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LOW COST 3D DOCUMENTATION SYSTEM APPLIED TO THE BAS-RELIEFS BY AGOSTINO DI DUCCIO IN SANTO SEPOLCRO CATHEDRAL AT ACQUAPENDENTE

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Abstract

This paper reports the procedure and results of 3D low cost documentation system applied to the marble bas-reliefs, which now decorate the front of the pulpits of Santo Sepolcro Cathedral in Acquapendente (Italy). The church also contains a beautiful Romanesque crypt, dating back to the twelfth century. Inside the crypt it may be admired the oldest surviving copy, in Europe, of the newsstand of the Jerusalem Holy Sepulchre. The two bas-reliefs, representing respectively Saint Michael the Archangel and Saint Raphael the Archangel, were attributed to Agostino di Duccio (Florence 1418 – Perugia, 1481).

Keywords: system, software, reconstruction, Agostino di Duccio, marble bas-reliefs

1. Introduction

1.1. Research aim

The aim of this work is to apply digital no invasive low cost 3D documentation based on close range image system, to investigate two marble bas-reliefs, with high metrological precision. In this way it is possible to take advantage of information on the entire 3D model of the bas-reliefs. This procedure is particularly useful in documentation, conservation, restoration phases because it makes possible a complete investigation of the surfaces of a 3D subject with a single model based on 1:1 scale with millimetre accuracy. Moreover the system is completely non-invasive and no-contact with the artwork.

The close range image system allows for analysing the preservation state of the surface, the material losses, the presence of superimposed materials, the reading of faded paintings and so on.

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1.2. Historical background

The foundation of the Basilica at Acquapendente is associated to a sort of legend telling that Matilda of Westphalia (895-968), mother of Otto I, undertook a journey in search of a place to build a church to be devoted to the Holy Sepulchre, and she found it after a revelatory dream in the town of Acquapendente (Figure 1).

The cathedral was consecrated in 1149 by Bishop Aldobrandino from Orvieto as documented in a papal bull of 1025 AD.

The façade and the interior of the building were transformed during restoration work ordered by Pope Benedict XIV in 1746, and as a consequence the Cathedral lost the medieval architectural aspect. The crypt (dated back to the 9th century) was the only remaining part of the old original building. The crypt houses a stone from the Holy Sepulchre of Jerusalem and for this reason is interested by intense pilgrimage [1].

In the interior of the Cathedral, two precious bas-reliefs can be observed on the foreheads of pulpits. These pulpits are placed on the sides of the two stair flights leading to the altar. These two artworks are attributed to Agostino di Duccio, and they represent Saint Michael the Archangel on the left, and Saint Raphael the Archangel with the young Tobias on the right.

The first saint tramples the defeated dragon from which small human figures come out. The saint holds up in his right hand a sword, and in his left hand a globe. Saint Raphael holds, with left hand the young Tobia, and with his right hand a long pole wrapped by a tape on which the following inscription is visible:

"EGO.SVM.RAPHAEL.ANG. VNVS.EX.VII.QVI.
ASTAMVS.AN.DOMINUM"

(I am the Archangel Raphael, one of the seven who stand in front of God.)

During the restoration works in the Cathedral, made necessary after the damages caused by the Second World War, the bas-reliefs were removed from the Chapel of the *Madonna del Fiore*, where they were previously placed to decorate the sides of the baptismal font, to be finally positioned in the pulpit. During this transfer, in the back side of the Saint Raffaele bas-relief, an inscription in black charcoal was discovered. This inscription, still visible, indicates the transport of the two artworks, paid by Monsignor Angelo Gessi, and their setting in the Cathedral, on April 12, 1893 (Figure 2).

Monsignor Gessi had great cultural value and he was general Vicar of the Bishop Veneri at Acquapendente and then at Rome. He was born in Pieve di Cento, a little town near Ferrara from where the artworks examined in this paper come. Probably the two pieces were detached from a disassembled monument to be donated to Basilica of *Santo Sepolcro* in Acquapendente.

In order to reconstruct a possible history of the bas-reliefs, a documentary research has been carried out in the Archive of Monsignor Angelo Gessi. The archive of Monsignor Gessi was donated to the Municipality by an heir and is

stored in the Municipality Library of Pieve di Cento. It is organized into ‘mailed letters’, ‘received letters’ and ‘other ones’, all by chronological order.

Figure 1. The Cathedral of Acquapendente (Viterbo, Italy).

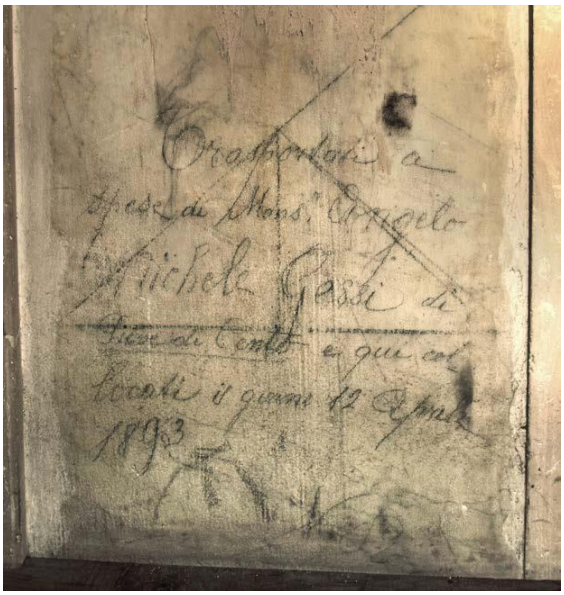

Figure 2. The inscription on the back side of the Saint Raphael bas-relief.

By examining the letters, it was found, in a letter received in May 1893, a reference to the bas-relief representing Saint Michael. The sender of this letter is illegible. The letter, very difficult to read, reported the continuation of an almost started conversation, but never arrived to Gessi, between Monsignor Gessi and the sender of the letter. In this conversation, Gessi referred to some photos of the bas-reliefs commissioned to Giovanni Batta Baldi, a photographer operating actively in Acquapendente. However, any trace of these photos has been found. They could be certainly useful to better understand the damages caused to the bas-reliefs during the re-positioning.

Pier Maria Fossati writes, in his book on the Basilica of *Santo Sepolcro*, that the bas-reliefs were attributed to a disciple of Mino da Fiesole or to Donatello or to the school of Agostino di Duccio. Few scholars who paid attention on the two bas-reliefs, proposed the attribution to Agostino di Duccio: starting from Ragghianti (1938), further confirmation was assessed by Pier Maria Fossati and orally by Italo Faldi (1950), and finally by Gustavo Cuccini (1990) who proposed a new dating of the artworks.

Only Ragghianti, in 1938, pointed out the artworks in their original location. He affirmed that the bas-reliefs were authentic and entirely carved by the Master at the beginning of his first stay in Perugia. Ragghianti further wrote that the artworks were probably sent from Perugia, as the artwork from Amelia, and they were executed between 1456 and 1462. According to Ragghianti, this hypothesis is strengthened by the style of the bas-reliefs that come first those of Saint Bernardino.

Subsequently, the discovery of the inscription on the back side of the Saint Raphael bas-relief indicates the origin of the artworks from the province of Ferrara (Italy) that was the origin place of Monsignor Gessi. For that reason Gustavo Cuccini proposed to date back the two bas-reliefs in the period between 1452 and 1454, being the last period in which Agostino di Duccio stayed in Rimini [2]. It is therefore possible that the two artworks came from Malatesta court, or from other clients in Rimini. Both sculptures seem to be derived from a monument as they are characterised by similar dimensions and style. Concerning this observation, Ragghiani proposed that originally the two bas-reliefs were parts of a triptych with three Archangels, the gable and the base. This hypothesis was suggested by the hieratic position of Saint Michael and by that of Saint Raphael turned to left. It seems to be lacking the Archangel Gabriel turned to right.

From a stylistically point of view, Archangels resemble the bas-reliefs of the Malatesta Temple, especially those in the chapel of the Planets and those of the Muses and the Liberal Arts. In fact, in both cases, it is possible to observe the same drapery appearance, the careful naturalistic details and the oval faces [3].

1.3. Description of the bas-reliefs

The bas-reliefs are now placed in the central frame of the pulpits, and they measure respectively 57x128 cm (Saint Michael, Figure 3a), and 56x128 (Saint

Raphael, Figure 3b). The edges appear uneven, with the marble chiselled, probably due to adaptation works, performed after the Second World War on the occasion of restoration in the Cathedral, in order to relocate the bas-reliefs.

(a) (b)

Figure 3. The bas-reliefs of: (a) Saint Michael, (b) Saint Raphael.

2. Experimental

The 3D low cost documentation of the tow bas-reliefs was performed by digital photogrammetric system [4-6]. This is based on acquisition of photographs through a Nikon D5300 camera and three 250 Watt incandescence lamps. The 3D survey of the bas-reliefs, by close range multi image system, was performed by applying the Agisoft PhotoScan® [http://www.agisoft.com/].

This software takes advantages of an image based system developed through the technique named Structure from Motion (SfM), which integrates digital photogrammetry with computer vision [7]. This technique allows to generate 3D structure through the use of a set of images acquired in such a way similar to traditional photogrammetry, but with the significant advantage of orienting the photograms in a completely automatic manner. SfM is image-matching process that uses algorithms elaborated from years 90s in the field of computer vision to calculate the spatial coordinates by means of pixels sampled in the digital photographic images.

As the traditional photogrammetry, SfM employs overlapped images, acquired from different points of view. The difference of SfM in respect to traditional photogrammetry is that SfM is able to simultaneously and automatically determine the internal geometry of the camera, its position and orientation. The high degree in photograms overlapping, useful to cover the entire geometry of the object, gives the name to the SfM technique: 'Structure for Motion'. The software workflow, after the photographs uploading, requires the use of SIFT (Scale invariant feature transform) algorithm, which was developed by Lowe in 2004 [8]. This algorithm is able, by using image descriptors, to calculate and reveal the homologous point position (pixel) throughout the set of images. The homologous points are enough to establish the spatial relationships inside a relative coordinate system XYZ, and consequently to arrange the photographs in accordance to the calculated parameters.

SIFT algorithm further allows to connect the common characteristics of photograms, also with scale variations, points of view of the shot, partial occlusions and different lights of the photographed object.

Then, the bundle adjustment algorithm controls and limits the errors during the transformation of 3D point coordinates of the object, into a point cloud, more or less dense depending on the revealed key points. The next step is the generation of a dense cloud points through the dense image matching algorithms. These last ones are: area based matching (AMB) algorithms, which perform the statistical comparison of the grey intensity scale detected on the images, but they do not extract the feature; feature based matching (FBM) algorithms that first search common features in the images and then proceed to extract them. The combination of both algorithms guarantees optimal results, but it is quite time consuming. The so-obtained dense cloud points can be used for mesh generating, which can be texturized for making a 3D photo-realistic digital model.

The first step was to provide a set of photographs on the field, sufficient for the realization of the digital model. The scene was illuminated with three incandescent lamps, taking special care to place the lamps so that to obtain uniform illumination and to not create strong contrasts and shadows. A set of about thirty photos for each bas-relief was realized to obtain the 3D model; the shots were performed so as to obtain 80% overlap between the images. In order to decrease the error and get an accurate alignment of the frames, the photographs were taken without flash, and using a fixed focal lens to avoid distortions in the processing for 3D model creation. The images were gathered with the Nikon D5300 digital camera, with these shooting parameters: F-stop f/4; exposure time 1/60sec, ISO-2200 sensitivity, digital focal lens 26 mm. In order to dimension the two 3D models, control points were identified in the acquisition area. These control point have been measured by laser total station, without 'contact' with the work of art.

The post-processing phase lasted about 8 hours for each model by use a PC with the following characteristics: CPU intel(R) Core(TM) i7-4770 CPU @ 3.40 GHz, Ram 32 Gb; Windows 8.1 64 bit, video card GeForce GTX 970 4Gb.

Figure 4. Detail of Saint Raphael with traces of gilding visible on halo and hair.

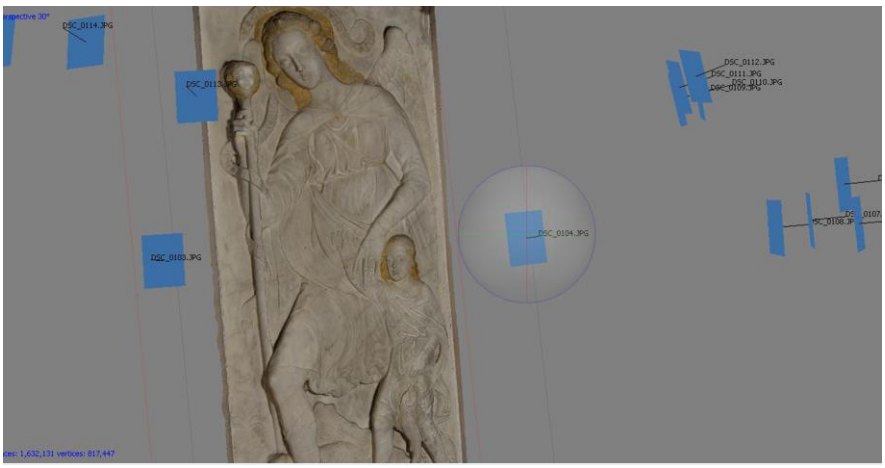

Figure 5. 3D model of Saint Raphael by Agisoft PhotoScan® software.

3. Results and discussion

The 3D model obtained after images elaboration is shown in Figures 4 and 5. For the first model, Saint Michael the Archangel, the software identified 25.231 tie points on the 29 photograms (resolution 300 dpi, RGB 24 bit, file .jpg 8Mb) and it created a dense cloud made of 10.286.770 points and a 3D model made of 2.057.353 faces.

The same procedure was repeated for de second model, Saint Raphael the Archangel: the software identified 25.160 homologous points on the 27 photograms (resolution 300 dpi, file .jpg 8Mb) and it created a dense cloud made of 8.160.662 points and a 3D model made of 1.632.131 faces (Figure 4).

The two models, constituting a sort of 'digital memory' of the artefacts, allowed to map the state of conservation of the surfaces. It was also possible to accurately map the constitution techniques and the visible remains of gilding. In the light of a possible future conservative intervention on the two marble bas-reliefs, this information is particularly relevant for conservators to address the surface cleaning and the subsequent operative activities.

4. Conclusions

The results obtained in this study demonstrated the high potentiality, at relatively low costs, of the documentation on a 3D model. In fact, it had been possible to carefully investigate the conservative status of the surfaces of the two marble bas-reliefs by simply rotating the 3D model generated at the end of the elaboration process. So, without using a lot of images of the different sides of the 3D object, but with a single interactive file, also in pdf format, it was possible to map the surface.

In the light of a future desirable conservative intervention, the information obtained by the 3D model will be certainly highly useful for the conservators.

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