NEW APPROACHES FOR 3D DOCUMENTATION OF PETROGLYPHS IN THE NORWEST OF THE IBERIAN PENINSULA

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Abstract:

The progressive awareness of public administrations and society towards the necessity of preserving the cultural heritage, particularly rock art, has become more and more important in developed countries. In Galicia (northwest of Spain), there are many petroglyph remains that are seriously affected by a severe acceleration in degradation due to urban expansion. In this situation, actions focused on the preservation of these patrimonial elements have to be accomplished. These protection forms must be preceded by a previous step of exhaustive documentation of the prehistoric element, in order to register the conservation state of the element so that it can be contrasted with future observations or studies.

The advances experimented by 3D digital techniques make possible to document rock art avoiding the inconveniences previously mentioned. The 3D digitalization of objects allows not only registering the metric and radiometric characteristics of objects, but also the diffusion and transference of results. During the last years, the two main exponents for 3D digital reconstruction of the shape of objects have been photogrammetry and laser scanning;therefore, they need to be validated in all those potential fields of application.

This article presents new approaches for rock art documentation using terrestrial photogrammetry and laser scanning as accurate and non-destructive tools. The methodological fundaments for an adequate documentation of petroglyphs are presented by means of several examples of digital recording in petroglyphs located in the Norwest of the Iberian Peninsula.

1. INTRODUCTION

Prehistoric art is an essential part of the worldwide cultural heritage since it was the communication system between communities previous to writing, and it plays a key role for the comprehension of prehistoric and primitive communities. In the case of the Norwest Area of the Iberian Peninsula, the more singular prehistoric artistic complexes are megalithic art and Bronze Age petroglyphs. The graphic representations that are usually engraved on the rock surface (traditionally called petroglyphs) are diverse, being mainly divided into figurative elements (animals, humans, weapons) and abstract elements (labyrinths, points, etc.) [1].

The awareness-raising of public administrations and society towards the necessity of preserving the cultural heritage, particularly rock art, has become more and more important in developed countries. Contrary to this affirmation, many archaeological sites are in danger due to urban expansion, new civil engineering constructions, erosion, inappropriate management or also abandon. In Galicia (northwest of Spain), there are many petroglyph remains that are seriously affected by this kind of situation [2] and a severe acceleration in degradation of these elements has been detected in parallel to the progressive exploitation of the Galician territory. This kind of situation seriously threatens the preservation of Galician petroglyphs. Furthermore, every protection form must be preceded by a previous step of exhaustive documentation of the prehistoric element, where all the conceptual, aesthetic and physic characteristics of the objects are collected [3]. This documentation is essential because it registers the conservation state of the element, which will be contrasted with future observations or studies.

At present, the idea of avoiding changes on the heritage element during the process of recording is increasingly extended [4]. On the other hand, many traditional techniques involve alteration of physical and chemical properties of petroglyphs: casting, tracing, rubbing, or chalking [5-7]. All those systems, which provoke an alteration in the physical or chemical state of the element, are considered as unacceptable (application of mechanical efforts, addition or elimination of substances, etc.). In this context, the development of non-destructive systems and methodologies for rock art recording is vital.

The advances experimented by 3D digital techniques make possible to document rock art avoiding the inconveniences previously mentioned. The 3D digitalization of objects allows not only registering the metric and radiometric characteristics of objects, but also the diffusion and transference of results [5]. During the last years, the two main exponents for 3D digital reconstruction of objects shape are photogrammetry and laser scanning [8-11], thus they need to be validated in all those potential fields of application.

This article presents new approaches to rock art documentation using terrestrial photogrammetry and laser scanning as accurate and non-destructive tools. The methodological fundaments for an adequate documentation of petroglyphs are presented by means of several examples of digital recording in petroglyphs located in the Norwest of the Iberian Peninsula.

2. LOW COST SURVEYING OF PETROGLYPHS BY PHOTOGRAMMETRY

2.1 Instrumentation

Data acquisition was performed using a digital camera Canon EOS 10, with a 6.29 million pixel resolution. This camera has a CCD sensor equipped with a RGB matrix.

Auxiliary material is sometimes required for a correct image recording as well as for a better reconstruction of the final 3D model. In this sense, one tripod and artificial circular targets are sometimes necessary in order to ensure a precise 3D reconstruction, and a total station is used for the scaling of the final 3D model. A total station Leica TCR 1102 was used during data acquisition.

2.2 Image acquisition

Image acquisition basically consists of the collection of several images from different points of view. According to the principles of convergent photogrammetry, images should have optimums angles of 90 degrees, with an overlap ration between images higher than 60% [12]. When the surface of the petroglyph does not fit into the field of view of the camera, the object can be divided into different models. To ensure a correct matching of the partial models with the global model of the petroglyph they have to share an overlapped portion of the image higher than 40%. Figure 1 shows the proposed camera network during image recording.

Control points are located over the rock and surrounding areas. They are used in order to make the identification of object points or references easier. During image recording, cross circular targets were used so that their central point was easily and accurately marked. Targets were placed ensuring that, at least, all the models had six targets and three of them were in the overlapping area between consecutive models. Finally, the 3D position of the center of each control point was measured with total station; this way, the final 3D model can be scaled and the accuracy of the 3D reconstruction can also be validated.

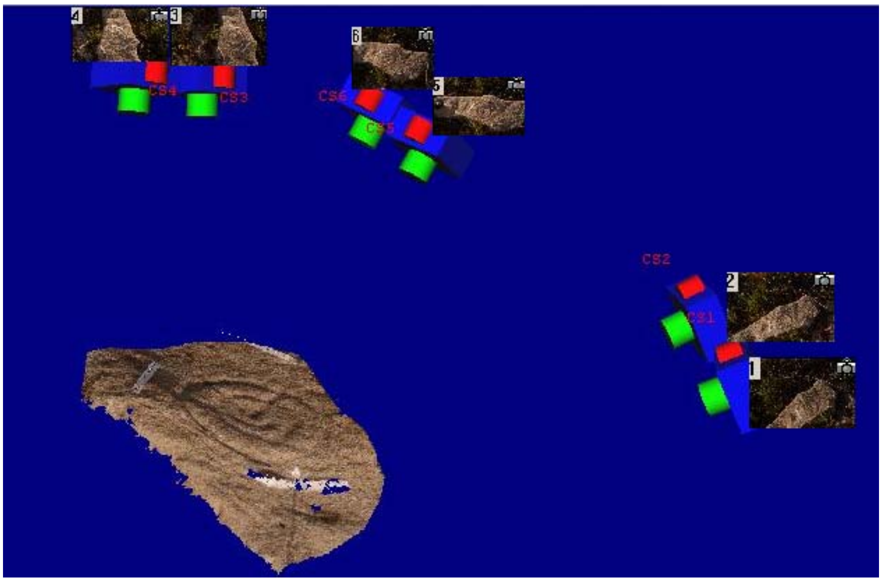


Figure 1: Camera network during image acquisition. Three main camera positions with maximum convergence angles around 90 degrees.

2.3 Data processing

After the field work, the images are introduced into the digital photogrammetric workstation Photomodeler Pro®. The first task consisted of introducing the camera calibration parameters which permit the calculation of the interior orientation of the photogrammetric process. Then, the relative orientation is done after identifying a minimum of six common points between images in each partial model. When all the partial models are oriented, they are matched by means of identification of a minimum of three common points located in the overlapped area. Finally, the global 3D model is scaled and leveled introducing the coordinates of control points measured by topographic methods.

Restitution

The restitution process is based on the determination of the 3D position of points over the rock surface in order to define the geometry of the petroglyph. The standard procedure consists of the identification of homologous points in pairs of photographs (Figure 2). Appart from restituting those points defining the petroglyphs, point clouds defining the geometry rock surface are reconstructed.

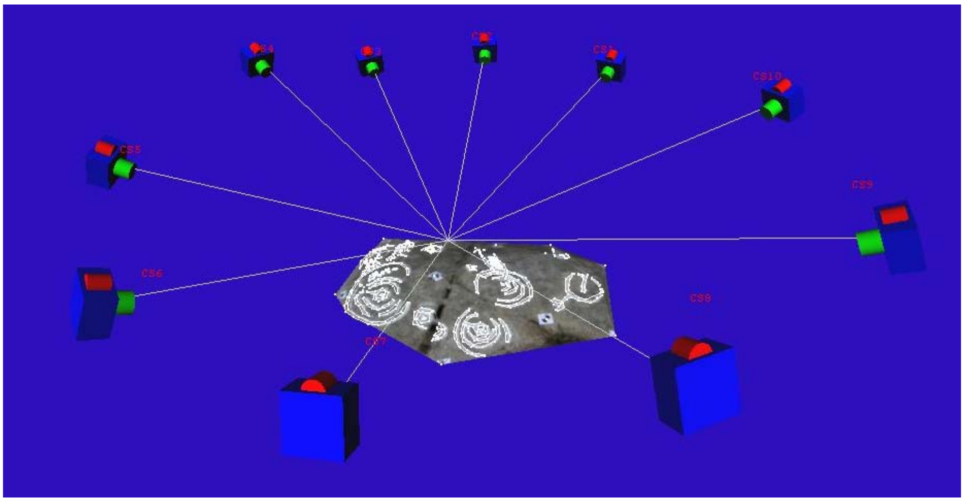


Figure 2: Restitution process: the 3D position of the selected point was calculated from all camera stations.

In recent years, image matching algorithms were developed in order to perform the automatic restitution of points. With this purpose, the software Photomodeler Scanner® includes the module *Dense Surface*

Modelling (DSM). After the achievement of the interior and external orientation of images, the program allows the automatic reconstruction of point clouds from image pairs. Since this module operates on the basis of cross correlation algorithms, the images used have to be almost parallel. Finally, the point clouds reconstructed from different points of view were subsequently aligned in a unique point cloud of the petroglyph.

2.4 3D modeling

As a result of the restitution process a point cloud was created, and contours were additionally outlined. In order to obtain a continuous surface that defines the rock face, a meshing process is needed. After it, real textures can be projected over the 3D model and the realistic model of the petroglyph is finished.

The precision of the final 3D model is not immediately known when the real dimension of the object under study is not defined. An indicator of the quality of the reconstruction of each point is the RMS residual of the bundle adjustment whose value is usually utilized in photogrammetric projects.

3. LASER SCANNING FOR DOCUMENTATION OF PETROGLYPHS

3.1. Instrumentation

A long range pulsed laser scanner RIEGL, model Z-390i was used for data collection in this case. The measurement range goes from 1,5 m to 400 m in common lightning conditions, and its nominal error in distance measurement is 6 mm at 50 m distance. This instrument emits a light beam with a wavelength between 700ŋm and 2µm, and has an acquisition rate between 8000 to 11000 points per second. It has a field of view of 360º horizontally and 90º vertically.

A semi-metric digital camera model Nikon D200 is mounted on the scanner body in order to incorporate texture to the 3D model generated by the scanner data. This camera has a CCD sensor, DX format with a resolution of 10.2 million pixel and a color matrix system 3D II (AE). A great angular lens, model Nikkor 20mm f/2.8D was used for image collection during the works presented in this article.

Additionally, topographic equipments were used in order to locate the acquired point clouds in the global coordinate system. A total station Leica TCR 1102 was used for the measurement of control points that allowed the global alignment of point clouds.

3.2 Data acquisition

Field work basically consists of the point clouds acquisition that defines the geometry of the petroglyph from different points of view (Figure 3). This configuration is needed because of the shadow areas produced by the complex shapes of the rocks.

Figure 3: Data acquisition with RIEGL Z-390i scanner from one of the scanner position.

Once the equipment is stationed, the first task consists of the camera mounting calibration in order to locate the camera sensor in the laser scanner coordinate system, and consequently achieving the orientation of images regarding to the global point cloud of the scanner. In order to perform this transformation as accurate as possible, circular flat reflective targets were located in the petroglyphs and their surroundings and then measured by both measurement systems (laser scanner and total station).

Once this previous tasks are done, it is possible to start the 3D scanning procedure of the petroglyphs as well as the color capture by means of image acquisition. The scanning methodology basically consisted of the following steps:

- Low resolution overall scan, whose angular interval is 0.2º. This scan collects points of the whole field of view and is used for the identification of control points (which are subsequently scanned with high resolution), and smaller areas with petroglyphs.
- Image acquisition configured with minimum aperture and maximum shutter speed, and flash so that reflective targets position can be easily and accurately identified. These images are subsequently used for the transformation of the camera coordinate system to the scanner coordinate system.
- High resolution scans. This kind of scan is performed in the selected areas of the first scan which contains petroglyphs, where maximum resolution of scanning is configured (0.002º). A 3D intensity image, as shown in Figure 4, is obtained.
- Image acquisition for each detailed scan, in order to register color information of petroglyphs.
- This procedure is repeated in every scanner position needed for the documentation project.

Finally, the position of control points is measured with a total station, which allows defining the project coordinate system.

Figure 4: 3D intensity visualization of one of the high resolution point clouds of the petroglyph.

3.3 Data processing

The alignment or registration consists on transferring the resulting point clouds in each individual scanner position, into the project coordinate system defined by surveying procedures. This procedure involves the computation of a 3D conformal transformation analogous to the photogrammetric process. In the software Riscan Pro, control points used for this transformation are extracted from the overall intensity scan. Tie points are usually located in the centroid of pixels defining the 2D intensity image of the detailed targets.

After composing the global point cloud for each petroglyph, cleaning and filtering operations are needed. Isolated points and noise are deleted, and those points corresponding to the petroglyph are separated from the surrounding point cloud.

Filters are applied to the petroglyph point cloud in order to reduce the noise caused by fluctuations of the environment and the nominal error of the system. This operation also homogenizes the density of points on the petroglyph's surface.

From the images acquired with the digital camera it is possible to assign colors to the point cloud so that each point has its three spatial coordinates (X, Y, Z), an attribute of intensity and RGB values.

3.4 3D Modeling

In order to develop a mesh model of the bridge, a 2D Delaunay flat triangulation was applied to the main plan of the petroglyph with respect to the viewing plane.

In order to assign a texture to every triangle, the selected image must satisfy three criteria: minimum distance between camera position and the centre of each triangle, visibility of the triangle in the image and minimum angle of view. Thus, a photorealistic 3D surface model is obtained and orthoimages of the bridge are generated by means of a differential rectification procedure.

4. RESULTS

4.1 Photogrammetry

Figure 5 shows the orthoimage obtained from the photogrammetric survey of Chandebrito Petroglyph. A total of 2131 points were manually restituted in order to define the contours of the petroglyph. The final root-mean-squared error of restituted points was 0.0012 mm.

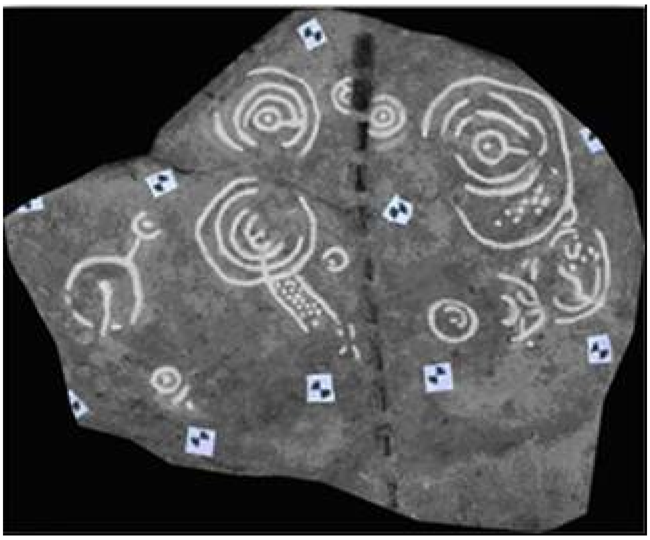
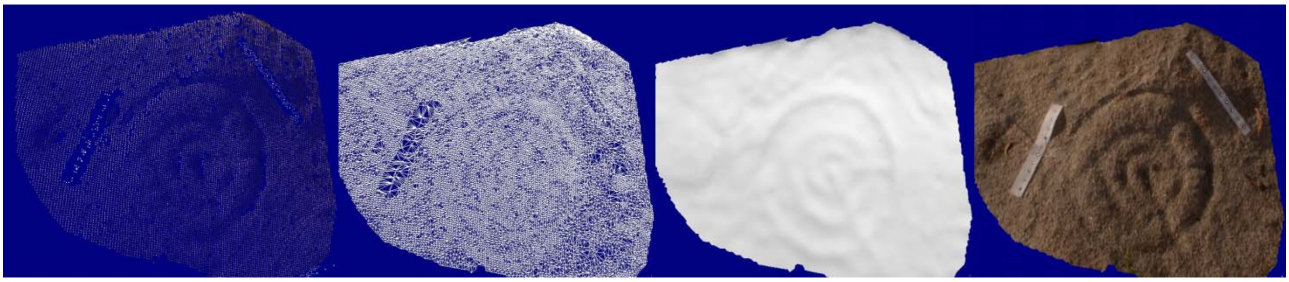


Figure 5: Orthophotograph of Chandebrito petroglyph (Nigrán, Spain) obtained from manual restitution.

Manual restitution requires a high time consumption; with the aim of solving this problem, the most recent photogrammetric software includes image matching algorithms that allow the automatic reconstruction of object surfaces. Figure 6 shows the results obtained in the Os Carreiros petroglyphs: a) point cloud obtained thanks to the DSM module in Photomodeler Scanner®, b) mesh generated from the previous point cloud, c) polygonal model of the petroglyph, d) textural model.



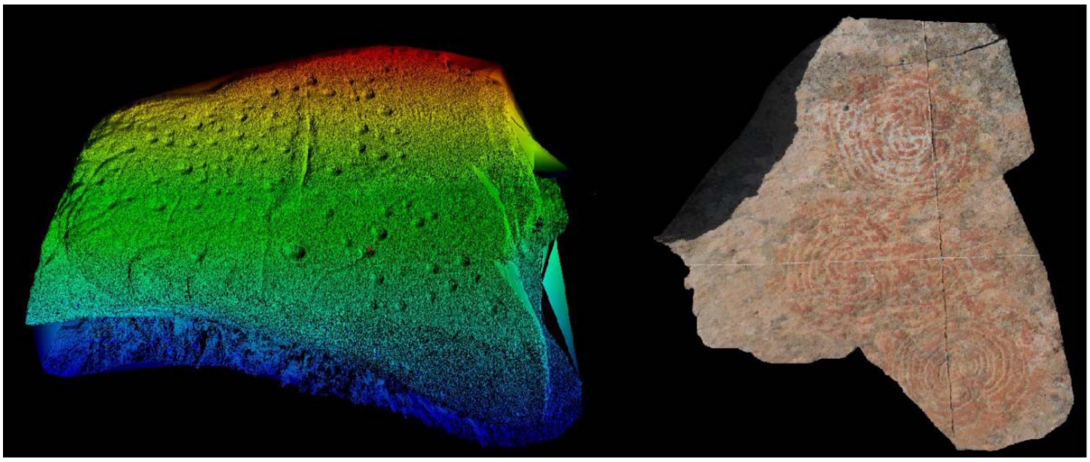
(a) (b) (c) (d)

Figure 6: Photogrammetric results of Os Carreiros petroglyph (Cotobade, Spain): from point cloud to realistic model.

4.2 Laser scanning

Figure 7 shows the point cloud collected with the laser scanner in Lucillo petroglyphs (Astorga, Spain). Left image shows the 3D model generated from two different point clouds, initially composed of 5.8 million points and 2.8 million points, with an angular resolution of 0.002º. After post processing the point cloud was reduced to a homogenized point cloud where triangulation was performed.

Once the 3D polygonal model was completed, the textures registered by the digital camera were projected over the 3D model. Finally, orthoimages of the main planes of the petroglyphs were produced, as can be seen in figure 7.b).



(a) (b)

Figure 7: 3D model (a), and orthoimage (b) of Lucillo petroglyphs (Astorga, Spain).

5. CONCLUSIONS

This paper shows two innovative and non-invasive methodologies focused on the documentation of rock art, mainly petroglyphs. These methods are based on the principles of close range photogrammetry and terrestrial laser scanning that allow collecting geometric and radiometric information of the archaeological elements without any alteration in the physic or chemical state of the element.

Based on the results showed in the present work, close range photogrammetry presents a great potential for the documentation of petroglyphs. High metric precision and textural information, combined with low cost equipment are the main advantages of this methodology.

Terrestrial laser scanning also produces high quality results in terms of metric accuracy and textures, and its applicability in rock art recording is recommended due to the amount of information that these instruments are able to collect in short periods of time, and the high resolution of these instruments, which allows the recording of very small details accurately.

Acknowledgments

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