Photogrammetric Recording in a Context of Preventive Archaeology : the "Place des Martyrs" Excavation (Algiers, Algeria)

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14th Congress of the Pan-African Archaeological Association for Prehistory and Related Studies
14–18 July 2014, Johannesburg, South Africa

PHOTOGRAMMETRIC RECORDING IN A CONTEXT OF PREVENTIVE ARCHAEOLOGY : THE “PLACE DES MARTYRS” EXCAVATION (ALGIERS, ALGERIA)

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KEY WORDS: Digital Photogrammetry, Preventive Archaeology, GIS, Methodology

ABSTRACT:

The construction of the underground station called *Place des Martyrs* in Algiers required preventive excavation. The context led us to favour recording methods leading to the rapid and exhaustive acquisition of data. Indeed digital photogrammetry made it possible to measure complex elements simply and rapidly. The originality of the solution implemented resided in the use of a free and open-source applications suite dedicated to scientific usage and making it possible to generate 3D models similar to those obtained by lasergrammetry. More than 1500 shots were acquired during this first measurement campaign. Plans and sections were extracted on request from the scatter plot. Tacheometric survey operations were reduced to measuring only control points required for geo-referencing images. The digital photogrammetric survey of such a volume of remains in a preventive archaeological context in an urban environment is to our knowledge unique. The importance of this case study also resided in the use of a fully free and open-source professional applications suite. In the end, this method could be used regularly on other similar excavations.

INTRODUCTION

The extension of the subway network in the city of Algiers is a project that began in 2010 and still ongoing. On the North of this extension, two new stations will be created : the *Ali Boumenjel* and the *Place des Martyrs* stations (fig. 1). The construction of the station *Place des Martyrs* operation requires a preventive excavation. Indeed, the project lies at the foot of the ancient *Casbah* of Algiers. It’s a historic district of the city of Algiers, founded on the ruins of old Icosium. A field evaluation (Stiti 2010) was conducted in 2009 by a Franco-Algerian team under the aegis of UNESCO’s World Heritage Center. It led to the detection of archaeological layers, almost six meters thick, bearing testament to two thousand years of Algiers’ history. The excavation began mid-2013 and involves an area of about 2500 m^2 (fig. 2).
Preventive archeology requires exhaustive recording of huge datasets in a limited period. This context led us to choose rapid recording methods. Digital photogrammetry enables to record complex elements in a simple and costless way. The originality of the implemented solution resides in the use of a free and open-source software suite. It is dedicated to scientific use and can generate three-dimensional models similar to those obtained by laser scanning.

Fig. 1. Extension planned of the underground network (Maxime Seguin, Inrap)

METHODOLOGY

Images were acquired with a Nikon D3200 camera and a 18-55 mm zoom. Only the extreme values of focal lengths were used. The table 1 shows the characteristics of the material used.

Camera / Lens	Specifications
Nikon D3200	24,2 megapixel CMOS sensor size : 23,2 x 15,4 mm
AF-S DX NIKKOR 18-55 mm VR	Focal lengths : 18 and 55 mm

Tab. 1. Camera and lenses specifications

This type of camera allows use in manual mode. This last point is very important ; it will help to maintain the same optical configuration throughout the acquisition and will determine the quality of the result. The photographs were recorded directly in RAW format so that they do not suffer a loss of quality. They were then developed to TIFF format before computing. The *Pastis-Apero-MicMac* software suite has been used to calculate and georeference point clouds and orthophotographies. Data exploitation was performed with *CloudCompare* (CloudCompare 2014) software.

Pastis - Apero - MicMac

The *Matis* [1] laboratory of French National Geographic Institute (IGN) has developed a software package dedicated to photogrammetry. This software is free and under open-source license (MicMac 2014). They are well documented and have an active community of developers and users. A three-dimensional model is obtained via three programs : *Pastis*, *Apero* and *MicMac*.
Pastis is an acronym for “Program using Autopano Sift for Tiepoint detection in the ImageS”. This software calculates the corresponding points between the images. It uses a variation of the

1. Méthodes d’Analyses pour le Traitement d’Images et la Stéréorestitution

Fig. 2. Excavation site (Cécile Martinez, Inrap)

algorithm SIFT[2] (Lowe 2004), modified to be able to process images of large size. The calculation can be performed indiscriminately on the set of images, but can also be optimized by specifying the acquisition strategy.
Apero (Pierro-Deseilligny 2011) is an acronym for "Relatively Operational Experimental Photogrammetric aerial triangulation". It calculates the internal and external orientations of cameras from the tie points detected by *Pastis*. It can also take into account other information such as the ground control points to perform georeferencing.
MicMac (Pierrot-Deseilligny 2007) is an acronym for "Multi-Image Matches and Methods of Auto Correlation". This module performs dense correlation with previously oriented images. It is based on a pyramidal approach using a function of energy minimization. The multi-resolution implementation speeds up the calculation. Indeed, results of low resolution are used as initial solution for the next step of the calculation at a higher resolution.

Data Acquisition

The excavation is documented with conventional techniques by topographic surveys, manual drawings and photographs. But the amount of built structures and their complexity make it difficult for a classical recording with the very short time allowed (fig. 3). The objective was to perform a full close-range photogrammetric survey of elevated structures, in order to record and document them as quickly as possible. It was also necessary to perform an aerial photogrammetric survey in order to complete the topographic survey and classical drawing operations (stone by stone). Using a UAV (Unmanned Aerial Vehicle) was unthinkable for security issues and administrative permissions. Platform of the building company crane was used to make the aerial survey of the site. A pole was also used to perform a more detailed vertical recording of certain items.
The pole is initially designed to sound recording. It is equipped with a two axes head permitting to correctly adjust the vertical position of the camera. It has the advantage of being handy and light, allowing the activation of a remote triggering system while holding the pole in position. It was not necessary to have a return video to the ground on the acquisition. The height of shooting and the focal length allow us to ensure a resolution of about 1 mm.
Most images were acquired on the ground with a focal length of 18 mm, in order to reduce the amount of data. When the distance was adequate, pictures were taken at a focal length of 55 mm. Paper targets were glued on some walls to serve as ground control points. They were used in the bundle adjustment process. It was not necessary to use natural points as ground control points because all parts of the structures were accessible. These points have been documented on record sheet and were measured precisely by topographic survey.
To have uniform illumination, most images were taken early in the morning or late in the afternoon. The presence of shadows may disrupt the correlation calculation and induce contrast making the finale images unaesthetic.
Finally a total of 1500 photographs were acquired during the first measurement campaign. Indeed, to generate point clouds from images, the correlation technique needs a ratio B/H (base over distance to the photographed scene) around 0.2. This is what partly explains the high number of images.

Fig. 3. Aerial view of Ottoman vestiges (Maxime Seguin, Inrap)

Data Processing

Images acquired were designed to produce an extremely dense three-dimensional model and various orthophotographies. They were acquired at approximately 1.5 m from structures.
Corresponding points were extracted with *Pastis*. Before that, the images in RAW format were converted to TIFF format 8-bit and 16-bit, and then sub-sampled with a factor of 0.4. The high overlap between images generated a large number of tie points. This large number of tie points resulted in a long computation time. The bundle adjustment has produced good results : an average image residual of 0.5 pixels.
The entire block of images (fig. 4) has been georeferenced in the Northern Sahara Lambert map projection. Ground control points were measured directly in the images using the graphical interface of the software suite. The absolute orientation has produced an average ground control points residuals of 3 millimeters.
MicMac was then used to produce depth maps which were then

2. Scale-Invariant Feature Transform

converted to point cloud. It is normally recommended to use the largest number of available images to calculate a depth map. But in our case, the images dataset was so large that it was chosen to optimize the number of images used for the correlation. After various tests it has been found that 3 to 5 images were enough to obtain a result with an acceptable level of noise. *MicMac* has the advantage of being highly configurable, allowing in this case to change the default values of some parameters to improve the final result.

The depth maps can be computed in different ways : ”cartographic” geometry, suitable for aerial survey, and ”image” geometry, suitable for close-range survey. The images taken from the pole and the crane have been processed in “cartographic” geometry, while the images acquired at ground level were treated in “image” geometry. The “image” geometry uses a master image from which the depth map is computed. It is also able to create a mask on this master image to restrict the area to compute. From a practical point of view, all the pictures have not led to the computation of a depth map. Master images were chosen to cover a maximum area while ensuring sufficient overlap with other depth maps, so that the final 3-D model doesn’t show any hole. Given the complex geometry of some vestiges, it would be necessary to calculate all the depth maps and choose the best for each element to compute. However this would have led to a huge quantity of data to manage, too important to compute manually. There is no automatic tool developed yet, despite early research on this issue (Gardon 2009).

As point clouds are calculated from the images, their resolution is almost identical. Their density is about one point per millimeter or more in some cases (fig. 5). Radiometry of these clouds is directly drawn by master images after a radiometric equalization process (fig. 6). This allows no difference of contrast between point clouds.

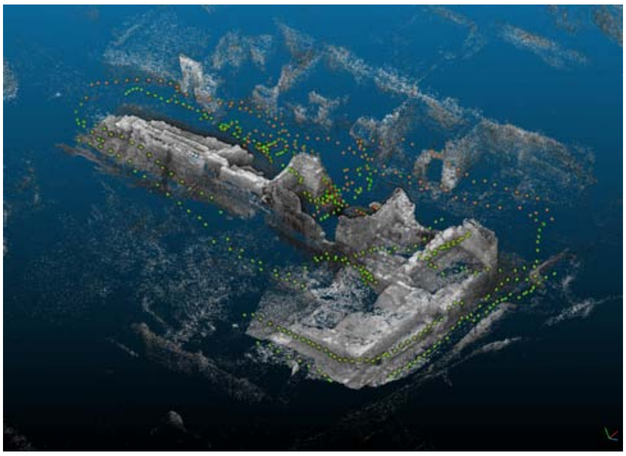

Fig. 4. Bundle ajustment of 490 images (Maxime Seguin, Inrap)

RESULTS

Point Clouds

A point cloud is a set of known three-dimensional coordinate vertices. It can be generated by dense correlation of images, but also with laser scanners (terrestrial or airborne) and with structured light scanners. The technique of image correlation enables to obtain point clouds density with as many vertices as pixels in the master image. Clouds obtained by digital photogrammetry are composed of vertices whose color value is taken directly from the master image. This, combined with their high density, can sometimes be used to generate orthophotographs with a resolution slightly lower than the resolution of the master image.

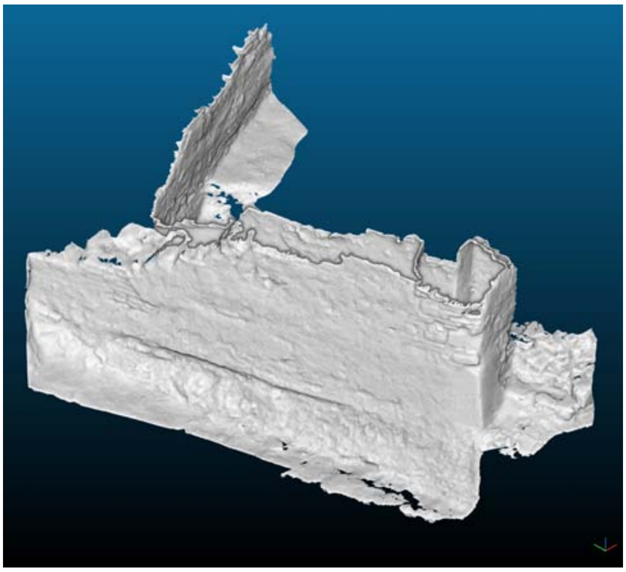

Fig. 5. Raw point cloud (Maxime Seguin, Inrap)

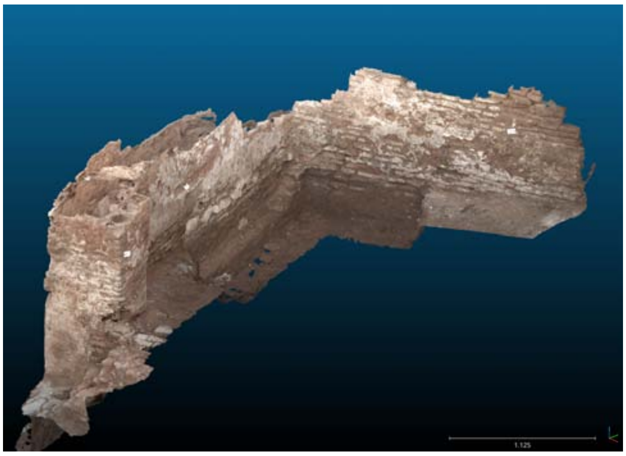

Fig. 6. Colorised point cloud (Maxime Seguin, Inrap)

For this project, point clouds deriving from master images haven’t been merged into a single point cloud. This allows archaeologists to open the point clouds of interest with *CloudCompare*. It is a free and open-souce software for processing point clouds. It was originally designed to make comparisons between clouds, but now has a whole toolbox. Its main interest arises from its ability to process large point clouds.

With this software archaeologists can produce orthophotographs of elevation structures (fig. 7). Point clouds were merged into a global cloud, sub-sampled at a point per centimeter (fig. 8). This light model allows general cross-sections in the excavation.

Orthophotography

An orthophotograph is a re-sampled photography for which the position of a point in the image is directly related to the position of a detail on the field. The difference with a plan is the absence of any human interpretation in his creative process. Interpretation is left to the final user. The orthophotograph, by its graphic aesthetic aspect, is also an excellent means of publication and communication to a non-specialist audience.

Creating an orthophotograph requires knowledge of the absolute

Fig. 7. Orthophotograph and cross section (Maxime Seguin, Inrap)

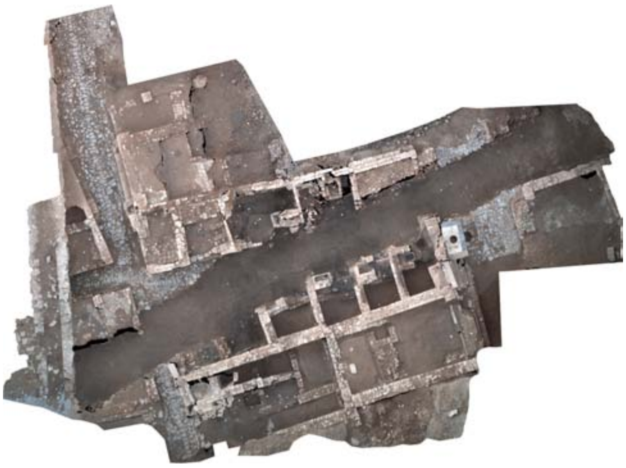

Fig. 9. Aerial orthophotograph (Maxime Seguin, Inrap)

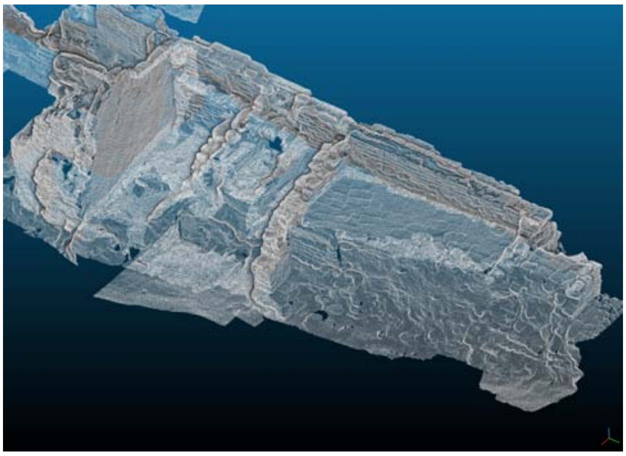

Fig. 8. Sub-sampled global point cloud (Maxime Seguin, Inrap)

orientation of the image and the shape of the scene. The accuracy of the orthophotograph therefore depends on the accuracy of these two data. The representation of relief, also called DTM [3] is obtained by the correlating step. The images used for the correlation can then be projected on the surface obtained.
Orthophotographs are georeferenced, which allows their direct integration into GIS [4]. They come with a DTM which enables direct measurement of the altitude of the elements through the GIS interface. The GIS software used for the excavation of Algiers is the free and open-source GIS *QuantumGIS* (QGIS 2014). Orthophotographs (fig. 9) are directly integrated into the GIS, in addition to traditional surveying and vectorized manual drawings. Stone by stone drawings are directly made from the orthophotographs through the GIS interface.

CONCLUSION

More than 3 000 images were acquired during the first measurement campaign. Density and accuracy of point clouds enabled to edit orthophotograph at 1 : 10 scale. Plans and sections were produced by archaeologists directly from the point cloud. Topographic surveys have been reduced to measurement of ground control points needed to georeferencing images. The results (point clouds and orthophotographs) and their processing with CloudCompare, directly by archeologists, allows them to take over the available data and make the most of them.
To our knowledge, this photogrammetric survey of such a volume of vestiges in a context of preventive archeology in urban context remains a first. The interest of this case study is also the use of a completely free and open-source professional software suite. Other campaigns of photogrammetric surveys are already scheduled. Ultimately, this method could be used on a regular basis on other projects of this importance.

3. Digital Terrain Model
4. Geographic Information Systems

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