ShoCK!

Sharing of Computable Knowledge!

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Contents

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The proceedings took into account the most advanced research in Computer Aided Architectural Design: Internet of Things, pervasive nets, Knowledge 'on tap', Big Data, Wearable devices and the 'Third wave' of AI… These disruptive technologies are upsetting a globalised world as far as it can be predicted henceforth.

So, academicians, professionals, researchers, students, innovation factories, … were warmly invited to further shake up and boost our innovative and beloved CAAD world. Obviously, computation is needed to match the ever-growing performance requirements but, at the same time, we have to deal with the essence of the problems: improve design solutions for a better life!

As life is not a matter of single individuals, we need to increase collaboration and to improve knowledge sharing. This means going back to focusing on human beings, and it involves the humanistic approach, and the long history of architecture…from handicrafts to thinking to technology... to handicrafts. A large spiral of the *architectura* as *eternal* as our city.

eCAADe 2017 has been hosted by the Department of Civil, Building and Environmental Engineering supported by DaaDgroup at the Faculty of Civil and Industrial Engineering founded in 1817, just two hundred years ago.

eCAADe - Education and Research in Computer Aided Architectural Design in Europe - is a non-profit making association of institutions and individuals with a common interest in promoting good practice and sharing information in relation to the use of computers in research and education in architecture and related professions. eCAADe was founded in 1983.

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From TSL survey to HBIM, issues on survey and information modeling implementation for the built heritage

The case study of the Temple di Bacco Ravello

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The research presents an application of HBIM to the recovery process and design, which allows to highlight some potentialities and criticalities of what has become an important instrument in the documentation and conservation of architectural heritage. The object of the research is the Temple di Bacco, built by Lord Girmthorpe as his final resting place and located within the gardens of Villa Cimbrone, Ravello (SA).The survey has presented several difficulties due to the particular configuration of the site, very steep, with very limited space around the object. If on the one hand the TLS obvious to the lack of edges of cylindrical objects, on the other hand it poses problems for the tangency of the scan points. The Scan to BIM methodology has proven to be effective and has allowed to overcome the difficulties associated with the conformation of the artefact and of the site, in the study of the analyzed object. In conclusion, some assessments and results are reported, aimed at sharing and defining strategies and methodologies of scientific validity regarding the application of the HBIM model to a process of recovery and consolidation of an existing building object.

Keywords: *BIM, HBIM, Built Heritage, TLS, Scan to BIM*

INTRODUCTION

The digital storage technologies, analysis and management of information have found in the three-dimensional models the substrate on which to develop their potential (Centofanti et al., 2016) and HBIM (Heritage Building Information Modeling) is now an important tool in the documentation and conservation of architectural heritage (Murphy 2009, Chiarabrando, 2016). The evolution of the BIM process, applied to the built heritage, has brought with it a wide spectrum of issues ranging from the development of the selection and reception capacity of the large data sets provided by the digital surveys, to be based on model building, to the reation of family libraries of objects for the existing (based, for example, on historical manuals) (Murphy 2011, Logothesis et al 2015), to the inculsion of information in the parametric model related to the characteristics of an already built object (such as materials, age of construction, state of conservation, state of progress of degradation) (Apollonio, Gaiani & Zheng, 2012). The research presented is placed in this field of investigation and was divided into several phases: historical and documentary study; a first campaign for the planning and the scheduling of direct and instrumental survey; an integrated survey campaign (TLS, direct surveys, other instrumental surveys); a non-destructive testing campaign for the mechanical characterization of materials and finally the implementation of the BIM model for the project of recovery and consolidation. The object of the research is the Temple di Bacco, built by Lord Girmthorpe as his final resting place and located within the gardens of Villa Cimbrone, Ravello (SA) - Italy (Fig.1).

STATE OF ART
AD BIM, AS BIM, HBIM

The basic difference in the use of BIM between new design and recovery of the existing buildings is well synthesized by Pătrăucean et al. 2015, which define the two categories of AD BIM (as-designed BIM) and AB BIM (as-built BIM): while the creation of an AD BIM (ie BIMs generated in the design of a building) is a simple process that becomes increasingly common, the generation of an AB BIM (ie BIM models that reflect a structure in its conditions at a given historical moment) is a challenge, but also a process required for building constructions not originally equipped with a BIM project, in which as-built conditions differ from those initially designed. The affinities between AB BIM and HBIM are therefore evident and numerous.Creating an AB BIM requires two main steps: collecting data and capturing current conditions in the first place, and then modeling the acquired data. The field of 3D reconstruction, related to laser scanning techniques, has filled the technological gap between the capabilities of AD BIM and AB BIM, which also includes the specificity of HBIM, providing tools for generating three-

Figure 1
Location of the Temple of Bacco, inside Villa Cimbrone, Ravello (SA).

dimensional models compliant with existing condition of buildings (Pătrăucean et al. 2015). While on the one hand, BIM helps coordinate the various figures of the building process by introducing its expertise in models (distinct in architectural, structural and plant engineering) to plan their construction and to calculate the quantities for the construction site, on the other hand instead, the specificity of HBIM focuses on the importance of defining the state of conservation of sites and materials to better plan conscious recovery interventions (Garagnani 2015).

Scan to BIM

The innovative feature of the process chain attributes a central role to the Scan to BIM methodology (Catugno et al., 2016): namely the integration of survey data using methods that include the use of terrestrial laser scanner (TLS) and digital photogrammetry in an exportable model in a BIM software. These elements are becoming a standard in the construction practice in heritage conservation and management of structures within a wide range of different sectors (Laing et al., 2015). The laser scanning technology (TLS) has thus emerged as a useful tool to document the existing condistions of the existing buildings, and one of the main applications concerns those belonging to cultural heritage (Shanbari et al. 2016). The use of TLS allows the development of point cloud models built in one stage of the life cycle of a building, with great precision and speed. The mass of potentially acquirable data with the laser scanner technology is such as to make complex the editing, making it necessary for this a selection of the elements of the point cloud, which presents itself as uncritical, targeted to the purposes defined a priori. In addition to laser scanning, there are emerging technologies that aim to integrate, and in some cases replace, laser scanning techniques with TLS. The techniques most widely used today include the use of photogrammetry (Shanbari et al. 2016), through the detection of 3D measurements from 2D images. Through the combination of thousands of these measures it is possible to generate a 3D model and constitute a standard output of photogrammetry operations. In recent years, many companies have developed methods and software that convert 2D images to 3D point clouds or mesh models. Golparvar-Fard et al. (2012), for example, used daily state-of-the-art construction photos as part of an automated monitoring system, demonstrating the ability to use site images to develop an as-built model that can then be implemented in the BIM process. Obviously, this particular technique does not have a direct impact on the HBIM scope, but it may have some interesting implications, alongside a first complete survey with LTS, a sequence of images, shot at defined time intervals, for monitoring the building. However, the models and point clouds developed by using traditional photogrammetric methods are linked to the available image quality and can not match the pinpoint accuracy of the 3D scanning. Barber et al. (2007), in their guide to laser scanning for archaeological and architectural applications, highlight how the process related to the use of TLS technology may be difficult due to occlusions and obstacles in scanning the product, which may limit available data if incorrectly addressed. Laser scanners can not obviously see through solid objects that can cause problems in sites with excessive amounts of mobile objects that block the planned capture areas or in places with elevations, obstacles and vegetation that prevent optimal display of the analyzed building, as in the case exposed here.

The next step to the relief is the processing of the digital BIM model. To date, current BIM software is still quite deficient in managing the dot data data mass. However, there are interesting research developments, such as the "GreenSpider" plugin, (Garagnani, 2013) that is able to make the points of the cloud imported in the BIM environment selectable, for modeling as faithful to reality. Other interesting tools are those related to the automated recognition of building elements (Pătrăucean et al. 2015), for their conversion into parametric families. However, this application still has many difficulties, especially when the object under analysis is part of the cultural heritage or has complex and non-regular geometries that require a thorough and punctual study, especially from a constructive point of view.

THE CASE STUDY: THE TEMPLE OF BACCO

The case study, Temple of Bacco temple in Villa Cimbrone, Ravello, has allowed to explore some methodological elements related to the identification of speditive and effective ways for the processing of point clouds and consequently for the construction of a parametric model in BIM environment, to associate with more information concerning the object of study. The Villa is located in Ravello on a rocky promontory that had already hosted a Roman villa in antiquity. In 1904 Ernest William Beckett, 2nd Lord Grimthorpe, bought the western side of the villa from the Amici family, the last owners. The wealthy banker came to Ravello to fight the depression following the disappearance of his wife Lucy Lee, just 28 years old. When arrived in Ravello, he recovered and completely devoted himself to the creation of the Villa, where he introduced innumerable and valuable decorative elements such as fountains, nymphs, temples, pavilions, stone and bronze statues into a clear reinterpretation of the "Roman villa": the cypress avenue little Temple, the Coffee House, the Mercury Palace and the Temple of Bacco. In particular, the Temple was built as part of the collaboration with Nicola Mansi, an eclectic citizen of Ravello known in England, who was able to give image and shape to the demands of Lord Grimthorpe, and its reading fully revealed the use of local workers (Fig. 2).

The circular temple is characterized by a dome covered in tiles, supported by eight columns in a rude Composite style. The survey campaign has presented several difficulties due to the configuration of the site, very steep, with very limited space around the object, and due the elements conforma-

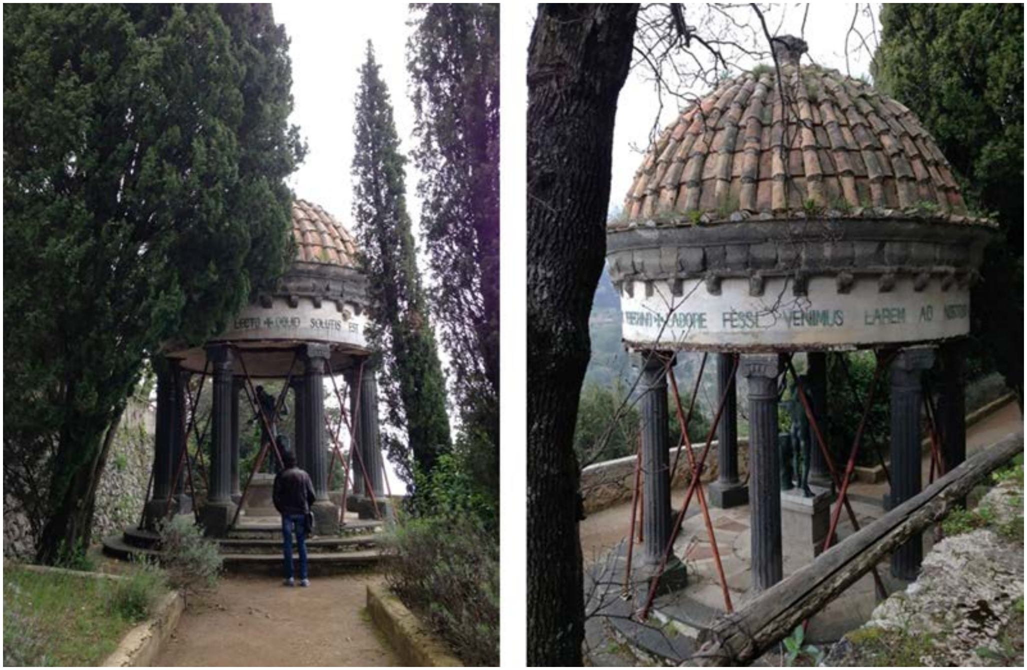

Figure 2
The Temple of Bacco. Two photographs: one from the path to reach the temple and one from the upper terrace.

tion, all with circular section, whereby with obvious difficulty in highlighting significant points for surveying. In order to obtain an executive survey of the geometry and constructive characteristics of the temple we proceeded with the integrated digital survey methodology (Paris, 2015). The generated 3D model was derived from a TLS scan sequence. In detail, the scan survey have been associated with direct measurements on the individual constructive elements and ornamentation, and non-destructive testing campaigns (NDT) for the determination of materials and construction equipment in order to associate the material data to the model. The survey through TLS has solved some critical issues in data acquisition: Has allowed to easily access distant parts of the architectural object, to define precisely the points of surfaces that are not geometrically attributable to exact constructions, given the circular object of the object and the all circular section elements.3D laser scanning was performed with a Faro Focus3D X 330 tool, with 7 shooting points to generate an overall cloud of points. The cloud was subsequently decimated with Faro SCENE software (Fig. 3), eliminating inaccuracies and "noise" of the survey, then imported into RECAP software for the management of the cloud itself and for the interoperability with Autodesk REVIT, within the BIM model was created.

The parametric model of the surveyed artifact was achieved by keeping the pointcloud and the photogrammetric data as a sort of 'scaffold' for BIM objects. The Scan to BIM procedure, implemented in the Revit environment, allowed the identification of the point cloud surfaces coinciding with the components of the temple and refine the location of the same, by transposing and properly representing the out of plumb of the columns, the inclinations and the translations of the drum and the dome. The dome is particularly interesting from the construction point of view, internally with an umbrella vault according to consolidated Amalfitans models, it has also been one of the elements more difficult to implement within HBIM model, both for its complex geometry that for correspondence with the point cloud.In the construction of the model we opted for the gen-

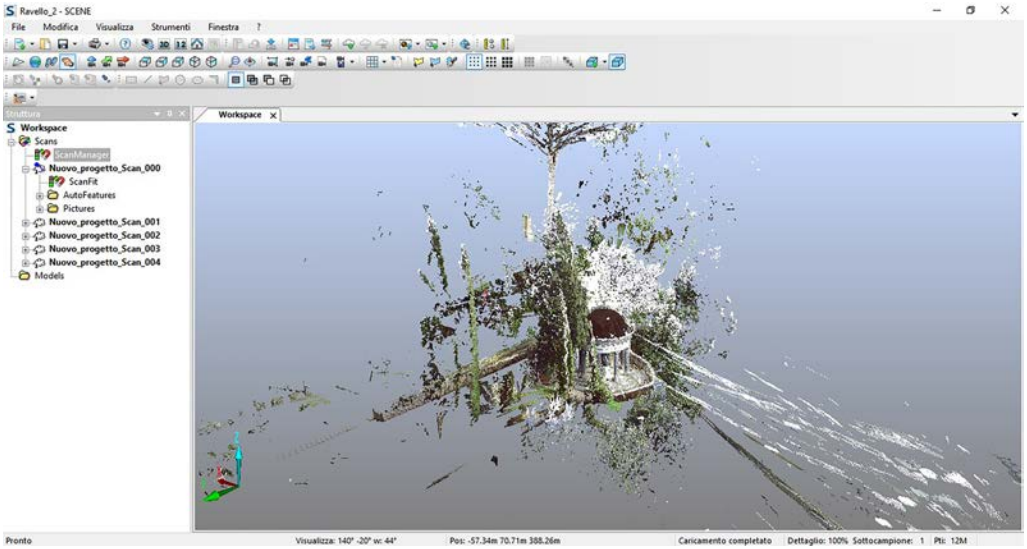

Figure 3
Point cloud processing resulting from the survey with Faro Focus3D X330 TLS, within the FARO Scene software.

Figure 4
Views of the BIM model: Correspondence between the model and the point cloud, Axonometric split and Elevation views of a column

eration of parametric objects and families consisting of masses, rather than a mere detailed reconstruction of the ornamental apparatus of columns and capitals with the consolidated technique of transposition of the point cloud to polygonal meshes. This choice has been determined by the will to achieve an effective BIM model and by the need to interface with the structural calculation softwares in the next steps of the research. The textural properties, weight and substance of the modeled objects were therefore absolutely important in the implementation of the model (Oreni et al., 2014). The strong interdisciplinary nature of the presented research, developed between the Architecture and building design, the Structural Engineering, the Representation and Survey and the History of Architecture, has found an equally decisive response in an integrated approach such as the HBIM one. In particular, the model made for the construction and architectural analysis has reached a Level of Detail equal to the LOD 300, then simplified to the LOD 200 for interoperability with the structural calculation software, removing and simplifying part of the ornaments of the analysed object (Fig. 4).

RESULTS AND CONCLUSIONS

The application on the present case study allows to highlight, alongside the achieved results, some critical features regarding the application of HBIM in the process of recovering an existing building object:

- Geometric survey and degradation
- Widespread error and concentrated error
- Grey areas
- Edge Effects: tangent points on curved surfaces

Figure 5
Photo of the extisting conditions of the constructive elements of the Temple where the states deformation and the existing cracking pattern are visible.

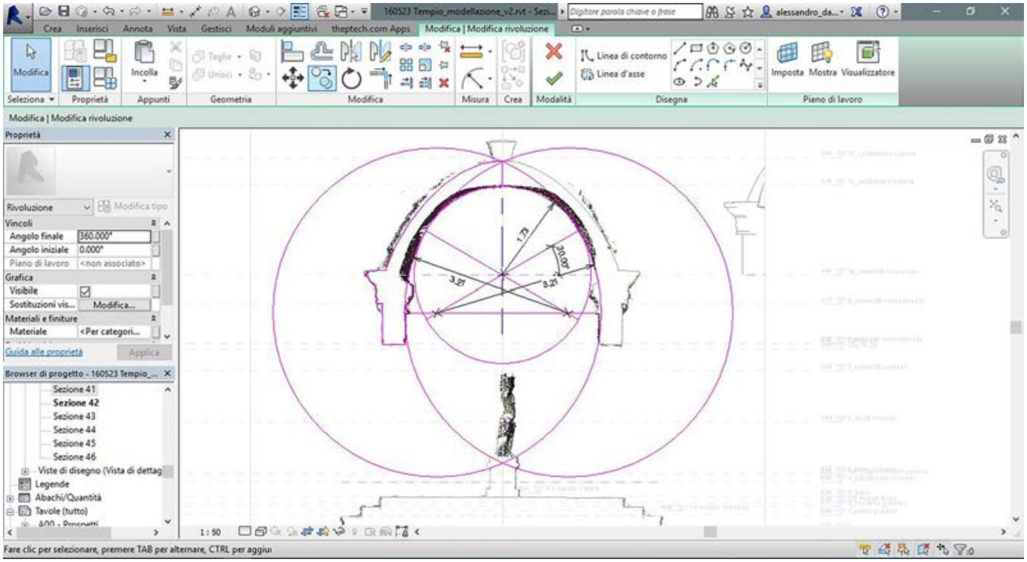

Figure 6
Geometrical construction of the umbrella vault inside the dome

Geometric survey and degradation

The survey performed has allowed to characterize all the component parts of the temple from the geometrical point of view, including the deformation states (Fig. 5). Therefore, it was possible to metrically quantify the drum translational evidenced by the inclination of the columns with respect to the vertical axis and locate the planes within such inclinations occurred and the angles of the slope of each column. In addition, the model embodies the cracking pattern affecting all the columns of the Temple of Bacco, generally at the base and at the top, confirming ist size and documenting its status for monitoring as long as the consolidation intervention is expected. These cracking phenomena have already been partially consolidated by the insertion of summit metal hoops of some columns, but these interventions, made of ductile iron, have not interrupted the manifestation of new lesions and the advancement of existing ones, as they continued the collapse towards the valley.

Widespread error and concentrated error

The technology of the laser scanner, which has allowed to define metrically with great precision the inclinations of the axes of the columns as a result of their rotation in the plane, it creates from another point of view known issues of accuracy: the cloud is a-critical and intercepts a density of points in a given desired surface without being able to operate the identification of significant intersections between the planes. In the unmanaged cloud there is a lack of significant points of definition for the main shapes of the architectural draw of the object. The probability that a point falls on a significant edge is low and it is therefore necessary to intervene with the well-known integrative actions represented generally by the association of raster images. In addition, as already mentioned above, it does not provide any details on a thorough construction study (Bonora and Sparò, 2004). This was precisely the case of the Temple dome which required a detailed study of the geometry and the constructive technique of the internal umbrella vault to be properly molded (Fig. 6).

Grey areas and Edge Effects: tangent points on curved surfaces

Finally, the case study analyzed has made it possible to deal with the problem of the effect called "mixed pixels", mainly related to the resolution and the spot size of the TLS used, as well as the occlusions present during the detection (Hebert and Krotkov, 1991), and with the results of scans on curved surfaces.It is useful to remember that the points detected with each scan are equidistant with respect to a spherical surface concentric to the instrument. It is therefore obvious that by scanning objects at different distances and covering each other, there is a lack of gaps (Fig. 7), namely the absence of measured data, which determine, with respect to the instrumental center, the "grey areas". As the object of study consisted of circular section elements, there were numerous grey areas present in the scans carried out and the point cloud was especially affected by this criticality. This is combined with the "mixed pixels" effect obtained in the detection of the elements, which led to a particularly dense cloud of "noises" around the constructive elements. An automatic recognition of surfaces (Tang et al., 2010), also by means of modeling plugin, is found to be totally ineffective, and so it was of paramount importance the critical evaluation processed by the operator assigned to the survey, processing and modeling.

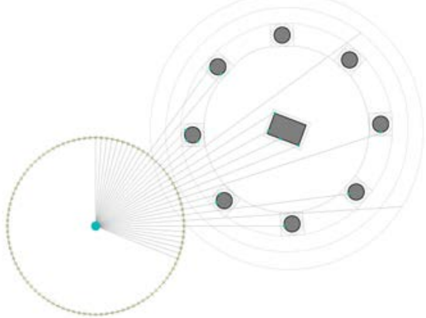

Figure 7
Scheme of grey areas problem and tangent points on circular surfaces during laser scanner survey

The problem associated with grey areas was partially solved by the number of scans carried out at different points, despite the small size of the object being analyzed: 7 scans, of which 5 are at temple level and 2 are from upper terraces. The mixed pixel phenomenon, however, was solved by critical analysis.

In conclusion, the applicative process of transition from cloud point to HBIM model, in support of research, has allowed us to verify the effectiveness of a workflow useful to the analisys of the built cultural heritage, optimizing the design process, improving data management, effectively supporting decisions and increasing the accuracy of the recovery and consolidation design.However, it should be noted that the existing modeling process is limited by several objective factors and therefore it is difficult to think of obtaining an AB BIM that reaches the same level of maximum detail of an AD BIM. This is because the AD BIMs contain semantic information about the designer's thorough knowledge of the product, but can not be deduced from a digital model, such as some specific technical details, costs or times of realization (Simeone et al., 2014). The level of detail gained by an AB BIM is therefore limited by practical aspects of data collection. Although presumably the technology used for data collection can capture particularly meticulous details, the added value of modeling these small elements does not justify the time and cost of gathering and modeling meticulously the data.Taking into account these limits, we must define the desired output of the integrated modeling process as a functioning BIM model, which will reasonably represent a smaller version of the complete BIM, but that can appropriately encode the constructive elements and the visible spatial elements with their relationships of nesting and connectivity, based on the a priori defined objectives and goals.

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