# DIGITAL CLOSE-RANGE PHOTOGRAMMETRY OF STATUE-COLONNES APPLIED ON THE TOURNAI CATHEDRAL (BELGIUM)

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**ABSTRACT**

This essay aims examine the possibilities of close-range photogrammetry applied on walls with pronounced relief differences e.g. statues. It involves softcopy photogrammetrical processing in a digital interface. Especially the achievability, to produce orthophotographs of walls with remarkable height-differences, will be studied. An orthophotograph is a photo with correct X-, Yand Z-coordinates and realised with two orthogonal snaps of the same object. These snaps, also called stereopair, must overlap each other for a certain percentage. In general mostly an overlap of 60 percent is advised. To calculate the correct height-coordinates (Z), we use the parallax difference of an object on the two snaps of a stereopair. In our case, we couldn't choose freely the distance camera-object. We were forced to work with a very short distance. Taking the large height-differences on the object into account, we are dealing with an important radial relief displacement, and thus parallax, resulting in important stereo shadow. This shadow always causes errors in the results, because certain picture information is lost. The software package ViruoZoTM was used to create orthophotos. This software offers the possibility to produce orthophotograph automatically and intervene manually if necessary. The latter is known as 'editing'. Editing enables to improve the results, by marking homologue points, lines or surfaces in the environment of problem areas. This manually correcting concerns the principal domain of our research. By editing, we were able to improve our results remarkably. The only possible way to futher improve the orthophotograph, is by reducing the amount of stereo shadow: the snaps of a stereopair should overlap at least 80 percent. The conclusion is that fine orthophotos of objects with pronounced relief, can be produced with the process of editing, e.g. statues. The product of our study could prove of great value as plans for architectural restoration. A schedule of how the process should be executed as economical as possible is proposed.

## 1. SITUATION OF SITE AND STUDY AREA

The studied site is the cathedral of Notre-Dame in Tournai, Belgium. Many old buildings in this area are built from the clayey limestone from the late-Tournaisian. The cathedral, with its length of 134 meter and an area of 5120 m², is considered as a masterpiece of Romance architecture in Belgium. The general structure of the cathedral consists of three major parts: the Roman nave, the central tranverse en the gothic chancel. Through the integration of two different architectural styles, the monumental towers and the rich sculptural detail the cathedral can compete with the other milestones of the western European roman architecture. The cathedral is currently being restored. Within the framework of this restoration works the 'Region Wallonne' offerred the possibility to perform the research presented in this paper.
The area studied is located at the Western Front Porch (Plan de l'Echêvé), the main entrance of the cathedral. There are statues all along the width (26 meter) and height (5.25m) of the façade (figure 1). The aim of the project was to make orthophotoplans and 3D models of the all the statues from this wall by means of stereophotography and total station measurements, using a digital photogrammetric workstation (DPWS).

## 2. DATA ACQUISITION

The photographs were made with a Rollei 6008 Professional SRC camera using a calibrated lens. Whenever possible the photographs were taken with the optical axis perpendicular to the façade. In some cases the maximum perpendicular distance from the wall was not more than four meter due to pillars, which hampered the photography. A total of 22 stereopairs was made.
To process the stereophotographs, there is a need of six ground control points (GCP) for each stereopair. A total of 240 GCP was measured eventually (90 artificial points, and 150 natural points) to ensure the minimum number of six points per stereopair.

Figure 1. Western Front Porch of the Tournai cathedral.

The larger redundancy of the natural points is due the incertainty of finding such points on the stereopair, while measuring the point in the terrain. All GCP were measured in the geometric framework that is permanently fixed in and around the cathedral (figure 2). In such, the results from this project can be integrated with other plans and measurements of the site. The GCP were measured with a Leica TCR 307 reflectorless total station.

## 3. STEREOPROCESSING OF THE PHOTOGRAPHS

The processing of the stereopairs from photo to orthophoto is

done with the DPWS VirtuoZo. For each stereopair the internal, relative and absolute orientation is performed semi-automatic. The image matching gives the parallax differences in the overlapping zone of the stereopair, and from it the surface model and the according orthophoto are calculated automatically.


Figure 2. Three-dimensional representation of the geometric base and the GCP measured in this project on the left side. In the upper left part, there are points from three other measuring campaigns.

The primary results of this largely automated process are not satisfying and have poor quality. The reasons for this are twofold. First of all the images are characterised by a large radial displacement due to the short distance between the camera and the wall. This causes areas of stereoshadow or occlusion, and parts of the object are displaced over another part of the object. This means that the image matching, which is based on finding homologue points in both of the images, cannot find a solution and generates an erroneous surface for the area in occlusion. A second cause of the errors is the strongly pronounced relief of the studied façade by which more candidate occlusion zones are present.

### 3.1 Minimising the possible matching errors

The matching errors are minised by using an overlap of at least 80% for the stereophotographs. Figure 3 shows that for a larger overlapping area the occlusion becomes smaller, thus less stereoshadow and a better matching result. It was found that it in this case the matching error was within limits from an overlap of 80% on.

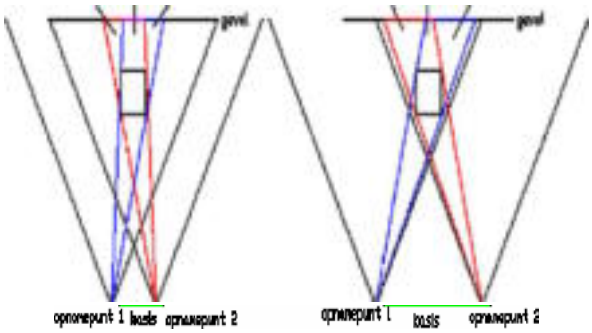

Figure 3. Graphical comparison of an 80% and 60% overlap for a stereopair

Also the use of a larger focal length would reduce the occlusion, but this option was not possible to use, for the scale of the photograps becomes too large in this case and the photographed area becomes too small (figure 4).

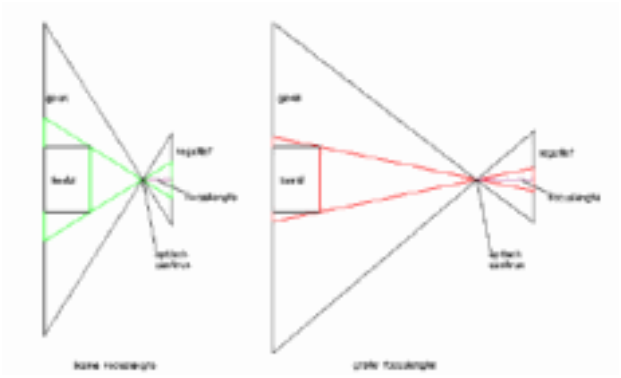

Figure 4. The situation with a 40 mm focal length on the left, and a 120 mm focal length on the right.

While taking the photograps it was taken care of that the optical axis of the camera was perpendicular to the wall. In some case however this was not possible, and this resulted again in larger occlusion areas. This was a second limitation of the terrain conditions for the photographs.
The solution to the matching problems encountered in the automated process is, to manually intervene by editing the stereomodel and the matching result. The largest part of the research was spent on how to reduce these errors and produce useful products from non-ideal stereophotographs.

### 3.2 Minimising the matching errors through manual editing

The automatic generation of digital surface models and orthophotos still contains some errors. During the manual intervention in the automated process to operator strives to make the matching process perform better. This is done by pointing homologue points in the epipolar images of the stereopair before the matching takes place. Those points are chosen in areas where the matching performs bad, mostly in areas with a lot of height differences and at the border of the stereoshadow. Figure 5 shows the difference between an orthophoto from the automatic process and the orthophoto after the stereomodel was edited.

Figure 5. Example of an orthophoto from an edited stereomodel (left) and an unedited stereomodel (right).

The editing is a very labour intensive and time consuming job. Therefore it is necessary to minimise the amount of editing by a careful planning of the taking of the stereophotographs. The evalution of the orthophotos was positive in general, although improvement is possbile in certain cases. Especially the huge amount of editing is a motivation to look for solutions for the problems caused by stereoshadow. A thorough planning and preparation of the fieldwork can solve a lot of problems. On the terrain the object has to be divided in virtual sections that will be photographed as overlapping zone of a stereopair. The type of object that is photographed is an important factor in this planning. If the object is characterised by a very pronounced relief, the estimate of the primary elements in the façade are an aid to divide the wall in sections. An item of attention in that frame is the presence of horizontal and vertical elements in the object. An example of such reasoning is the choice to work in an 'up-down' stereo position instead of the classic 'left-right' position. The photographs are then rotated over 90° so that they can be entered in the photogrammetrical system as a 'left-right' stereopair.
Figure 6 shows a plane view of a situation with a left-right stereopair, while figure 7 gives the plane view for an up-down stereosituation. It is clear that in the latter case there is much less stereoshadow, this would lead to a better matching and thus better products.

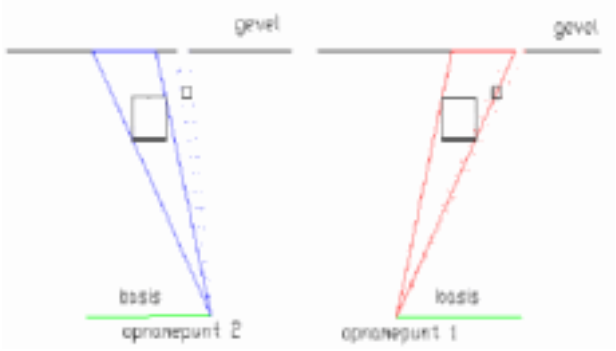


Figure 6. Plane view of a left-right stereosituation. The smalle object on the right is in the stereoshadow of the left image.

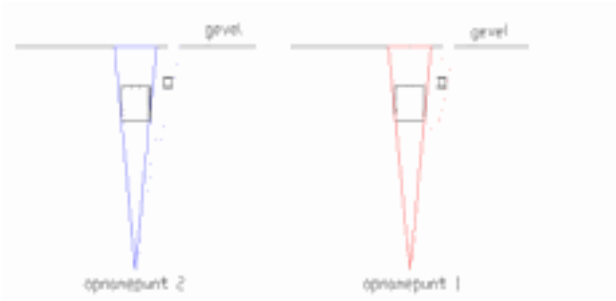


Figure 7. Plane view of an up-down stereosituation. The smaller object on the right is out of the stereoshadow of both photos.

To conclude we also mention that the illumination of the object during the photography has influence on the matching result. If the two photograps of one stereopair have a contrast that differs too much, matching results will be poor.

## 4. PRODUCTS

The final result of the project is an orthophotplan of the whole western façade (figure 9). Every point is known in three dimensions. The orthophotplan combines the metric properties of a plan and the interpretationvalue of an image.

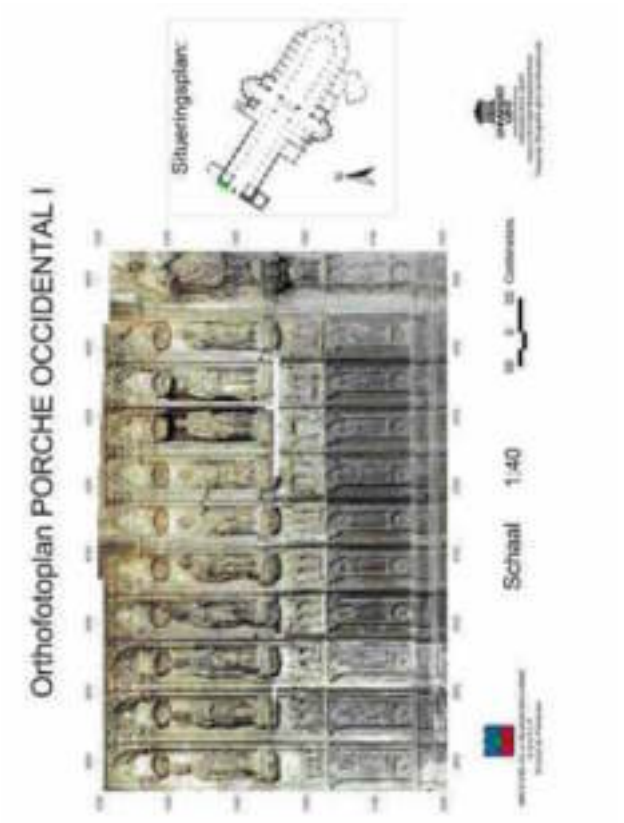


Figure 8. The final orthophotoplan of the western façade of the cathedral of Notre-Dame in Tournai, consisting of 22 single orthophotos.

The technique of rectifying a single image can give a better result at first sight, but when investigating closer, they will appear to have non-metric properties, and are tempered with scale differences.

## 5. CONCLUSION

This research showed that, even in difficult and non-ideal circumstances, it is possible to create good-quality and reliable orthophotoplans from architectural façades with a pronounced relief. During the processing of stereophotographs one can encounter a series of problems, which make it impossible to obtain the results that one has in mind. Especially the rise of the amount of stereoshadow caused by pronounced relief causes a lot of difficulties. It is important to recognise these problems and to minimise their effect on the product.
If those considerations are not taken into account the processing of a stereopair can take a lot of manhours or become even impossible. The amount of manual corrections in the stereopair will increase as the relief creates more stereoshadow. One could even say that this method is the application of analog and analytical photogrammetric methods on a DPWS. While editing points, lines and polygons are drawn that consolidate the parallax on those points. The way of editing adds a degree of uncertainty to the process, and therefore the editing should be limited to a minimum.
This research has shown that a meticulous planning and

preparation of the work is indispensable. Furthermore an insight in the way of working of the DPWS is necessary to anticipate and deal with the possible difficulties that can occur.

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