A FEASIBLE METHODOLOGY FOR THE USE OF CLOSE RANGE PHOTOGRAMMETRY FOR THE RECORDING OF ARCHAEOLOGICAL EXCAVATIONS

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ABSTRACT:

The reveal of digital photogrammetry caused an evolution from a complex and expensive measuring method to a fast, cheap and straightforward technique to be applied for archaeological excavations. A consequence is that the possible applications are nearly boundless at the present day. Despite of this, close range photogrammetry has not seen a widespread application in archaeological excavation recording. The creation of plans and sections has continued to be carried out by the traditional archaeologist's methods.The goal of this project was threefold. The first step was to research and to describe how photogrammetric records can be made on an archaeological site. A lot of attention was given to the specific problems in the field and to the possible solutions and the recommendations to prevent them. Secondly described the dataprocessing is described, i.e. the stereopairs and GCP's, with a DPWS (VirtuoZo v3.2). Again a lot of attention was given to the problems which occured during the processing and to the possible solutions for them. Both of these steps resulted in the development of a feasible methodology for the recording of archaeological excavations. The main problems that arose during the processing were caused by the angle by which the stereopairs were taken. It was found that the conditions on the site (surface, accessibility of the terrain…), the available equipment and the demands of the archaeologists are the base aspects that have to be taken in account. Sometimes one or more of these aspects forced us to take nonoptimal stereopairs, which asked a tough processing with a lot of manual editing. In some cases a processing wasn't even possible.The third goal was the effort to convince the archaeologists of the advantages of digital close range photogrammetry on the traditional methods, especially by showing the strength of photogrammetric products as DEM's and orthophoto's. Research was done on three different sites: the ruins of a Cistercian female abbey at Clairefontaine, Belgium; the excavations related to the restoration of the Tournai Cathedral Notre-Dame and the excavation of the foundations of the Onze-Lieve-Vrouw church, Ghent, Belgium.

1. INTRODUCTION

Over the past few decades photogrammetry has evolved strongly due to digital technology that allows working faster, more flexible and with cheaper hardware. While the fundamental principles remain the same, the field of application and the possible applications are nearly endless.
Surveying and documenting are basic steps in an archaeological excavation, mostly because of the "destructive" character of an excavation. Above that documenting cultural heritage is also an important step for the conservation and/or reconstruction of it, while it informs researchers, present and future generations about the value of a site. Starting from interesting properties of photogrammetrical products such as orthophotos and 3D models, the least one can say is that these could be an important supplement to the general documents of site-documentation.
Unfortunately it is found that close-range photogrammetry is not yet a common utility in archaeology. An important reason for this is the need of linetype documents to display structural units. This type of document however can be easily derived from an orthophoto. A second reason is the common use of rectified photography instead of orthophotography. Though the first is much cheaper in production cost, it is not a metric document, but it is often used as such.
The research presented aimed at the formulation of a methodology for the terrestrial close-range photogrammetry of archaeological excavations. It is tried to give a description of the way in which a photogrammetrical survey can be performed on a site, together with difficulties that can arise and solutions and recommendations relevant to that matter. A second part concerns the optimal handling of the acquired data, being stereocouples and ground control points (GCP), to derive the photogrammetrical products.

2. SITE DESCRIPTION

Figure 1. The site of Clairefontaine

Research was done on three different archaeological sites in Belgium, all of them being the ruins of valuable historical buildings. The working situation on each of the sites was different in terms of terrain circumstances, the available material and the demands considering the products.
In Clairefontaine, near Arlon in the south of Belgium, photographs are taken of the ruins of a Cistercian abbey. The remains of a Pre-Romance church and a medieval cemetery formed the studied site of Tournai. In the TweekerkenStraat in Ghent the foundations of the Onze-Lieve_vrouwe-kerk were photographed. Particularly in this last case documentation was indisputable, since the terrain will serve as an underground parkinglot from 2006 on.

Figure 2. The cathedral of Tournai

3. METHODOLOGY

3.1 Data-acquisition

The data-acquisition on the terrain goes relatively fast in comparison with other methods of measurement. The actual measurement of the photographed objects is performed later on, based on the restitution of the photographs. The short measuring time on the terrain is an important issue in archaeology, since an excavation is a continuous dynamic process.
Taking photographs is the first thing to do. In this project, the option of stereophotography was chosen. The site is imaginary divided into parts that will be photographed and treated as stereopairs. Primarily some aspects of the photographs are decided upon:

- Metric or non-metric camera
- Orientation of the optical axis
- Kind of passpoints (natural or artificial points)
- Position and number of passpoints

This list makes clear that the taking of the photographs needs to be planned thoroughly, keeping the demands of the product specifications and the particular circumstances of the site in mind. Finally the choice of the available tools and equipment depends on the available budget (e.g. ladder or scaffolding). The three sites were each treated in a different way, by choosing the optimal combination of the above-mentioned parameters.

3.1.1 Clairefontaine

On the site of Clairefontaine photographs of the façades were made with a Rollei d7 metric camera using a 28mm lens. The optical axis of the camera was chosen perpendicular to the wall, where possible, and the axis of both photographs of one stereopair were parallel. These cicurmstances are close to the "normal" conditions of classical aerial photography and allow the easiest treating of the stereopair.
To fit the stereomodel in an absolute reference system, some 3D terrain coordinates of the photographed object are needed, in the overlap zone of the stereomodel. With the metric camera at least four points need to be measured but it is advisable to have a redundancy of ground control points (GCP). Artificial passpoints, pieces of cardboard with marked diagonals, were fixed to the walls. Those offer the advantage that they can be measured much more precise than natural points. The 3D coordinates were measured with a Leica TCR307 reflectorless total station in a local coordinate system for each stereopair.

3.1.2 Tournai

On the site of Tournai photographs of a ground excavation were made with a Canons EOS-1DS digital camere using a 24mm lens. The position of the camera was above the object. The height and the space of the room was limited, so the photographs needed to be taken from a ladder, standing against the sidewalls. This means that the stereopair consisted of two oblique photos with intersecting optical axis. Although the limitations of such stereopairs are known, it was still interesting to find what the possibilities are of these photographs.
On this site we used natural GCP, because it was not possible to collate artificial marks on the freshly exposed artefacts. Well recognisable and unambiguous points were chosen and well documented with photos and drawings. The points were measured with a Trimble 5600 total station, starting from a materialised geometric base. This ensured that the photogrammetrical products are positioned with reference to other measurements on the site.

3.1.3 Ghent

On the site of Tweekerkenstraat in Ghent the terrain circumstances were similar to the ones in Tournai, the methodology for the photographs is the same. The GCP were measured with a Pentax R-325 total station.

3.2 Data processing

The photogrammetrical stereo-restitution contains the conversion of raw image information, subject to radial relief displacement, into a geometric representation of the object depicted in the photograhs. The VirtuoZo 3.2 softcopy photogrammetrical software is used. Large parts of the process are automated in this software.
A number of transformations of the GCP is necessary before the 3D coordinates can be entered in the photogrammetrical system. While the terrain coordinates are fixed in a coordinate system in which the only specification is that the Z-axis coincides with the geodetic vertical. In the photogrammetrical system however, the X-axis coincides with the imaginary line connecting the two camera positions, the Y- and Z-axis perpendicular to the X-axis, and the Z-axis positive from object to camera position. The image quality of the stereopairs was adjusted with Adobe Photoshop to enhance the contrast and brightness. Finally the internal, relative and absolute orientations are performed in VirtuoZo.

3.3 Problems and difficulties in the data processing

3.3.1 Obliqueness of the stereopair: the main problems that occurred are due to the oblique converging stereopairs and the often very pronounced relief of the studied objects. Nevertheless it will happen frequently that one is obliged to use such photographs. The fundamental issue in using converging stereopairs is the scale that varies continuously over the images. The scale not only varies with the height of the object but also with the place of an object point in the photograph, resulting in a differential distortion (figure 3).
The two converging images of a stereopair with differential distortion complicate the process of automated image matching, used in the relative orientation to find homologue points in both images. In some cases only 10 homologue points were found in an automatic way, and 100 to 200 points were pointed manually depending on when the points led to a stable solution for the

relative orientation. This is an important argument to take the photographs with the optical axis perpendicular to the object. This might result in a higher cost for the photography, but will certainly improve the result and reduce the processing time.

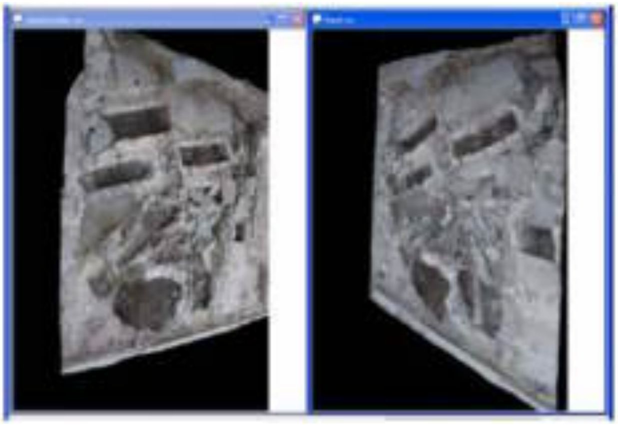

Figure 3. Example of a converging stereopair. Parts of the image that don't belong to the object of study are masked.

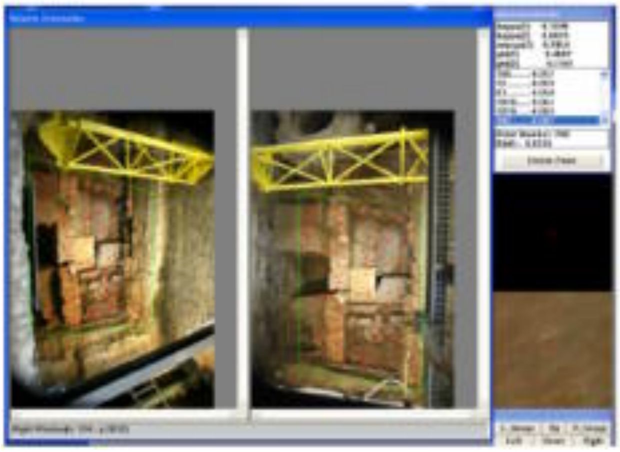

Figure 4. Interface for relative orientation were homologue points are pointed out manually.

3.3.2 Occurrence of occlusion: Another basic difficulty is the occurence of stereoshadow or occlusion cause by the relief and ruggedness of the object and the conical projection of the photograph. The displacement of a higher region causes that a lower part behind it is shielded and not depicted in the image (figure 5). Those occlusion zones however should be visible in an orthogonal projection. In an area that is tempered with occlusion no image information is available, and no homologue points can be found to calculate the height from. The occlusion areas are interpolated between the known surrounding surface points, but this does not represent the true surface and introduces errors such as blurring and double image. The problem of stereoshadow can be minimized by taking pictures perpendicularly to the object and by choosing an optimal height to base ratio.

Although the products are generated largely automatic by the software, they will not be perfect because of the mentionend difficulties and manual input of an operator remains necessary.

This manual intervention is mainly trial-and-error based by looking at the automatically generated products and identifying problem areas. In the case of photography in poor acquisition conditions or a very pronounced relief, this was a very labour intensive process, and it was not a solution for 100% of the problem areas.

Figure 5. Example of the editing of a stereopair. The arrow indicates and occlusion area.

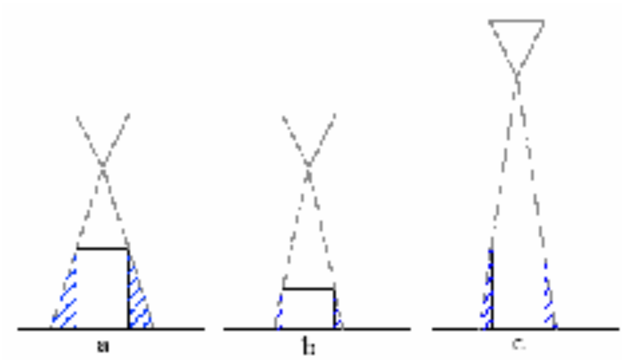

Figure 6. The occurence of stereoshadow in relation to the height of the object and the distance of the camera.

4. DERIVED PHOTOGRAMMETRIC PRODUCTS

Digital Surface Models (DSMs) and orthophotos were derived from the stereopairs and the measured GCP. An interesting property of these products is that they combine geometric accuracy with a vast visual detail. They are in the first place a photographic representation of the object, containing a lot of visual detail that is not biased by any interpretation of the operator, and they have the metric properties of a plan. Together those properties allow an accurate intepretation and measurement of the state, dimension, position and orientation of a structural element of a site or a site as a whole. The DSM opens the possibility to enhanced visualisation using the third dimension (figure 3). This kind of representation is useful for researchers and for presentation towards a broad audience. The photographs that were taken perpendicularly appeared to give nice results without much manual input, while the converging photography needs a large manual intervention.

5. CONCLUSION

To conlude about the methodology described in this paper we can say that it is feasible to produce relatively fast an orthophoto of an archaeological site during an excavation.

Figure 7. Example of a 3D visualisation, by draping an orthophoto over the corresponding surface model (Tweekerkenstraat, Ghent)

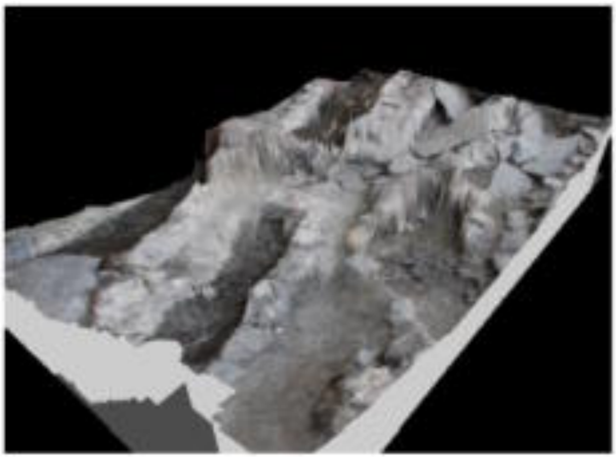

Figure 8. Drape of an orthophoto from Tounai, before editing the stereomodel.

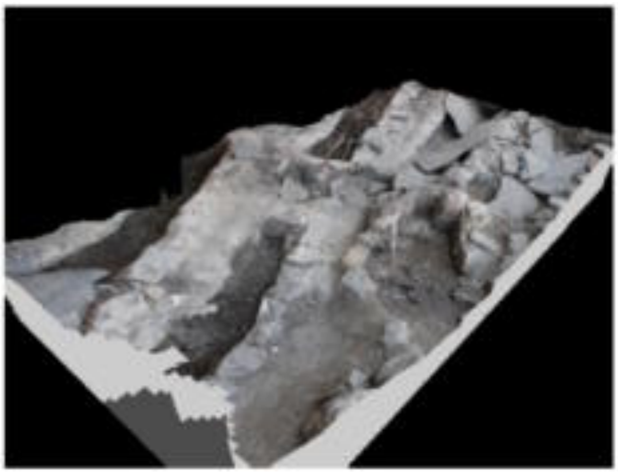

Figure 9. The same orthophoto as in figure 8, after the stereomodel was edited.

Since the data acquisition is a very short step in the process, the measurements or better the documents to measure on (photographs and passpoints), can be repeated very fast during the excavation. Even in non-ideal circumstances (oblique photographs, insufficient number of stereopairs, too pronounced relief, etc) results can be achieved. A uniformous workflow is hard to set up, because of the ever changing terrain conditions for each different project. However, keeping the criteria mentioned in mind, it is certainly possible to make some important choices that can be of great influence on the processing of the photographs and the quality of the final results.

A comparative study between an orthophoto and a plan, made by traditional archaeological measurements methods, should give an idea of the relative accuracy and production cost of both methods. This study is beyond the scope of the research presentend in this paper, but is considered very important in terms validation and valorisation of this research.

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