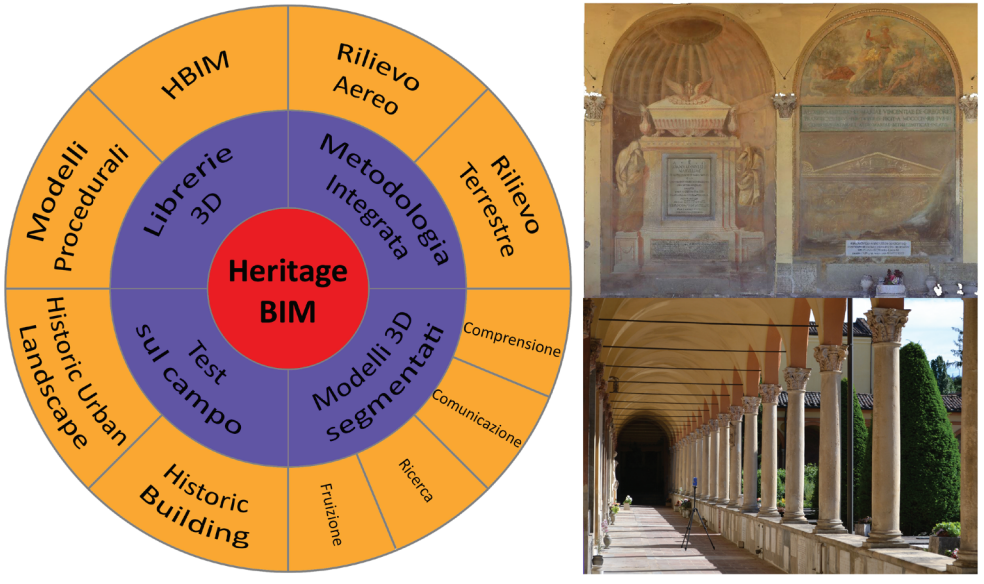

Figure 1 Research programme overall layout and applications to the urban and monumental systems of the Comune di Bologna.

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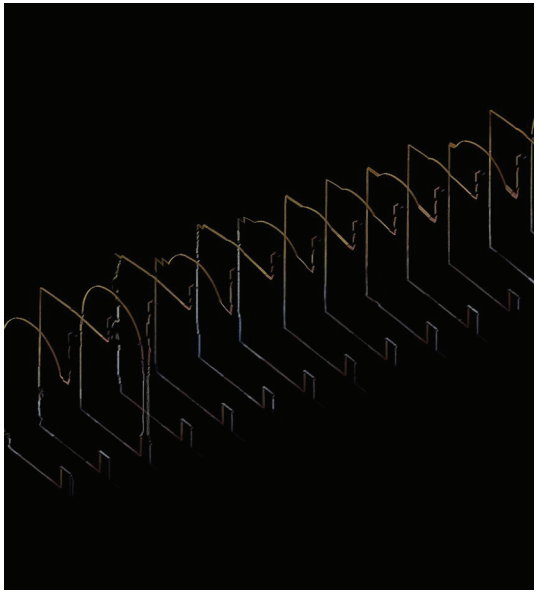
Figure 2 Semantic segmentation of the architectural path in the cloister III of the Certosa di Bologna.

Figure 3 Semi-automatic output of vertical sections of the architectural path in the cloister III of the Certosa di Bologna.



based ones expands the scope of this process by supporting the dissemination of heritage knowledge. The Heritage BIM is a specific solution in which the interactive parametric objects, which represent architectural elements, are constructed from historical information and 3D data collected in the field; therefore, if properly developed gives the possibility of creating 3D libraries that describe the architectural lexicon and the specific geometric shapes.
These segmented models differ from simple 3D visualization products because they represent different levels of accuracy and detail.
The research project is being validated through the collection of datasets at the Certosa di Bologna processing the integration of 3D data from laser scanner with the subsequent interpretation and segmentation of clusters and also sharing with the expeditious display

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systems. The methodology of surveying and modeling has been based on street-level acquisitions for 3D digitization of spaces and historical artefacts.
The survey can also be integrated with data from RPAS (Remotely Piloted Aircraft Systems) integrating the advantages and flexibility of aerial acquisition with the use of various sensors (imaging, LiDAR, thermal, etc.).
The elaboration of 3D points dense clouds from active sensors and algorithms of Structure-from-Motion is represented by discrete and continuous models as the mesh polygonal surfaces.
The methodological progress is based on different acquisition modes integrating sensors (active and passive) most suitable in relation to the scale of the artifacts and the required accuracy related to details of the construction elements.
The choice is also influenced by the type of graphic products to be obtained through the survey and if the geometric quality rather than the visual and formal one has priority.
To frame the adequate information environment the architectural 3D libraries for major architectural elements have to be defined; these libraries, if they concern diffuse heritage, must be generated with the Generative Systems Modeling Language (GML) and in combination with the 3D architectural survey.
The challenge is to identify a limited set of parametric building elements that can ensure both the generality that the versatility. As regards the BIM solutions can be introduced procedural forms to produce BIM-like 3D models of historic buildings (HBIM).
The result will be a set of 3D models to be integrated into the main commercial BIM software solutions: these models, segmented and detailed semantically describe the architectural components and will be used for visualization, generation of creative contents and restoration purposes.
Another specific goal and result of the research, answering to a specific request from the institutions that deal with municipal estate, it is to involve both technical and non-technical users (eg architects, restorers, conservators, archaeologists, public administrators, etc.) being able to share 3D product, multimedia visualization and also creating tactile prototypes.
The operating methodology allows in a short time to perform panoramic visual montages of images collected by sensors (for example, 85 images for each

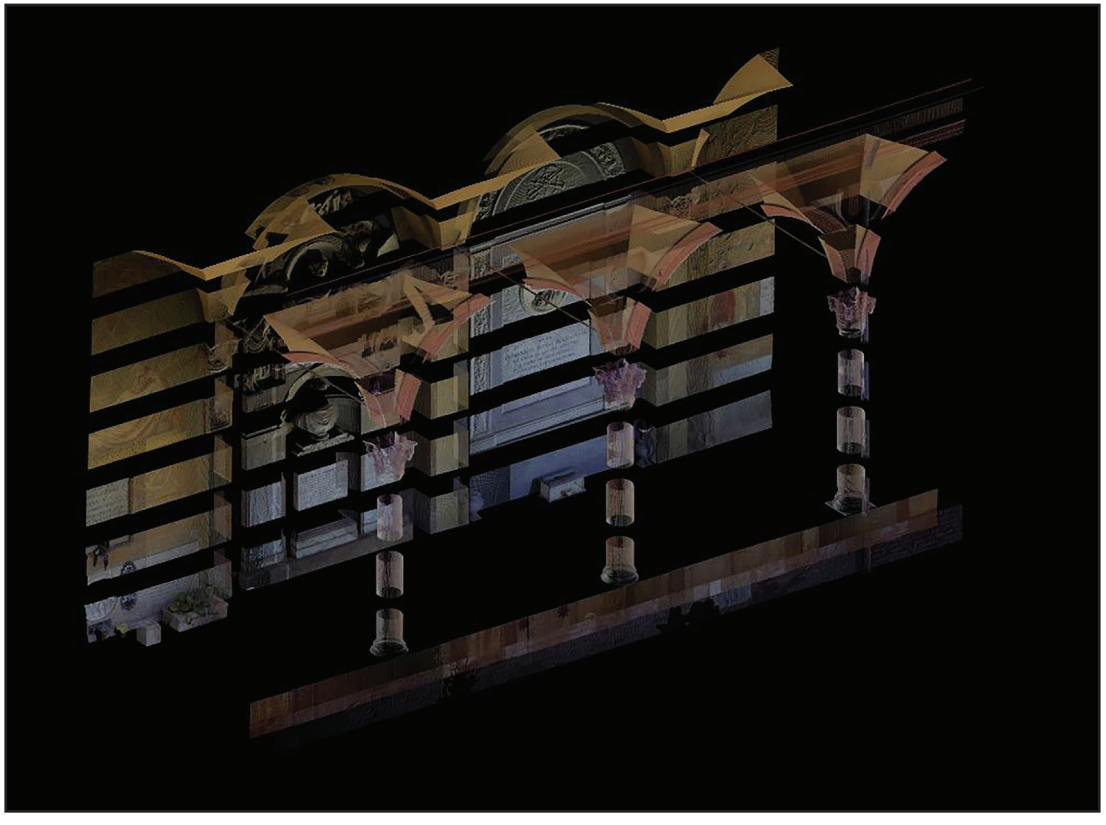

Figure 4 Horizontal sections output of the portico in the cloister III of the Certosa di Bologna.

scanning session with the Faro Focus 3D scanner) producing a series of virtual tours to make them also available on the web or mobile devices.
Another field application under development concerns augmented reality applications and immersive visualization with low cost devices.
Knowledge transfer at different levels is the most important goal both in the technical framework than in the cultural information one.
During the validation and demonstration of multimedia products, users will learn to create and exploit the 3D models for management, maintenance, conservation, understanding and communication of historical heritage.
A further objective will be the promotion of field workshops for the massive data collection and architectural surveys, the proposition of tutorials and operational guidelines, and the promotion of new entrepreneurship related to the fruition of heritage and digital technologies.
The identity of places and their value is the result of a not always positive stratification of signs and traces which, in line with the technological systems of the different periods of intervention, require the use of in-

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Figure 5 Polygonal mesh model of the portico, segmented arcade (left) and typological segmented architectural model (right).

NOTES

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Scientific Direction and research methodology: Giuseppe Amoruso.
Field survey and laser scanning: Piero Lusuardi, Andrea Manti
Representation, data processing, editing: Andrea Manti, Giuseppe Amoruso

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tegrated scientific analysis and of new representation devices and management and fruition of data from the survey.
The research in the area of representation must identify the appropriate methodologies in order to transfer the tangible values but also intangible ones and their meanings; it is important to no longer mono-functionally working on the drafting of technical papers but rather by acting as catalysts for knowledge in all forms that multimedia tools now allow.

Figure 6 Axonometric view of the overall 3d point cloud of the cloister III of the Certosa di Bologna.

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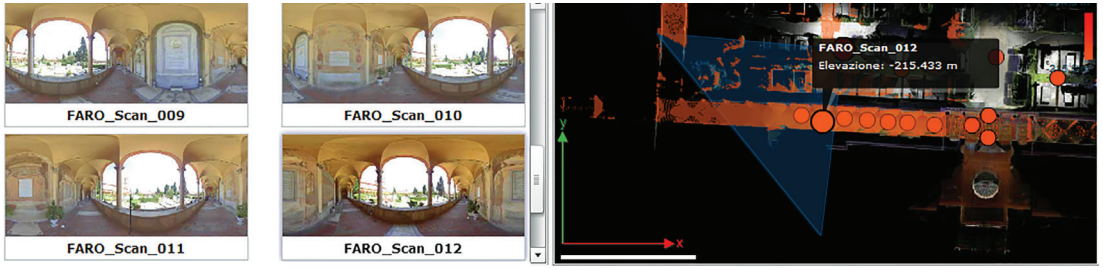

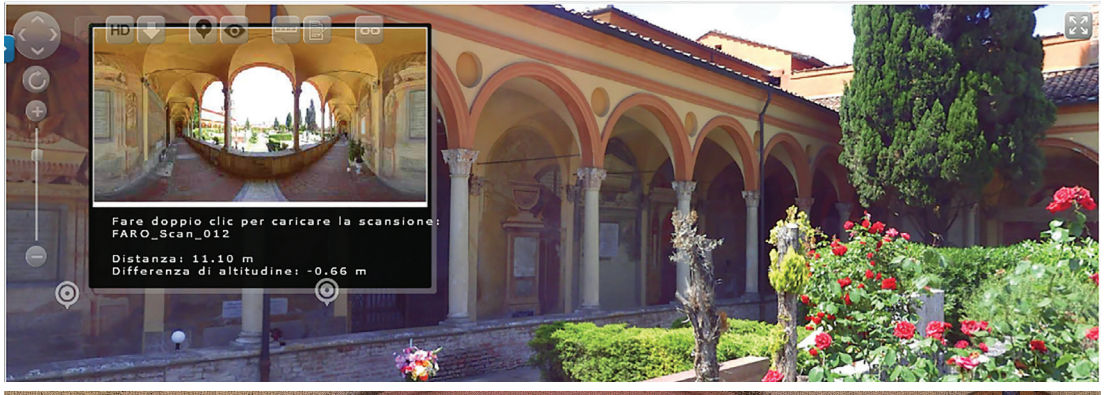

Figure 7 Information data sharing platform from active sensors architectural survey and interactive photographic navigation.

Figure 8 Integration of datasets from active sensor (range-based processing) with dense clouds and textures from Structure-from -Motion algorithms (image-based processing).

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