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Research Article

Architectural Perspectives in the Cathedral of Palermo: Image-Based Modeling for Cultural Heritage Understanding and Enhancement

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Abstract. Palermo offers a repertoire of both artistic and architectural solid perspective of great beauty and in large quantity. This paper addresses the problem of the 3D survey of these works and their related study through the use of image-based modelling (IBM) techniques. We propose, as case studies, the use of IBM techniques inside the Cathedral of Palermo. Indeed, the church houses a huge and rich sculptural repertoire, dating back to 16th century, which constitutes a valid field of IBM techniques application.

The aim of this study is to demonstrate the effectiveness and potentiality of these techniques for geometric analysis of sculptured works. Indeed, usually the survey of these artworks is very difficult due the geometric complexity, typical of sculptured elements. In this study, we analysed cylindrical and planar geometries as well as carrying out an application of perspective return.

1 Introduction

The architectural and artistic heritage concerning the solid perspectives in Sicily is of inestimable value both in quantitative/qualitative typologies: antependiums, frescoes, sculptures, tiles, theater, false vaults, and more. Already by the end of the 1400's, architects and artists were involved in the national problem of the embellishments of the interior spaces of both places of worship, such as churches and oratories, and civic buildings. The greater mastery of the techniques of perspective launched a new style in which geometry, art, dexterity, and architecture blended into a single amalgam of great visual and emotional effect; such as magic boxes that reveal the mastery of the use of geometry in the service of perception perspective (Figure 1). Thus, a prismatic space is transformed into an aberrated pyramidal prism where narratives are represented, subjects characterizing the context (D'Alessandro, Inzerillo & Pizzurro, 1983; D'Alessandro & Pizzurro, 1989; Inzerillo, 2004, 2012).

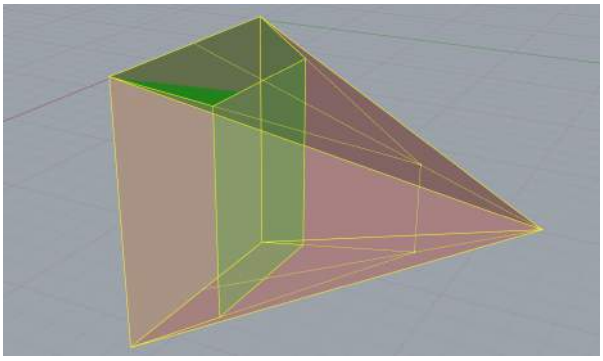

Figure 1: The prismatic space in solid perspective

In Palermo, the applications of solid perspective range from the majestic illusions of spherical domes to the panels depicting the lives of saints. In this study, we analyze the exemplars inside the Cathedral of Palermo in particular. This research aims to develop new avenues of investigation designed to detect, build, develop, manage and visualize three-dimensional models of important architectural examples of the solid perspective in spectacular sculpture. The goal is to study, develop and transmit to future generations, through innovative, non-invasive and low cost methods, this cultural heritage in a unique way that combines geometry, art and architecture.

In this research, the choice of the most significant cases was influenced by the inherent beauty and sophist-

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ication of the work, its location within a production rainfall in the area (authors who have created many works, which have been much investigated by historians, etc.), and the availability of the same work (possibility of access, permissions granted, heights compatible with the instrumentation, etc.).

The quality and variety of works in solid perspective in the Cathedral of Palermo provide a case study that can identify effective methods of investigation for acquisition through 3D image-based modeling techniques that can then be applied and verified in further studies.

The Cathedral of Palermo, and its art works, have always been the subject of studies and insights for historians, archaeologists, art historians, lovers of sacred places, etc., in terms of artistic and sculptural aspects. Nevertheless, in spite of previous historical interpretation conducted, the different art works – also those in solid perspective - have not been investigated with the aim of modeling and perspective rendering.

2 Repertoire of Solid Perspectives in the Cathedral of Palermo

The Cathedral of Palermo is the result of historical stratifications that have made this monument an extraordinary palimpsest of exceptional scientific value (Amato, 1728; Basile, 1938; Bellafiore, 1999; Zanca, 1989). The building dates back to the Norman age, from Archbishop Walter of the Mill in 1184. The first changes that incisively modified the exterior, according to the taste of the Aragonese-Catalan, took place between the fourteenth and the first half of the fifteenth century. The fourteenth century additions concerned the great western tower, the four corner towers, the main façade and main entryway, the portal and the south of the sacristy, the windows of the aisles, the chapels and the sacristy. From the second half of the fifteenth century to the end of the sixteenth, the interior of the cathedral was remodeled with fine moldings, altars, portals and several sculptures by the Gaginiana school (Domenico, Antonello and his sons), Laurana and Spadafora.

In particular, the work that most changed the internal space of the grandstand marble monument was built by Antonello Gagini and his sons between 1507 and 1574, which sheathed the apse and gave birth to a gradual "whitening" of the church interior 2.

The podium, with two orders and vertically articulated by pilasters, was composed of 75 sculptures, including sculpture in the round, and 14 episodes of the lives of the saints in high relief made of solid perspective and placed at head height so that they were visible to the visitors. This extraordinary podium was removed at the end of the eighteenth century as a result

Figure 2: Main nave of the Cathedral of Palermo

of the renovation of the Cathedral according to the project commissioned by Ferdinando Fuga (1761) and later finalized between 1781 and 1801 by Giuseppe Venanzio Marvuglia, assisted by Salvatore Licata Attinelli and Frate Felice La Licata (Basile, 1926; Giuffrè & Urbani, 1993).

The surviving pieces of the podium were relocated inside and outside the cathedral. Among these were 14 panels relating to episodes of the lives of the saints found in the apse and the transept (Kruft, 1980; Rizzuti, 2007; Vesco, 2011). They consist mostly of perspective scenes built according to Brunelleschi style: a central perspective with a stage set that through coffered ceilings, sidewalls and succession of vaulted arcades amplifies the depth of the environments Figures 3 u 4. Originally, the scenic locations of the panels were colored (blue and gold). Of some tiles (St. Philip, St. Matthew and St. Paul) we have the completion date (1527) (Di Marzo, 1880, 1884; Mancino, 2007).

Further surviving elements of the Gaginian podium are located in the chapel of Mary of the Angels along the northern nave, flanked to that of the baptistery, which houses the statue of the Assumption of Mary and the bier of Mary. Below this, there are three solid perspective scenes made in 1535 and of uncertain attribution, some indicate Antonello while others Fazio Gagini (Figure 6).

In addition to the work of Antonello Gagini, inside the cathedral there are more panels in solid perspective such as those made by his sons, Fazio and Vincent. These include such works as the marble arch of the chapel of the Crucifix between 1557 and 1565, although this work was dismantled during the works which destroyed the podium. Only a few panels with episodes of the Passion of Christ were reused and reassembled to form the altar of the Crucifix as it appears today (Figure 5).

The baptismal font (Figure 7(a)), made by Filippo and Gaetano Pennino in 1797, is next to the chapel of Mary of the Angels. The octagonal basin is supported by a group of sculptures depicting the tree of knowledge and Adam and Eve. Scenes of baptism according to the

Figure 3: Episodes of the lives of saints: "St. Philip and the Dragon"

Figure 4: "Jude Thaddeus of Edessa, who converts king Abgar"

Figure 5: Altar of the crucifixion

Figure 6: altar of Mary of the Angels

descriptions of the Acts of the Apostles are carved in bas-relief on the eight faces of the basin.

Other precious masterpieces include the two fonts set against the two pillars placed near the north and south entrances. The attribution of holy water placed near the southern entrance is uncertain (Figure 7(b)). Di Marzo (1880) attributes the work to Gagini (the father of Antonello), the Accascina (1959) to the choral work by Domenico Gagini, Pietro da Bonate and Gabriele di Battista, and dates it to 1475-1480. Recent studies attribute the font to Pietro da Bonate and date it to 1464-1469 (Kruft, 1972).

Above the tank there are two lunettes, the lower one showing the scene of Jesus' baptism, and the upper showing the blessing of a baptismal font. The font was completed by an octagonal canopy surmounted by a statue.

Some scholars date the basin on the opposite side (entrance from the north portico) to 1553 and assume that it was commissioned to the sculptors Giuseppe Spadafora and Antonio Ferraro, also known as "Imbarracochina", and that it is an imitation of the one already present in the cathedral (Figure 7(c)).

According to Di Marzo, bas-reliefs of the two lunettes, top and bottom, which depict scenes from the healing of the paralytic (lower) and the miracle of Moses (above) were made by Ferraro.

Also inside the cathedral, in the chapel of the shrine, is a work of gold with scenes in solid perspective: the silver ark which contains the relics of St. Christina, created in 1556 by sculptor goldsmith Paolo Gigli, assisted by Fazio Gagini and Scipione Casella.

Finally, outside, leaning against the side walls of the southern portico are two additional solid perspective reliefs. Both are bas-reliefs, the first commemorating the coronation of Victor Amadeus of Savoy, King of Sicily, in 1713 made by G.B. Ragusa (1714), and the second commemorating the coronation of Charles of Bourbon (1735).

3 Methods of Acquisition and Restitution

In this first phase of work, innovative techniques for Image-Based Modeling (IBM) have been tested. The photogrammetric techniques, known since the late nineteenth century, along with the advent of digital and testing of new mathematical algorithms have achieved impressive levels of processing to the point that today, thanks to research conducted by international groups in the field of Computer Vision, it is possible to extrapolate three-dimensional models from photo shoots through the use of several IBM packages (Apollonio, Ballabeni & Gaiani, 2014; Bandiera, Beraldin & Gaiani, 2011; Bertocci & Bini, 2012; Remondino & Elhakim, 2006; Remondino, Spera, Nocerino, Menna & Nex, 2014; Rodriguez Navarro, 2012; Toschi, Capra, De

(a) Baptismal Font, (b) southern font, (c) southern font,

Figure 7: Baptismal

Luca & Beraldin, 2014).

Algorithms digitally translate photogrammetric techniques, and lead to digital photogrammetry, retracing the steps that lead to the stereoscopic model (interior orientation, relative orientation, absolute orientation). We have used the so-called algorithms of Structure from Motion (SFM) that can reconstruct, from a sequence of photographs, the internal parameters of the machine and the position in space of the homologous points through the recognition (manual or automatic) of correspondences between photographic images, generating a set of three-dimensional points. While these SMF techniques have previously been used for a purely tourist purpose on the web, they also have the potential to generate great interest in reducing the time and costs in the acquisition and processing of data in the field of cultural heritage.

Among the various types of IBM software, our attention has focused on two, both free and available for download, that work as web services: Autodesk *123D Catch* (web application) and *Recap* (Autodesk 360).

The service acts in a semi-automatic way. The user creates the project, chooses the resolution of the model (low, ultra), the smart cropping and/or texturing option and the export format (eg OBJ). Images are then uploaded and sent to the cloud. The user is notified by email when the model is ready. They can then improve the model themselves by adding survey points or reference distance and manually stitching photos and then resending it to the cloud. The model thus obtained, in OBJ format, can be imported into dedicated software for 3D modeling and rendering.

A crucial phase is the realization of the photographic network of the object: it is recommended that the angle between one shot and another is about 5-10 degrees so that the overlap between neighboring frames is of about 70 %; furthermore the images around the object should be taken with different rotations and different heights so as to vary the angle of the shoot.

The experiments conducted so far are very promising even when using amateur cameras. However, the use of professional cameras with a fixed focal length and low distortion may improve the visual and metric quality of the obtained models.

4 Results and Discussion

Experiments carried out on various samples and on architectural scale, both from the building to the architectural detail, have demonstrated the visual and metric reliability of these types of software, albeit with certain usage limits and with the inescapable presence of the store of knowledge of photogrammetry (Galizia & Santagati, 2013; Casu & Pisu, 2013; Inzerillo & Santagati, 2013; Inzerillo, Santagati & Di Paola, 2013; Santagati & Inzer-

illo, 2013). In particular, for this object size the metric accuracy has been tested in other studies by the authors and is about 2-3/ millimeters and is a function of GDS (Ballabeni, Apollonio, Gaiani & Remondino, 2015).

Among the limitations, we stress the need to create a data set in which the photographic subject is framed in its entirety in a final usable model. However, if these types of software on architectural scale show the limits of a certain entity, on a small scale they have given quality results, allowing, in some cases (for example visualization purposes), the drop out of laser scanners, typically of high cost instrumentation and requiring specific expertise and long processing times.

In this paper we report some applications carried out inside the Cathedral of Palermo (Figures 8, 9, 10 and 11), that houses numerous sculptures of *quadratura* perspective of great value.

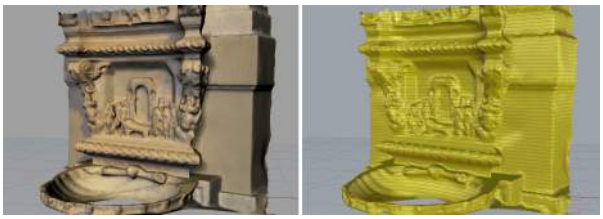

Figure 8: Elaboration on the lower bezel "Healing of the paralytic" north basin.

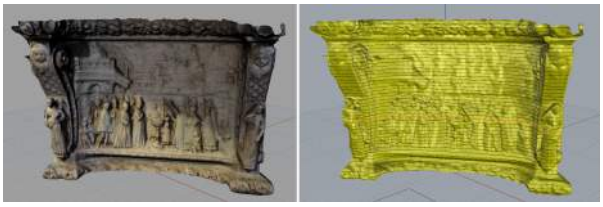

Figure 9: Elaboration on the upper bezel "Blessing of the Baptismal Font" southern basin.

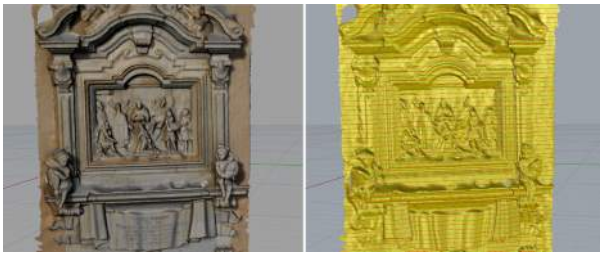

Figure 10: Elaboration on the memorial of the coronation of Charles of Bourbon.

Thanks to the use of these techniques, it will be possible to return the perspective of these model works in question through a representation that allows the interpretation of the signs and construction (Figures 12 and 13).

Figure 11: Elaboration on the upper bezel "Miracle of Moses" north basin

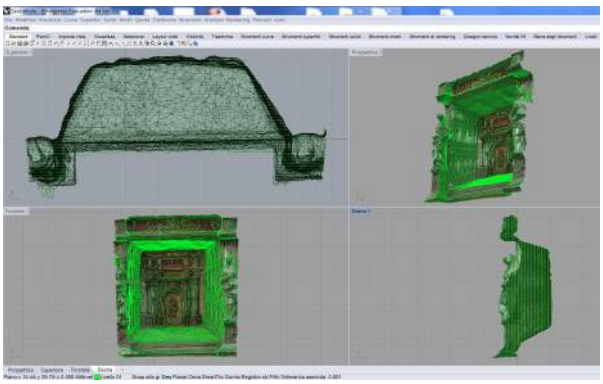

Figure 12: Processing one of the scenes of the ark of St. Christina

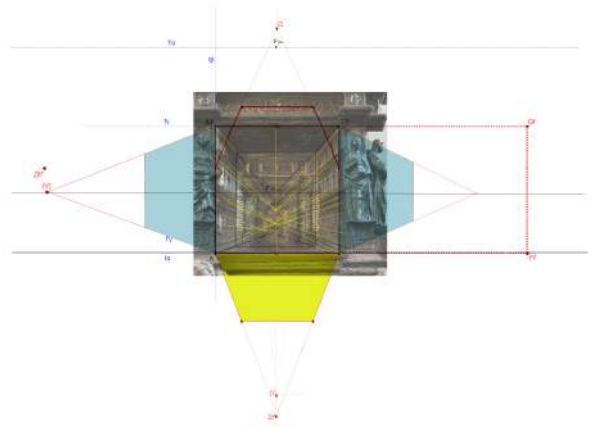

Figure 13: Restitution on the ark of St. Christina

5 Conclusion

Nowadays technology offers image based modeling packages that allow novel approaches to the traditional 3D acquisition and restitution of cultural heritage. The obtained 3D models via 123D Catch are reliable and accur-

	Camera	Resolution of the camera	Number of images	Focal Distance (mm)	Calculation time (minutes)
Healing of the Paralytic	Nikon D 3200	12 Mpix	76	18	80
Blessing of the baptismal font	-	-	20	35	30
Commemorative Monument	-	-	25	24	37
Miracle of Moses	-	-	27	18	40
Ark of St. Christina	-	-	21	18	32

Table 1: Parameters pertinent the elaborations

ate both from the visual and the metric point of view.

The benefits, in terms of lower costs and lower knowledge of photography and 3D modeling, are really surprising: even without having knowledge in the specific field, you can get 3D models with the use of *123D Catch*.

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