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Original article

New methodology for the assessment of cleaning treatments. Applications of photogrammetry for restoration

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ABSTRACT

The development of new technologies in recent years, together with their cost reduction, have fostered their use in different fields such as Cultural Heritage. Likewise, new software and easy accessibility, either through trial versions or due to open-source software, have endorsed their establishment as essential tools in our everyday life. In this paper, a new methodology based on photogrammetry is proposed for the assessment of cleaning treatments. A set of wall painting fragments was the subject of study. By generating and comparing the photogrammetric model of the fragment before and after the cleaning treatment, this methodology enabled to determine those areas in which the treatment had been more effective – thus removing a higher quantity of dirt – and, on the other hand, those areas in which the treatment had not performed well – and the surface had been left intact. Therefore, photogrammetry offers a low cost, portable and simple solution for objectively assessing the efficacy of a cleaning treatment.

1. Introduction

In the face of a conservation and restoration project, an in-depth analysis of the possible treatments to be implemented during the intervention is essential, with the objective of analysing possible interactions between them and the artwork itself. Therefore, previous research becomes a crucial stage in which the use of new technologies and 3D models is more necessary over the years [1].

There are plenty of examples of cultural heritage being digitalised with very specific aims. Such is the case of the archaeological site of Uppakra, in Sweden [2], where photogrammetric models of the different excavation stages were obtained; the work carried out by A. Gruen and F. Remondino [3], generating a 3D model of the Great Buddha of Bamiyan for its reconstruction; or the restoration of the *Madonna di Pietranico* [4], whose digitalisation aimed at reducing fragments' manipulation.

It is therefore evidenced that new technologies provide a valuable tool in the conservation and restoration of cultural heritage, since they comply with the fundamental requirement of being a non-invasive and non-destructive methodology. Notwithstanding, a big adaptation and innovation effort is required in most cases, due to the fact that these technologies are not specific to this field and hence they need to be adapted to its requirements and need. In this sense, new specific programmes such as MeshLab [5] and Hyper3D [6] have been developed, together with new tools and protocols [7].

In this framework, this paper aims at adapting the well-established technique of photogrammetry to a specific need of restoration, such as the assessment of treatments, and within them, cleaning treatments in particular.

2. Research aims

This paper aims at defining a new methodology for the assessment of cleaning treatments, based on the quantity of dirt crust removed. To date, most evaluations of cleaning techniques were based on the final aspect of the pictorial layer (changes in colour or shine, resistance to abrasion) [8] and those which actually focused on determining the removed substance required specific equipment and software which in many cases entailed a high cost [9].

This paper aims at:

- proposing a methodology for objectively assessing the cleaning treatment by means of quantifying the thickness of the removed layer on each point of the painted surface;
- providing a technique which does not entail an extra cost, by making the most of the advantages of new software, such as trial versions and open source, and using a tool which is available in most cases, such as a photographic camera;

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- outlining a non-invasive methodology, generic enough so that it is not restricted to one piece of artwork in particular but can be repeated in other cases.

3. Material and methods

The proposed methodology, explained in detail below, is based on the digitalisation of the pictorial layer before and after the cleaning treatment by means of photogrammetry and the comparative analysis of both models.

3.1. Material

The sample for this study consisted of small fragments of wall paintings from two archaeological sites. On the one hand, fragments of Roman wall paintings from the 2nd century A.D. were selected, belonging to the *Sala del Mosaico de los Amores* from the archaeological site of *Castulo* (located in Linares, province of Jaén, Spain). On the other hand, fragments of wall coverings from the 14th century, belonging to the *Alcázar de los Reyes Católicos* in Córdoba (Spain), were selected. Their sizes range between 5–8 cm length and 4 cm width, approximately (Fig. 1).

Choosing these samples enabled us to test the proposed methodology in two wall paintings of different characteristics, since they had been executed with different techniques and presented varied alterations. While two surfaces were differentiated in the wall coverings of *Castulo*: a smooth polished one and a brushstroke coarse one; the wall painting from Córdoba presented a smooth surface in which the incisive preparatory drawing was noticeable. Alternatively, one of the fragments of medieval wall painting showed an accretion of crust which was quite homogeneous and thick; and less thick and more isolated dirt accretions appeared on the other selected fragments, thus demanding more thoroughness and attention to detail when registering the models and in the subsequent comparison.

3.2. Execution of the photogrammetric model

As it has been previously stated, photogrammetry was the chosen technique for the digitalization of wall paintings fragments, due to the fact that it is a low cost, portable, flexible and simple technique which creates high quality models regarding geometry and texture [10].

Photogrammetry is based on partial overlapping of several photographs, shot from different angles, for the 3D reconstruction of the outer and visible surface of the object [11]. The established work process was as follows [12]:

- acquisition of the images by means of a digital photographic camera;
- image alignment with specific software which automatically rotates the images and extracts their equivalent point pairs;
- generation of the dense point cloud, which results in the 3D model;
- creation of the polygonal model and, finally, its texture.

The advantages of this technique are such, that its use as tool in conservation and restoration projects is increasingly widespread [13,14].

3.2.1. Digitalisation of wall paintings fragments

As it has been described, photogrammetry techniques allow the creation of 3D models based on photographs of an object taken from different viewpoints. The photographs shot must cover the whole surface of the object to be digitalized and must overlap so that equivalent point pairs can be obtained. Lighting conditions and the position of the object play a fundamental role when shooting the photographs; specially in this case in which two models are created: one corresponding to the initial state of the fragment, and the other one corresponding to its state after the cleaning has been carried out.

A Nikon D5100 with 18–55 mm lens was used for the shooting sessions. Each fragment was located together with two scales, which served as reference points to facilitate later alignment of both models. Occasionally, the dirt of a fragment is such that the details of the pictorial layer cannot be recognised. Additionally, the surface of the fragment, and therefore also the resulting model, might be modified due to the fact that many equivalent point pairs between the models to be compared disappear, thus complicating subsequent alignment of the models. In order to make it easier, certain external elements were added for the shooting, ensuring that the fragment (before and after the cleaning) was always placed at the exact position towards them; this is the case of the two scales which, apart from enabling the scaling of the model, were fixed elements which remained in a constant position, therefore providing a higher number of equivalent point pairs. Finally, normal lighting conditions of the room were improved with two spotlights located in such a way that they prevented the appearance of accentuated shadows. The photographs were taken using a tripod to rotate the camera around the fragment at two different heights: one of them positioning the lens almost parallel to the surface, and the other one maintaining a 45° angle with respect to the horizontal. The option of turning the camera around the object was preferred instead of using a rotatory table, given the fact that it provides better results, as argued by I. Nikolov and C. Madsen [15].

A wide variety of 3D reconstruction programmes are available nowadays for the creation of a photogrammetric model based on various photographs. Each of them offers different actions to be implemented on the model, and therefore all of them imply advantages and disadvantages. The objective of implementing a low cost methodology was highlighted since the beginning of this paper; this is the reason why the chosen programme fulfils the needs of a work of this nature and, at the same time, is affordable. The program chosen for composing the photogrammetric models, in this case, was *Autodesk Remake* [16]. This programme creates

Fig. 1. Photogrammetric model of the three fragments of wall paintings analysed in this study. Initial state of the fragments. A: Fragment 019, beloging to the archaeological site of Castulo. B: Fragment 01, beloging to the Alcázar de los Reyes Católicos in Córdoba. C: Fragment 10, beloging to the Alcázar de los Reyes Católicos, in Córdoba.