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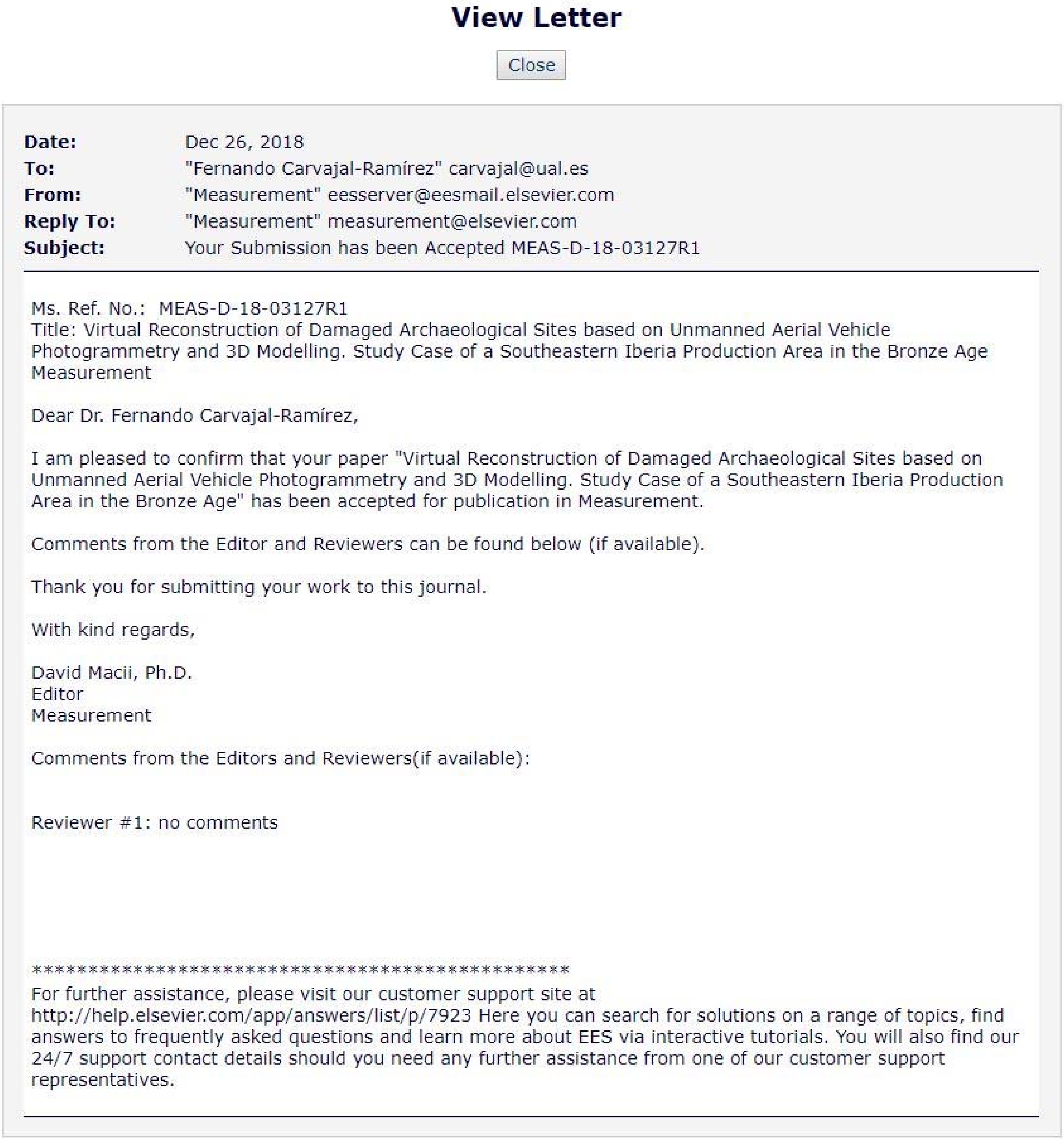

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# Virtual Reconstruction of Damaged Archaeological Sites based on Unmanned Aerial Vehicle Photogrammetry and 3D Modelling. Study Case of a Southeastern Iberia Production Area in the Bronze Age

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**Abstract:** Knowledge about cultural and archaeological heritage can dissolve or even disappear with the passage of time, especially when the protection level of the archaeological site is weak.

The recent development of techniques based on remote sensing from remotely controlled light platforms, so-called Unmanned Aerial Vehicles (UAV) or drones, carrying sensors in visible and other spectral ranges, allows to measure efficiently the current surface morphology of a damaged archaeological site.

In this work, a deteriorated and unique archaeological site due its chronological and functional singularity was chosen as the study case. Mound structures made of stone, interconnected one to each other in a regular network, covered by vaults, and well adapted to a smooth slope topography have no known precedents in the Iberian Peninsula in the Bronze Age. Nowadays, this site is seriously damaged, and its protection level by the administrations is weak. Nevertheless, two archaeological campaigns were carried out recording interesting information.

A UAV-Photogrammetry project based on Structure from Motion (SfM) and Multi-View Stereopsis (MVS) algorithms was applied to model the surface terrain where the structural basis and connection channels were built, obtaining a dense point cloud, an orthoimage and a Digital Surface Model (DSM). The topographic data covering altered areas were removed from the dense point cloud, and then a new interpolated surface was obtained representing the unaltered morphology.

Finally, the information recorded in the archaeological campaigns was materialised in a virtual reconstruction located between both surfaces, measured by UAV-Photogrammetry and interpolated, and then the original architectural complex in its context was recreated and shared with the scientific community through Google Earth, contributing to recovering and preserving this cultural heritage, even after its disappearance.

**Keywords:** Unmanned Aerial Vehicle Photogrammetry, Bronze Age, 3D modelling

## 1. Introduction

The acquisition of graphic data is a critical process in archaeological campaigns, especially in those sites where materials have been disturbed by human actions. When walls or structures made of stones appear partially destroyed, scientists and technicians have to focus on developing a hypothesis about the original geometry and use of the archaeological materials. Recently, Unmanned Aerial Vehicle Photogrammetry (UAV-Ph) has become an efficient and low-cost technique to acquire high-quality cartographic and geometric information [1], needed for 3D modelling and virtual reconstruction of archaeological sites [2–7].

UAVs are designed to carry on board a broad variety of sensors including digital cameras that record radiation in visible, thermal and multispectral spectra [8]. One of the most interesting characteristic of UAVs is their flexibility to adopt the needed scale to achieve high-accuracy cartographic products through the variation of flight heights and the possibility to orient the images orthogonally to the target surfaces [9].

In order to reference the cartography to a universal reference system and to obtain quality control of the cartography, a survey campaign has to be carried out previous to UAV flights. A set of control points were targeted and their locations measured using high accuracy survey equipment. The recent photogrammetric algorithms known as Structure from Motion (SfM) [10] and Multi-View Stereopsis (MVS) [11] allow to reduce significantly the time required for the survey campaign, the absolute orientation process [12,13], the post-processing and the computing time. Nevertheless, the characteristics of each UAV-Ph project have to be set according to the specifications for each prospection project.

Recent studies have been carried out using UAV imagery and SfM/MVS techniques for archaeological documentation and material detection purposes [14–17]. A detailed review of 3D techniques applied in the archaeological field was collected by [2]. In particular, archaeological structures have been accurately characterised using UAV-Ph in the cases of a medieval wall [18], archaeological buried structures [19] and Neolithic stone tool production [20]. The geometric information obtained was applied to 3D modelling and reconstruction in several cases of cave geometry [21], or an ancient Turkish theatre [22].

Cortijo Nuevo is an archaeological site located in an intensive agricultural zone in southeastern Spain, in the Almería province, with an area of 68,000 m$^2$. According to [23] this site is chronologically and functionally unique. Mound structures made of stone, interconnected one to each other in a regular network, and well adapted to the smooth slope topography have no known precedents in the Iberian Peninsula in the Bronze Age. The site is currently very disturbed, owing to its closeness to human and agricultural activities, official protection level reduced by judicial sentence and intentional looting carried out even when the protection level by the government was still high.

The remains of some structures and other materials can currently be observed as a result of excavations of the terrain in the northern zone of the site, the discovery of an interesting profile, and a mixture of materials moved towards the southern zone. Nevertheless, the network of structures was damaged, and the slope of the natural talus was altered.

Two archaeological campaigns were carried out in the 1970s and 1990s by local authorities, where materials were studied and recorded before and after the severe disturbance of the site. A hypothesis about the geometry and functionality of this archaeological site, based on evidence of both campaigns and additional information, was developed by [23]. The graphical information was limited to some pictures and digitised drawings in the archaeological campaigns.

Thanks to latest technology based on Unmanned Aerial Vehicle Photogrammetry (UAV-Ph), the high-accuracy cartography needed to represent the morphology of the archaeological remains can be generated in an efficient and low-cost manner [9,24–26].

The aim of this work was to stablish of the most appropriate methodology for virtual 3D reconstruction of damaged archaeological sites comprising, construction or building structures, based on high-quality cartography obtained from UAV-Ph, and then applying this to the case study of Cortijo Nuevo, Almería (Spain). The highlights of this work were the development and methodologic adaptation of Remote Sensing well-known technology to a scale level of an archaeological site like Cortijo Nuevo, and the use of virtual reconstruction of damaged this unique archaeological site for cultural heritage conservation purpose.

## 2. Materials and Methods

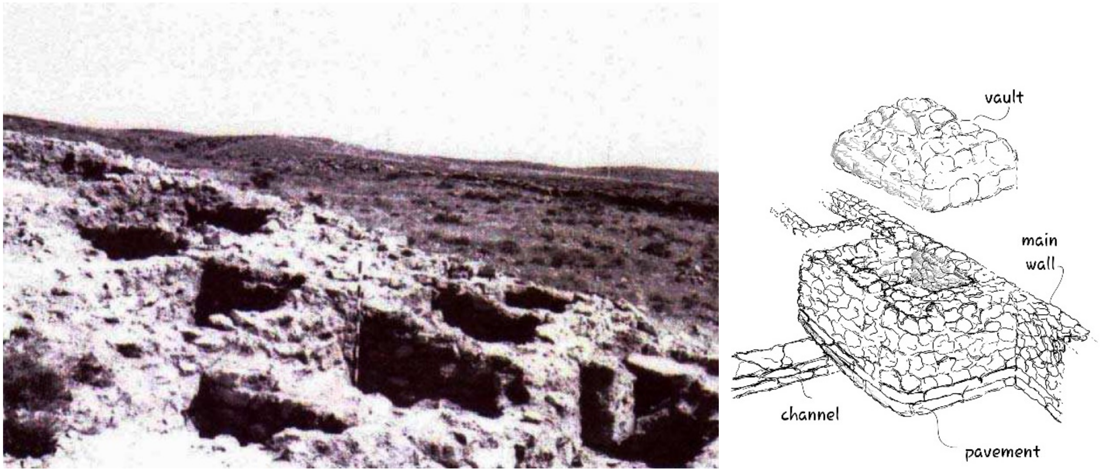
### 2.1. Study Area

The studied archeological site is located in Almeria province, southeastern Spain, with geographic coordinates 36°49'24.5"N latitude, 2°13'59"W longitude. Almería province has evidences of ancient societies including remains of Roman establishment, salt extraction mines and coastal infrastructures, an Islamic city with necropolis, defensive walls and fortress [23]. Cortijo Nuevo is delimited by an area of 22,360 m$^2$ approximately, close to Rambla Morales and Ruescas (Figure 1).

**Figure 1.** Study area. The location of Cortijo Nuevo is now in a greenhouse intensive agriculture zone.

This site is in a natural drainage system leading to the Mediterranean Sea formed in Early Pleistocene, which nowadays has ecological significance [27], 2 km from the Barranquete Necropolis, which belongs to third century BC. According to [28], the settlement of Cortijo Nuevo consists of an architectural complex belonging to second century BC and dedicated to some productive activity related to maritime traffic flow, due its strategic location with respect to Rambla Morales, the Mediterranean Sea and livestock paths. It represents typical coastal geomorphology with a slope of a 13%. This archaeological site is unique to Iberian Peninsula prehistory because there is no knowledge about any other examples of similar building structures [23].

Two official archaeological campaigns were carried out in 1977 [29] and 1997 [23]. Despite the terrain surface being quite altered from one campaign to the other, no cartographic information was generated in either case. The discovered archaeological structures were defined as an architectural complex on a grid. A total of 17 interconnected structures were documented, and 14 of them excavated, comprising quadrangular bases and areas from 1.53 m$^2$ to 3.53 m$^2$. The bases and walls were made of local limestones, and the heights of the walls were from 0.5 m to 1.92 m. These structures were covered by a vault or tumular also made of limestones. The bases of the structures was originally supported directly upon the geological terrain, in four levels on the hillside (Figure 2a).



(**a**) (**b**)

**Figure 2. (a)** Architectural complex in Cortijo Nuevo archaeological site in 1979. **(b)** Details of one of the structures.

From the top to the lower zone of the slope, 2, 2, 3, 3 and 4 structures were located at five separate levels, adapted to the original terrain orography. Furthermore, the area of the bases and heights of the walls were larger according to the increased terrain heights. The building technique is homogeneous in all the structures and is based on the use of large pieces of limestone mortared with mud for the base and two lower swathes of the walls which are followed by medium-sized pieces of limestone, also engaged with mud, for the rest of the walls and the vault. Four continuous walls were built following the maximum slope direction, and then the structures were joined to the main wall (Figure 2b).

The structures laying on the same level are connected by a channel that crosses the base under the pavement following the contour. These 30 cm-wide channels are not impermeable and are made of large and flat limestones engaged with mud. Regarding the protection level of this singular archeological site, several events occurred that are shown by the timeline of Figure 3.

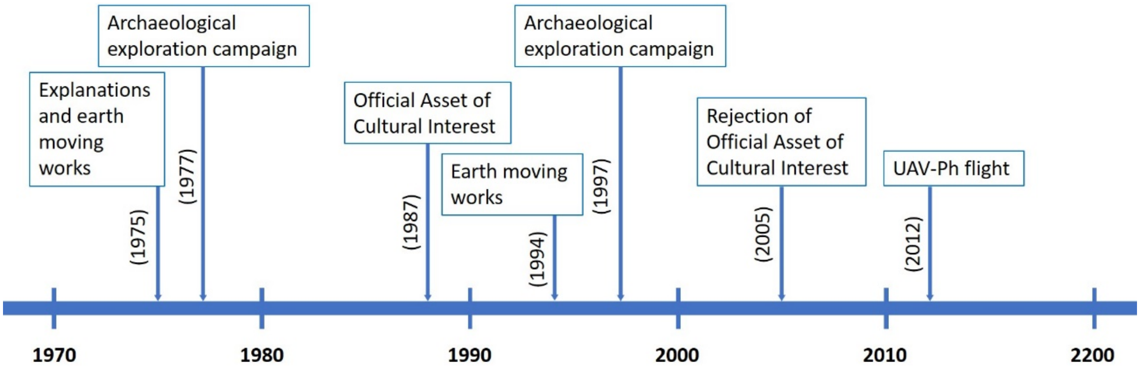
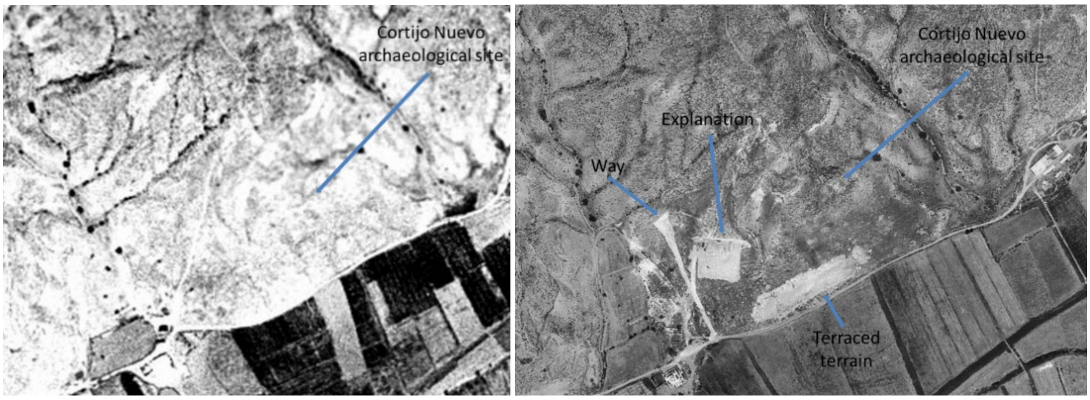


**Figure 3.** Timeline of Cortijo Nuevo archaeological site.

In the mid-1970s, some damages in Cortijo Nuevo and surroundings were reported, and the earthworks for building a new house in 1975. Development of agricultural activity can be detected by comparing official cartography made by the Government of the United States, after the Spanish Civil War, between 1956 and 1957 and the photogrammetric flight carried out by the Spanish Government in 1977 (see Figure 4).

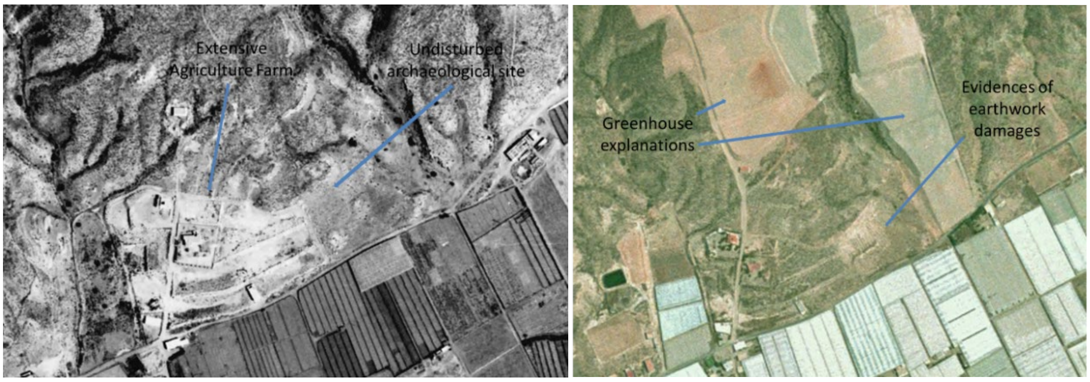


(**a**) (**b**)

**Figure 4.** **(a)** Official Cartography made in 1956–1957. **(b)** Photogrammetric flight made in 1977.

Consequently, this same year 1977, an Official Archaeological Campaign was carried out, in which the structures were excavated and documented by [29], and ten years later the Official Asset of Cultural Interest was declared.

A few years after the declaration of high protection level, in 1994 the structures were severely damaged by a drilling machine, which was reported to the authorities. Figure 5a shows an official orthoimage made by the Spanish Government where extensive agriculture infrastructures have been developed close to the site, but the structures were not altered in 1984–1985. Figures 5b and 5c show evidence of the damage and new leveling for intensive agricultural activity, observed in the RGB orthoimage obtained by the Andalusian Government in 1998–1999 and on the site respectively.



(**a**) (**b**)

(**c**)

**Figure 5.** **(a)** Photogrammetric flight made in 1984–1985. **(b)** RGB orthoimage made in 1998–1999. **(c)** Altered front slope. Evidence of structures at present.

As a consequence of reporting about the damage caused by the earthworks on the structures, a new archaeological campaign was carried out by the authorities in 1997 [23]. At this time, a rigorous study documented the materials including ceramics, fauna, carpology and chronology, but sadly all the structures were seriously damaged or destroyed in most cases.

Furthermore, the heritage protection level of the archaeological site was rejected in 2005 by the sentence of the Supreme Court of Justice of Andalusia, and nowadays the asset is only protected by a local municipal regulation of Almeria.

In 2012 a UAV-Ph project and a corresponding survey campaign were carried out by our research group with the aim of geomorphological characterisation of the disturbed terrain in Cortijo Nuevo, obtaining a dense point cloud, a Digital Surface Model of the terrain (DSM) and an orthoimage. All these digital cartographic products have been used to derive the morphology of the original terrain and reproduce the architectural complex located at its original location and represented by a 3D virtual reconstruction.

### *2.2. Unmanned Aerial Vehicle, Sensor, Control Base Station and Surveying Device*

A rotary-wing quadcopter UAV was used, model Microdrones md4-200 [30], with programmable capabilities for flight routes and actions at each waypoint on the flight. The payload is a maximum of 200 g, enough for carrying a compact digital camera, model Pentax Optio A40, with 12 megapixels, and the gimbal that stabilises the camera (Figure 6).


(**a**) (**b**)

**Figure 6.** (**a**) Microdrones md4-200. **(b)** Detail of digital camera Pentax Optio A40 and gimbal on board.

The base station and UAV were linked by a standard data radio communication. The technical specifications of the UAV include navigation based on GNSS, gyroscopes, altimeter and magnetic compass data from which are registered during flight operation. Orientations and positions of the camera at each waypoint are used in the photogrammetric processing of the acquired images.

In order to assign a Universal Coordinate System to all the cartographic products obtained from the UAV-Ph project, and to carry out a quality control, a set of targeted control points was measured using a Trimble R6 GPS Receiver [31] in Real-Time Kinematic mode (RTK), followed by post-processing with the time data corrections saved at Torrecádenas Hospital Station, belonging to the Andalusian Positioning Network (RAP) [32].

### *2.3. Photogrammetric and 3D Virtual Reconstruction Software*

Both flight routes and flight control of the UAV were planned and programmed using mdCockpit Standard Edition v. 2.8.0.6 [30], software which is compatible with the Microdrones UAV.

All the data collected in the survey campaign was managed through Trimble Geomatics Office, software for post-processing and topographic modelling [31].

The photogrammetric project was processed using Agisoft PhotoScan Profesional Edition v. 1.2.2 [33], a low-cost software based on the SfM algorithm [10] designed for close-range photogrammetric projects [8].

Once the point cloud, DSM and orthoimage were obtained, a new terrain surface was interpolated, based on the undisturbed areas of the current DSM, representing the terrain prior to the earthworks in 1979. This interpolation was done through Autodesk Civil 3D v. 2017 [34], a software applications developed for management of terrain surfaces and earthworks in civil engineering.

The virtual reconstruction of the architectural complex was carried out using the 3D tools available in AutoCAD v. 2017 [35].

### *2.4. Flight Route Planning*

The target area to be covered by the photogrammetric flight was close to 2.2 ha and is located at the main damage to the architectural complex. Figure 7 shows the evidence of the cutting, drilling marks and the unaltered terrain surface in the northwest of the site. The limits of the flight area were the dividing line of the natural slope at the north, the road at the south, the watercourse axis at the east and the terraced plot at the west.

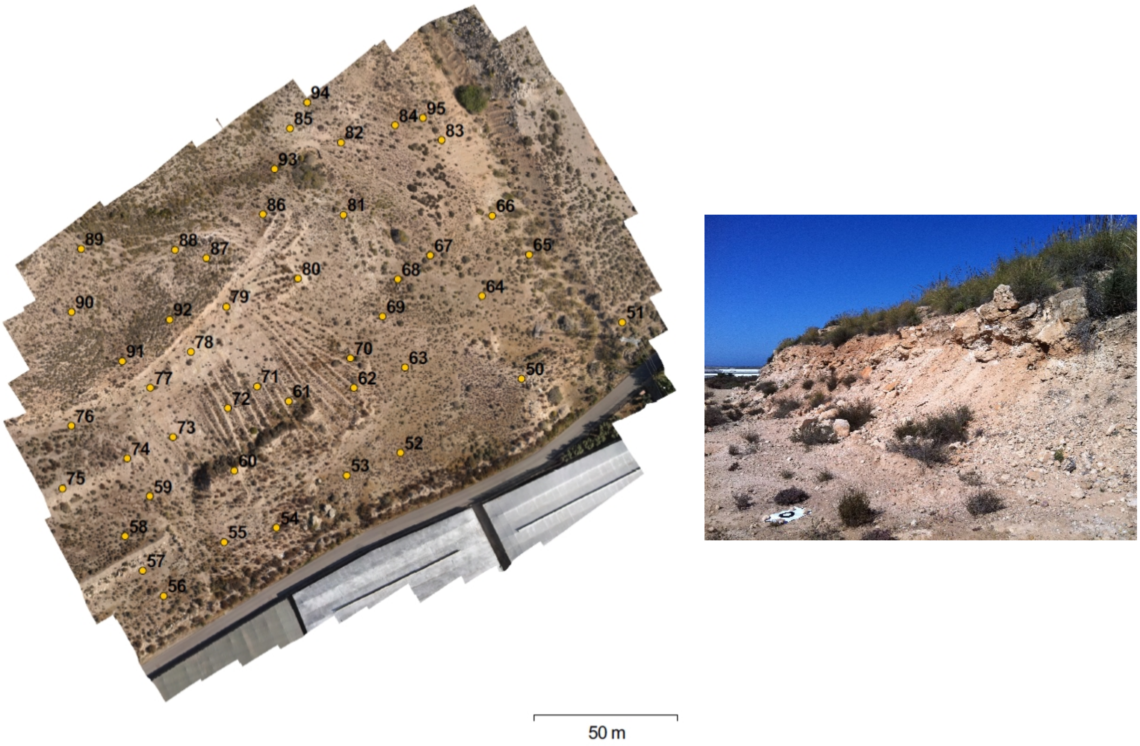
**Figure 7.** Target area to be covered by the photogrammetric flight and the two central paths of flight.

The initial point of the flight was established on the highest point on the site, and the longitudinal and transversal overlaps between consecutive images set at 75%. According to the field of view of the sensor and the overlaps, the flight consisted of six paths aligned with the large dimension of the site, separated by a distance of 12 m, each with 11 waypoints. The height of flight was 80 m over the initial point, which is 20.12 m above sea level. The total flight route was 1200 m, and the flight time was close to 21 min due to the speed of the UAV and the stabilisation time over each waypoint where three images were taken. Then a total amount of 66 images were selected to avoid blurr effects, occurring at each waypoint. The entire flight operation was carried out automatically by the programmed UAV, except landing and take-off manoeuvres, in the presence of wind speed close to 5.1 m/s from south.

### *2.5. Survey Campaign*

The survey campaign consisted of the measurement of a total amount of 46 targeted points (Figure 8a), 13 of which were used in the orientation process (Ground Control Points, GCPs) and 33 for statistical characterisation of errors included in point clouds, DSM, and orthoimage (Check Points, CPs) according to the criteria established by [36], [25], and [9]. The targeted points were A4 in size.

The ground station from where the corrections were saved during the campaign was at Torrecárdenas Hospital, belonging to the Andalusian Positioning Network (RAP) [32], 19.2 km away from the studied area. These corrections were applied in post-processing to the measured coordinates of the targeted points in the RTK process (Figure 8b), based on the Universal Transverse Mercator UTM coordinate system, located in northern hemisphere, zone 30. The European Datum 1950 with the geoidal model Ibergeo was used.



(**a**) (**b**)

**Figure 8. (a)** Distribution of target points of the survey campaign. **(b)** Northern profile at Cortijo Nuevo archaeological site. Details of one of the target points.

### *2.6. Photogrammetric Algorithm*

SfM and MVS are well-known techniques that integrate computer vision and image analysis and are able to solve the position and camera orientations [10,37] and the geometry of a 3D scene without previously specifying a network of targeted points with known coordinates [38]. The 3D geometry is derived from the multiple overlapping images based on MVS, which is one of the most robust techniques, especially when images present large variations in scale and point of view [39,40].

The accuracy of 3D models obtained from photogrammetric methods is directly influenced by the texture and contrast recorded in the images which is a function of the flying height, the focal length and resolution of the camera, illumination conditions and speed of UAV. Specifically, SfM and MVS 3D reconstruction have been shown as adequate for high-precision archaeological characterisation. E.g. [41] compared Euclidean distances between measurement positions of featured points and their coordinates obtained by SfM, resulting in an average standard deviation of 0.004 m.

## 3. Results

### *3.1. Photogrammetric products*

Once 66 images free of blurr effects were selected, the alignment assessment was carried out through the SfM algorithm, estimating camera position and orientation for each image, and obtaining a sparse point cloud that includes matches of corresponding points in any two images and an initial 3D model without scale or coordinates in a known system (Figure 9).

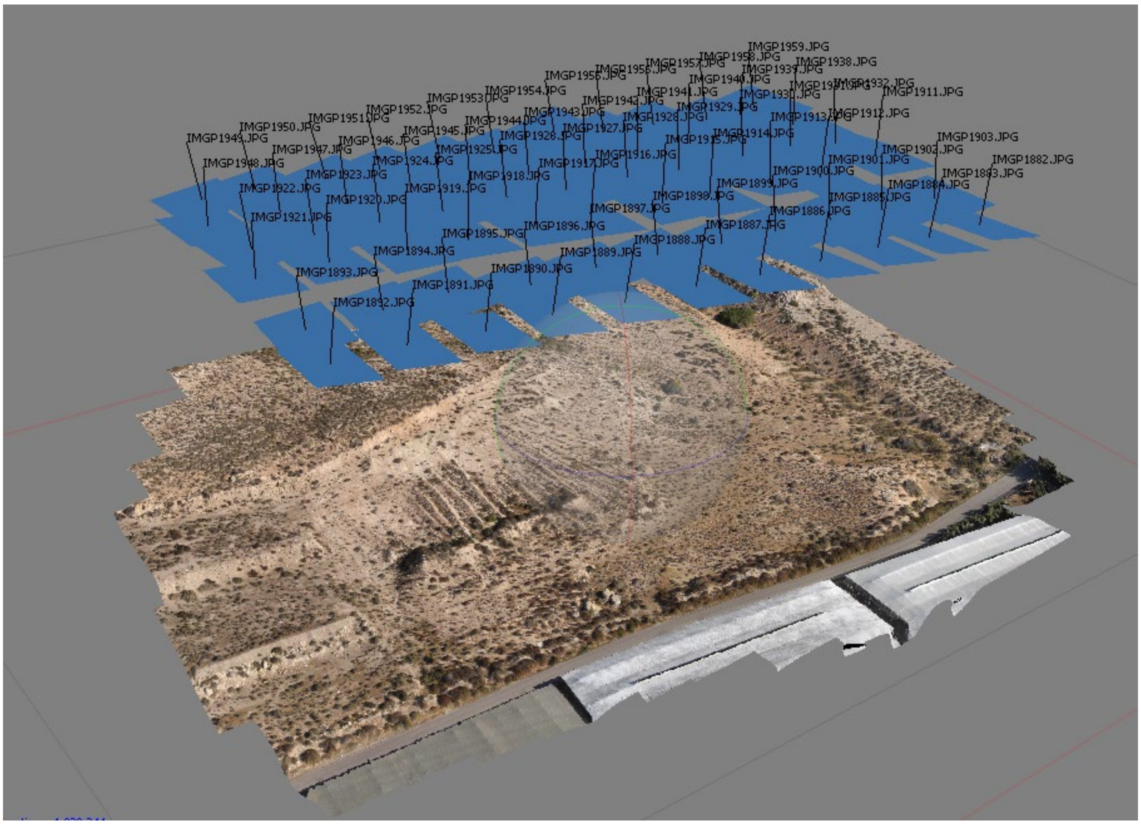


**Figure 9.** Unoriented and unscaled 3D model resulting from the alignment process of 66 images.

Previously, both internal and external camera orientation parameters were estimated. Typically calibration reports include focal length, format size and lens distortions of the camera according to the field calibration method [1,42]. Table 1 shows the obtained results.

**Table 1.** Calibration report of Pentax Optio A40 camera after field calibration post-processing.

| | | |
|---|---|---|
| Focal length (mm) | | 7.934 |
| Format size (mm) | | 7.196 × 5.397 |
| Principal point (mm) | | 3.587, 2.565 |
| Radial distortion function parameters | K1 | −0.183711 |
| | K2 | 0.109743 |
| | K3 | 0.0895092 |
| Decentring distortion function parameters | P1 | −0.000203794 |
| | P2 | −0.00353266 |

In order to set the Coordinate Reference System and scale to all the products resulting from the photogrammetric project, the measured coordinates of at least three points of the scene should be specified. In this project, 16 targets points were designated as GCPs and identified in all the images in which they appeared (Figure 10) to achieve redundancy and a robust transformation [25]. Determining scale of the photogrammetric products enables for surface area and volume measurements and georeferenced 3D modelling [33].

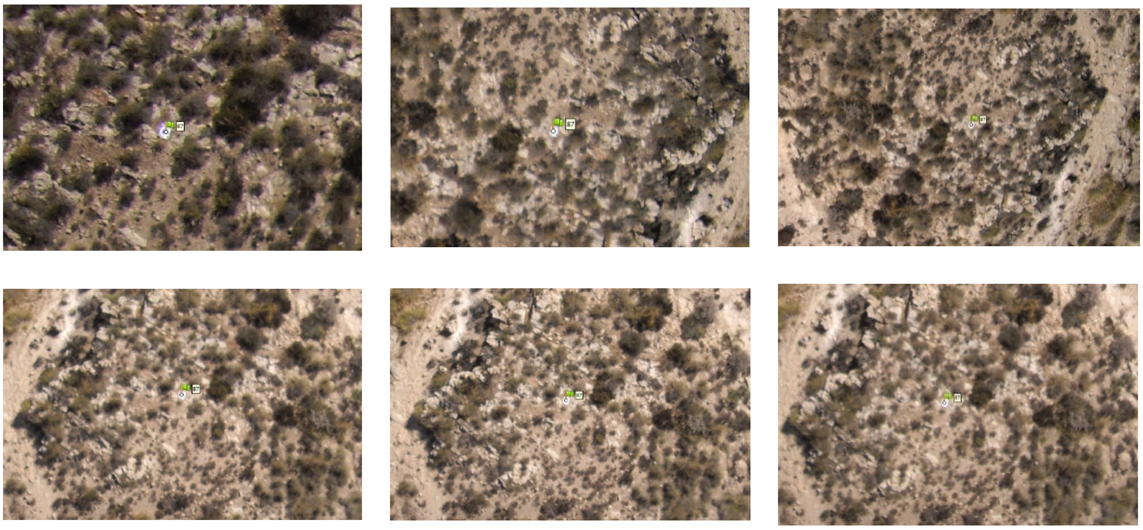
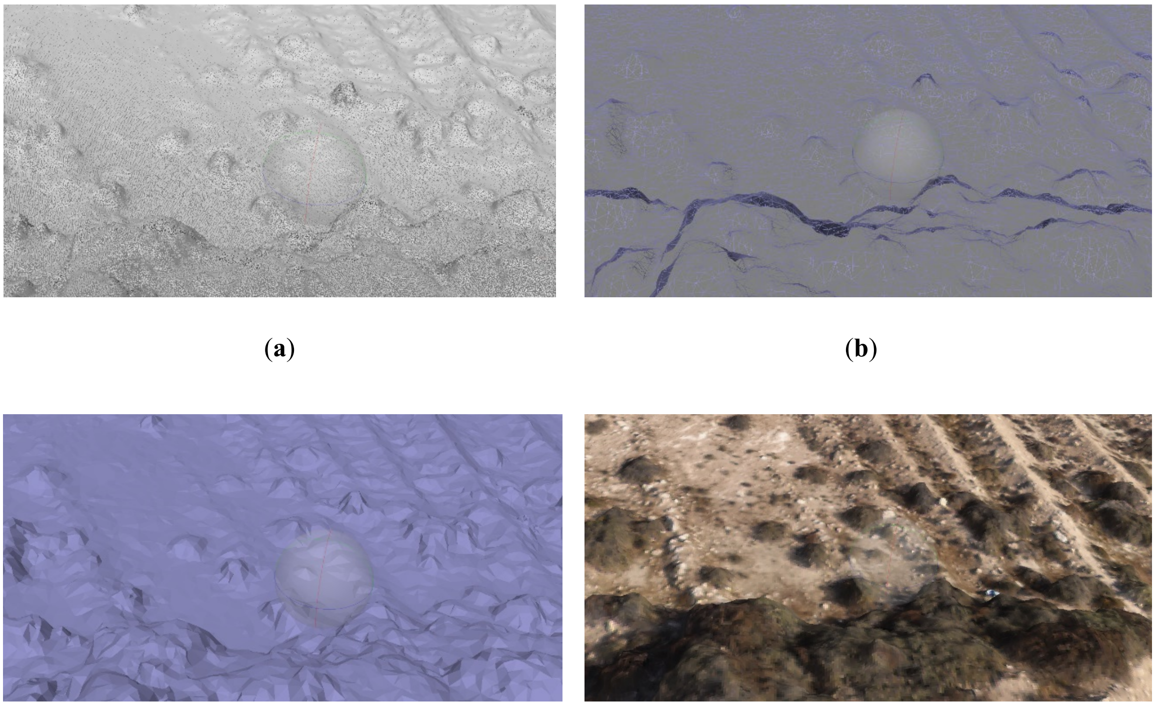


**Figure 10**. Detail of identification of a GCP in all the images where it appears.

Based on the estimated camera positions, a dense point cloud of more than 31 million points was obtained, distributed throughout the archaeological site. After editing and noise filtering, a Triangulated Irregular Network (TIN), was derived in which more than 2 million facets connecting neighboring points of the cloud. The next process was to assign texture to the TIN, extracting the RGB coordinates of each of the facets from the taken images (Figure 11).



(**a**) (**b**)

(**c**) (**d**)

**Figure 11.** Perspective of a detail of the archaeological site: (**a**) dense cloud; (**b**) triangulated irregular network (TIN); (**c**) mesh surface; (**d**) textured surface.

A Digital Surface Model (DSM) and orthoimages are two of the most useful photogrammetric products for 3D surface representation. The DSM was obtained interpolating a grid from the TIN, with a separation of 0.04 m, by the radial basis function method [1,43].

The orthoimage was the result of both a orthogonal projection of the photogrammetric model over the sea level surface based on the topography of the DSM, and an interpolation process by the nearest neighbour method [44] for deriving missing data between projected information, with a resulting ground sample distance of 0.02 m. Figure 12 shows a hypsometric DSM representation and the orthoimage with overlapped 2 m contours.

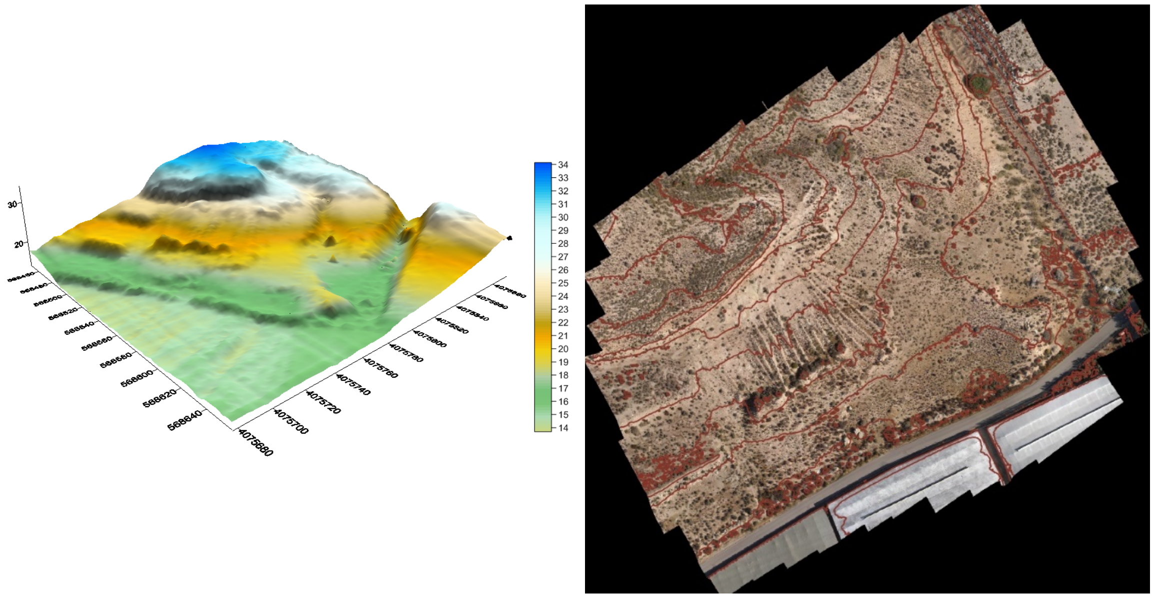


**Figure 12.** (**a**) DMS of the archaeological site with elevation referring to height above sea level, in m. (**b**) Orthoimage with overlapped contours, each 2 m.

## 3.2. Quality control

Root Mean Squared Error (RMSE) is one of the most used statistical measures for estimating accuracy of the photogrammetric products, e.g. DSM, point cloud and orthoimages [45–47]. Observed coordinates of the 33 CPs measured in the survey campaign with the high-precision GNSS device were compared to those coordinates obtained from the photogrammetric project in the same locations. The number and distribution of CPs were previously established to be a representative sample of the surface morphology at a certain confidence level.

Due to the orthoimage containing only planimetric information and the DSM and point cloud containing both planimetric and elevation information, horizontal and vertical component RMSExy and RMSEz respectively were calculated through equations (1) and (2) and integrated as a total error.

$$RMSE_{xy} = \sqrt{RMSE_x^2 + RMSE_y^2} = \sqrt{\frac{(Ex_1^2 + \cdots + Ex_{N-3}^2) + (Ey_1^2 + \cdots + Ey_{N-3}^2)}{N-3}} \tag{1}$$

where N is the total number of CPs, 33 in this work, and $Ex_i$ and $Ey_i$ are the differences between the observed planimetric coordinates and those obtained from the orthoimage at the i-order CP, respectively.

$$RMSE_z = \sqrt{\frac{Ez_1^2 + \cdots + Ez_{N-3}^2}{N-3}} \tag{2}$$

where $Ez_i$ represents the difference between the observed Z coordinates measured with GNSS and the Z coordinates obtained from the DSM at the i-order CP.

The results were RMSExy = 0.0246 m, RMSEz = 0.0262 m and the total error or vector sum of 0.0359 m.

### *3.3. Unaltered surface interpolation*

Once the terrain surface was modelled through UAV-Photogrammetry, a new surface was interpolated based on those areas without evidence of modification by the excavator machine.

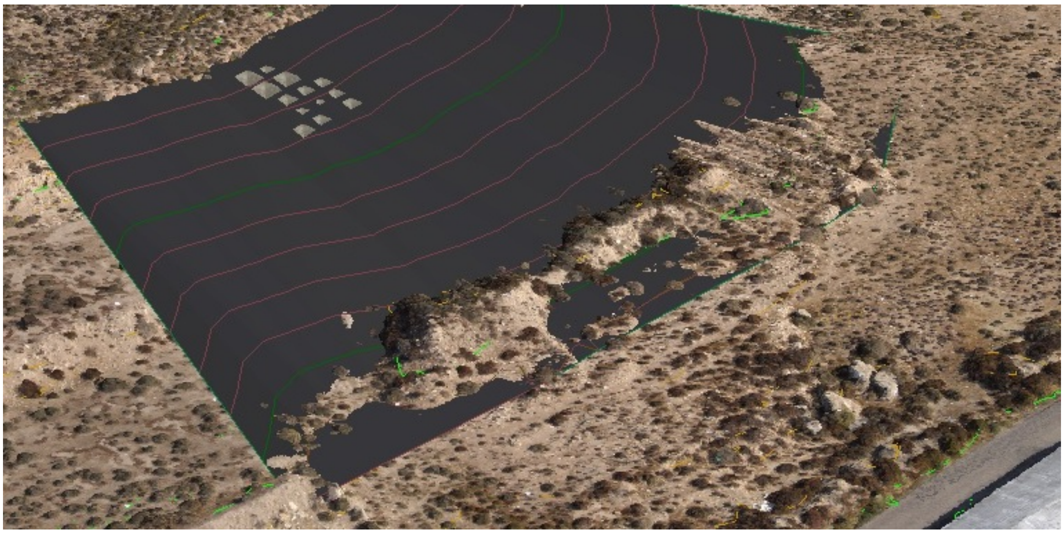
It was assumed that the ground level after the mechanical alteration in 1994 coincides with the construction base of the structures, according to [23].

More than 4.9 million points belonging to altered areas were removed from the 31 million points of the dense point cloud produced by photogrammetry. Applying the Delaunay triangulation [1] over this new point cloud, a TIN surface was obtained in which no one point is located inside the circumscribed circumference to any triangle. The average slope of the resulting surface was close to 13%, and orography matched the description of the site before alterations [29].

### *3.4. Architectural complex 3D model*

The architectural of the complex including structures, vaults and interconnection channels was represented according to descriptions registered in both archaeological campaigns [23,29] and based on the evidence obtained by UAV-Photogrammetry about current and past terrain morphology of the archaeological site. The surface of the bases and the depth of the structures used for the 3D model were measured in the excavation works. A total of 13 structures well-adapted to the geologic slope were distributed in five levels, containing 4, 3, 3, 2 and 2 structures respectively, from the lower to higher elevations (Figure 13). The bases of all the structures over the geological terrain were represented by the point cloud obtained by UAV-Photogrammetry, while tops of the structures were based on the unaltered level terrain, represented by the interpolated TIN. The vaults appear above the the ground level where the site is unaltered, and the interconnections between bottoms of structures at the same level are aligned with the contours. All the virtual structures were covered with a texture of limestones engaged with mud.

(**a**)



(**b**)

**Figure 13.** (**a**) Architectural structure model overlapped with point cloud obtained from UAV-Photogrammetric representation the current altered surface. (**b**) New TIN surface interpolated representing the original terrain morphology, with 1-m contours. Vaults can be observed over the slope level.

In order to share the 3D model of the archaeological site with the scientific community, the 3D model of the architectural complex, surfaces and environs was exported using a Google Earth standard file of interchange, with KMZ extension.

## 4. Discussion

The three typical photogrammetric products, DSM, orthoimages and point clouds, were obtained in this work following a similar methodology to other kind of applications described by several authors (e.g [8], [10], [39]), but with archaeological purposes. Regarding their application possibilities, point clouds let to record the current 3D position of all the elements of an archaeological site with very high accuracy, DSM are used as the basis for virtual models through texturing process and orthoimages can be used for measurement purposes due its metric characteristics.

Recently, some works have been carried out with an archeological objective with a similar magnitude to Cortijo Nuevo. [18] presented a digital reproduction of the original structure of the mediaeval wall in Pontevedra using close-range digital photogrammetry as well as orthophotos, which thoroughly documented the dimensional and textural characteristics of the archaeological site. [14] applied UAV-Photogrammetry in an excavation of a site containing ancient tombs which included several uncovered objects in the Nasca region in Peru and the Maya site of Copán in Honduras.

The original terrain morphology in Cortijo Nuevo was modeled and graphically represented, based on the morphology after several lootings and damages, based on those measured by UAV-Photogrammetry and on information recorded in two old archeological campaigns. [16] undertook a similar kind of data integration, using low-altitude aerial photography, showing the drawbacks and advantages in archaeological researching, concluding that the use of UAVs will increase in future.

The quality control applied to the derived photogrammetric products revelated a horizontal error of 0.0246 m, a vertical error of 0.0262 m and a total error of 0.0359 m. These values are in accord with several applications studied by [48] who compared 10 cases of 3D topographic reconstructions based on the SfM algorithm with similar conditions to those in this archaeological site. In all the cases the precision of measurements was on the order of centimeters.

The virtual reality technique used in this work for reconstruction the architectural complex and the original surface have been applied in several fields [49]. The shape, geometry and texture of the structures were reproduced and integrated with the virtual interpolated surface. [50] demonstrated an integration of high-resolution spherical panoramas, a variety of maps, GNSS, sound, video, and text information for representation of numerous cultural heritage objects located in Bulgaria. Regarding to the texture, [51] provide a discussion of three implementations, demonstrating advantages and disadvantages of different system designs for texture measurement.

The heritage recovering and conservation carried out in this work through the virtual model of the archaeological site was applied too by [21] in a cave for paleolithic rock art and by [22] in Assus Ancient Theater located in Turkey.

## 5. Conclusions

Two types of conclusions were derived from this work, corresponding to the established objective. UAV-Photogrammetry based on SfM and MVS algorithms resulted in an effective method for measurement and representation of terrain morphology of the archaeological site Cortijo Nuevo in Almeria, Spain, after having been severely damaged by mechanical methods.

The implicit errors of the cartographic products including dense point cloud, orthoimage and DSM were $RMSE_{xy} = 0.0246$ m in planimetry and $RMSE_z = 0.0262$ m in altimetry. This quality allows modelling the current state of the morphology surface of the terrain in the archaeological site, corresponding to the basis of the original architectural complex.

Based on a transformed point cloud, excluding disturbed areas, a surface was interpolated representing the terrain morphology of the archaeological site before mechanical damage. Using both surfaces, measured and interpolated, a rigorous virtual reconstruction of the original state of the architectural complex was carried out through textured solids and surfaces representing walls, connection channels and vaults. The virtual reconstruction has been shared with scientific community in one of the most used and accessible 3D contexts that is Google Earth, contributing to recovering and preserving this cultural heritage, even after its disappearance.

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