NEW METHODOLOGIES FOR CULTURAL HERITAGE ENHANCEMENT: THE CASE STUDY OF AUTERI CHAPEL IN CATANIA FROM SURVEYING TO IMAGE BASED MODELING

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Abstract

This article is the outcome of a research on survey digital techniques for acquiring knowledge, documentation and enhancement of the architectural heritage. Through this research, the current low-cost image-based modeling techniques have been tried and tested. The goal was to identify an operative methodological way for the transmission of the cultural heritage through metrically reliable 3D photographic models that can be used both in the contexts of fruition and in 3D virtual repository (3D Icons, Europeana). In particular, in this article, I report the results of research applied to the Auteri Chapel, a micro-architecture of 1871, located in the monumental cemetery of Catania. The proposed methodology takes advantage of analytical drawing and survey tools to understand and decode not only the geometric and formal aspects of the architectural building but also the symbolic and semantic ones (use of symbolic shapes, search for beauty, meaning of decoration) related to the specific connotation of these architectures of memory.

Keywords: Surveying, Image-based modeling, Funerary Architecture, Digital Cultural Heritage

1. INTRODUCTION

The research explores the use of digital techniques for understanding, documenting and enhancing historical architectural heritage. Today digital techniques provide a creative and innovative approach to Cultural Heritage (CH) enhancement starting from the 3D acquisition to the creation of engaging cognitive paths with 3D interactive contents [1, 2, 3]. Thus, it is necessary to retrace the entire knowledge process in order to identify an effective methodology able to document and communicate the architectural assets, focusing on optimization of time and costs.

One of the critical steps is the creation of the 3D model. Although digital acquisition and modeling of CH has become a common process, traditional survey and 3D modeling, image–based modeling and range-based modeling techniques are still tested and studied in relation to their time, costs and final outcomes [4, 5, 6, 7, 8].

In particular, Structure from Motion (SfM) techniques allow the realization of image-based 3D models in an automatic/semi-automatic way starting from simple sequences of uncalibrated photographs. These technologies, originally developed for touristic viewing and web navigation of cultural assets (Photosynt), archaeological and architectural sites [9, 10, 11, 12] have been implemented up to obtain effective tools for low cost digitization and visualization of real objects.

Presented here are the results from a very interesting field of application: the funerary chapels built between the end of XIX century and the beginning of XX century in the Cemetery of Catania. Indeed, the historical part of this Cemetery is a real "open air museum" that contains a great number of artistic and architectural works that are the remnants of local artists, designers and a culture of master builders [13,14].

For the purposes of this research, the Auteri Chapel built in 1871 by the architect Carmelo Sciuto Patti was chosen [15]. This paper is structured as follows: historical-iconographical research, geometric interpretation, surveying and graphical restitution (by means of traditional or technically advanced methods). As previously stated, this latter phase of surveying and restitution is very onerous as far as software packages, equipment and man/machine hours are concerned. The use of image-based modeling could totally substitute this entire third phase.

The research is oriented towards the exploration of the potentialities of image-based techniques for the creation of 3D textured models, testing a free tool – 123D Catch by Autodesk – based on SfM techniques in order to verify its reliability and use in such projects.

2. METHODOLOGY

The historical-iconographical approach is the first step in the knowledge process aimed at the documentation and enhancement of architectural heritage [16, 17]. Thus, it disregards from the intervention methodology that is going to be tested for the metric acquisition and the graphical restitution of the cultural assets. Therefore, the case study has been investigated in order to deeply comprehend its design and historical-geometric value as well as to verify and compare traditional surveying approach in relation to image-based modeling techniques in order to confirm their visual, geometric and metric reliability.

2.1 Brief Historical Overview and Iconography of the

Auteri Chapel in Catania

The Auteri Chapel, designed and built in 1871 by the architect Carmelo Sciuto Patti, is an emblematic example of neoclassical style in the cemetery of Catania. It is one of the first chapels constructed in the cemetery, even before it was inaugurated and opened to the public in 1886. In fact, the building events of the Cemetery of Catania span a time period from the day when the site became available to the start of the works and finally to the official opening year. In these years, several projects and architects come in succession: this is confirmed by the comparison between the design project (fig. 1) and a following map of 1897 (fig. 2).



Fig. 1-2: (on the left) the project of the Cemetery of Catania, (on the right) a map dated 1897.

The Auteri Chapel was built in an area that changed its function, thus remaining isolated among hypogeous graves and *aedicules*, in an area without threes and vegetation. The chapel is shaped like a little pseudo-peripteros temple with a circular plan and typical neoclassical features.

The base is made from lava stone and the top ends form a segmental dome, with high symbolic value, that lies on three circular podium, reminiscent of the Mediterranean *tholos*.

From a typological point of view, this chapel is a unique exemplar in the cemetery of Catania due to both its circular shape and the presence of an underground crypt in which there were the burials. This way, the area destined to burials is clearly distinguished from the one destined for relatives to pray. Most likely, the poor functionality of the circular shape caused the abandonment of this typology in favour of rectangular plan typologies that allowed the placement of a greater number of burials.

The Auteri Chapel is a cylinder with eight Doric columns (incorporated for 1/3 in the wall), that support the entablature. This one is composed of an architrave, a frieze with triglyphs and metopes, a cornice with mutules and guttae, a geison with lion head shaped gargoyles in axis with columns. Under the entablature there are some bas-relieves that visually tell the iconographic themes linked to memento mori theme: "the little angel with bones", "the little angel with hour-glass", skulls and crossed tibias, torches with a downward flame.



Fig. 3: The Auteri Chapel network of streets where it is located



Fig. 4: Bas-relief of "the little angel with bones".



Fig. 5: Bas-relief of "the little angel with hour-glass".

In this case, the neoclassical architecture combines the three vitruvian design principles - utilitas, firmitas and venustas - with another one vanitas.

The drawing design, held by the "Accademia di Scienze, Lettere e Belle Arti degli Zelanti e Dafnici" in Acireale, represents the plan and the principal elevation of the chapel (fig. 6). We can notice the fidelity between the project and the realized architecture, except for the decorative apparatus at the entrance that foresaw the realization of tripods and sleeping lions.



Fig. 6: The drawing design of the Auteri Chapel [15]

2.2 Direct Survey and Interpretative Analysis

The size of the chapel and its isolated and rising position in respect to its' surroundings, allow a direct approach to both planimetric and altimetric surveying by means of traditional methodologies. Furthermore, the radial symmetry of the elements that characterize it, simplifies the data acquisition strategy.

Figure 7 shows the trilateration survey of the chapel in the network of streets where it is located; figure 8 and 9 show the graphical restitutions in the plan, elevation and cross-section that document the geometrical features of this architecture.

Nevertheless, the passage from the traditional elaborates (plans, elevations and sections) to the 3D textured model - usable in virtual environments for the enhancement and dissemination of the architectural assets- can have benefits by the application of 3D acquisition methodologies such as image-based modeling. As discussed in section 2.3, by analyzing the outcomes, the wealth of this field of experimentation can be deduced.

However, it is necessary to highlight the ontological difference between the two 3D models obtained. The image-based model is a polygonal textured model that accurately and comprehensively describes the surfaces, the textures and the irregularities of the object, whereas the model obtained by traditional 3D modeling relies on the study of geometric profiles of the surfaces to get a mathematical description of the same (NURBS surfaces) and an abstract geometric model. This last one, while on the one hand can be considered approximate, on the other hand has a cognitive and semantic surplus in structuring and communicating the information [18, 19].

In fact, the construction of the geometric/mathematical model, requires the expert's attention and a deep study of the shapes and the language of historical architecture. Whilst, no preliminary knowledge on architectural language and history of architecture is required to carry out a 3D model using image-based modeling techniques [20,21,22].



Fig 7: Trilateration survey of the Auteri Chapel and its surroundings

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Fig 8: Principal elevation of the Auteri Chapel



Fig. 9 Cross-section and plan of the Auteri Chapel

Furthermore, in order to get a deeper understanding of this chapel, I investigated the symbolic contents hidden in the essence of the shapes that constitute the chapel (circle, octagon, dome) and in the mystique of numbers.

The research of the geometric shape in its confirmative and configurative values leads to the conducting of a process of figurative abstraction of the chapel; this allows the connection of the appearance of the final shape to its pure essence and the discovery of archetypal geometrical shapes and their assembly into the final built shape (fig. 10).



Fig. 10: Exploded Axonometric view of the Auteri Chapel where the archetypal geometrical shapes are highlighted

In this way, together with the symbolical decryption of the shape, from a geometrical-mathematical-semantic point of view, I will get the real value of the architectural asset, of the design idea and of its being a medium for conveying moral and Christian faith teachings.

On the plan the eight columns are placed along the vertices of an octagon (fig. 11). We can deduce this to be the squaring of the circle theme, that according to a symbolical interpretation, corresponds to the passage from the earthly to the divine dimension.



Fig. 11 Geometrical analysis of the plan which shows the underlying octagon

2.3 Image Based Modeling Techniques.

Once the traditional survey was finished, the low-cost imagebased modeling techniques that, as already said, are able to reconstruct a 3D model of an object from an annotated photographic images sequence were tested. The experiments carried out on the Auteri Chapel define an operative protocol that can be repeatable for other architectural assets with similar size or shape.

Several metrics and geometric and visual checks were implemented on the 3D model obtained in order to assess the actual applicability of the method and to deduce the guidelines that should be followed.

For this experiment, the web-based and, at present time, free software from *Autodesk*, *123D Catch* was used. It is one of the best software for capturing 3D sculptural or archeological objects.

Exploiting the photogrammetric approach and the algorithms of Computer Vision, *123D Catch* is able to automatically reconstruct internal parameters of the digital camera and the position in space of the homologous points from a number of correspondences between sequences of photographic images, if suitably taken.

The steps to follow are to: - Capture a photographic sequence of convergent photos of the object with an overlapping of about 70%; - Upload the photos to the Autodesk cloud (the user can decide whether to wait for the 3D reconstruction or receive an email notification when complete); - Improve the results by manual stitching of homologous points on triplets of images and submit the scene to the cloud again; - Export the 3D polygonal model thus obtained in OBJ format and use it in other 3D packages for editing, mesh cleaning and so on.

The number of the dataset photo collection depends on the scale of the object and on the image resolution.

There are two strong conditions to carry out a useful mesh: 1) use the same camera and the same focal length; 2) have a structured photos data set collection where each image captures the entire object. These latter two conditions are mandatory to have a regular geometric and metric mesh without any distortions [8].

The small size of the Chapel (4.20 m in width and 5.14 m in height) and the possibility of framing it in full and at close range, favour the design and realization of the surveying project. However, the presence of other funeral monuments, placed at close proximity to the building, has caused some problems in the surface reconstruction.

In fact, the circular geometry, which connotes the planimetric system, makes this chapel very interesting from a purely

geometrical point of view for the verification of the correctness of the reconstruction algorithms of the surfaces involved.

For the shots I used a Nikon E8800, with a resolution of 1549x2065 pixel and a focal length 35 mm.

Given the shooting distance and the resolution of the photographic image, the scale of the frame corresponds to 1/10-1/20 and, therefore, it is suitable to describe the object both according the geometrical aspect and the architectural detail.

Table -1: Auteri	Chapel	dataset
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	Auteri Chapel
Dimension of the object	4,20x5,14 m
Number of images	40
Resolution	4 Mpixel
123D catch mesh	590,869 triangles
	306,001 vertices

Table 1 provides a complete overview of the Auteri Chapel dataset: dimension of the object, mesh quality, number of vertices and triangles (faces) of the 3D model.

Figure 12 demonstrates *123D Catch* 3D model visual accuracy apart from the covering (this problem occurred because I was unable to photograph it). Figure 13 shows the sharpness of cylindrical surface both of the building and of niches and columns.



Fig. 12: Auteri Chapel 123D Catch dataset visualized in Meshlab



Fig - 13: Auteri Chapel 123D Catch model visualized in Meshlab

123D Catch 3D reconstruction encountered some problems due to a lack of continuity in the dataset images, caused by obstacles in the way.

For the metric accuracy test, I used horizontal and vertical cross sections compared with Ground Control Points (GCP) carried out by the direct survey (section 2.2).



Fig - 14: Auteri Chapel 123D Catch model smooth visualization in Meshlab



Fig - 15: Auteri Chapel reconstruction error evaluation on overlapped horizontal profiles made at 0.75m: the yellow line corresponds to *123D Catch* model, the red one to GCP survey



Fig 16: Auteri Chapel reconstruction error evaluation on overlapped horizontal profiles made at 1.50m: the yellow line corresponds to 123D Catch model, the red one to GCP survey

Therefore, the *123D Catch* model was scaled and vertical referred for overlapping to two-dimensional drawings. Figure 15 and 16 show an evaluation of metric accuracy by looking at two significant horizontal cross-sections: one at 0.75m and the other 1.50 m. Except for the areas where 3D reconstruction is not geometrically exact, the gaps are about of 0.01m, thus confirming the accuracy of this package.

CONCLUSIONS

The experimental results achieved on the Auteri Chapel show the potentialities and advantages of using image-based modeling techniques for documenting and enhancing architectural cultural heritage. The experimentation conducted in *123D Catch* has allowed me to detect a software limitation: the processing capabilities of 3D model are closely dependent upon the ability to take pictures of the object in its entirety, and this is not always possible in the architectural field.

Therefore, I conclude that these techniques based on the processing of a photographic dataset, may be the future of data acquisition and 3D modeling, through further implementations and insights. This field is in continuous evolution and we can envision that, in the near future, these low cost techniques will affordably flank current techniques.

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