REALIZATION OF A DIGITAL PHOTOTHEODOLITE

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ABSTRACT

With photogrammetry now well entered into the new era of digital imagery, our old conventional phototheodolites still using films and glass plates have begun to look like dinosaurs. Most of the terrestrial metric cameras using that kind of plates are now virtually out of service, no more plates being available, except maybe in the case of a huge special order. On the other hand, nowadays, several non expensive digital cameras are on the market, like the Kodak DC-50. The goal of the investigation was to test the feasibility of coupling such a camera with the Leica TC-1600 geodetic Total Station. After calibration of the system, by using a calibration site, each picture taken with the digital camera becomes georeferenced, as soon as the position of the station is computed and the azimuth of the picture is known. By using two such pictures with some overlap, the coordinates of any point in the overlap can be computed by measuring in each picture its photo-coordinates and introducing these data into a special program containing the necessary photogrammetric equations and the parameters of the calibration. Results obtained with the calibration site measurements are discussed, as well as the results of a sample application in an urban area.

1. INTRODUCTION

Nobody can deny that direct (cameras) or indirect (scanners) digital imagery has revolutionized the domain of photogrammetry. New softwares replacing analog instruments as digital plotters (Agnard *et al.*, 1988), digital rectifiers (Boulianne *et al.*, 1992) and digital parallax-bars (Agnard *et al.*, 1994) were developed as well as new softwares replacing conventional way of doing as automatic aerotriangulation using image matching techniques (Agouris *et al.*, 1996). In fact there is no conventional device or method that cannot be favorably replaced by a digital approach. The realization of a digital phototheodolite goes with this logical approach.

2. THE COUPLING

In the past years, when only specialized instrumentation was used for terrestrial photogrammetry, its spread into the surveyors' domain was very limited, not because of the lack of possible applications or potential contracts, but because of the price of investment into such systems. Even more, nearly all of the phototheodolites on the market were built in such manner that the theodolite itself on its own could not or could hardly be used for other regular surveyor works.

Nowadays, to invest less than $1 000.00 to transform a Total Station, costing itself a few tens of thousands of dollars, into a phototheodolite, seems within reach of any surveyor, and the investment will be normally easily absorbed at the end of the first terrestrial photogrammetric contract completed.

This is why we have successfully coupled a cheap Kodak DC-50 digital camera with the Leica TC-1600 geodetic Total Station, two instruments available at our Geomatics Department.

Figure 1 shows the aluminium adapter, designed to fix the digital camera on the top of the Total Station, once its handle has been removed. The same points of fixation have been used to fix the adapter. The adapter receives the camera in such a manner that, once installed, nothing can be moved, neither the camera on the adapter nor the adapter on the Total Station. A rail has been specially made for avoiding any movement. This is important because once the system is calibrated, nothing is supposed to move (Figure 2).

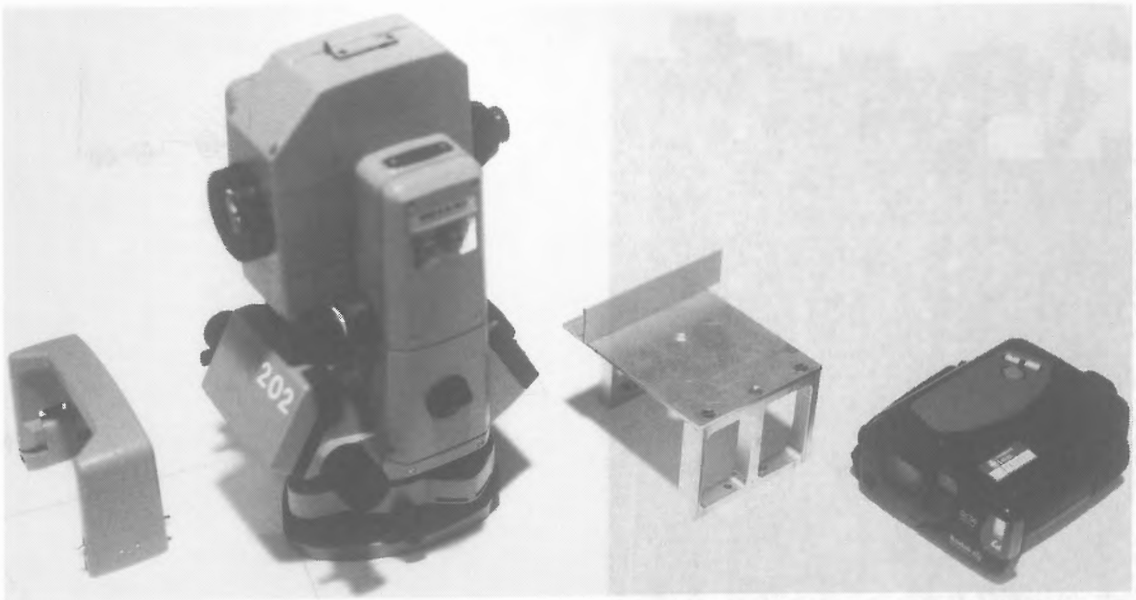

Figure 1 - Total Station, Adapter and Digital Camera

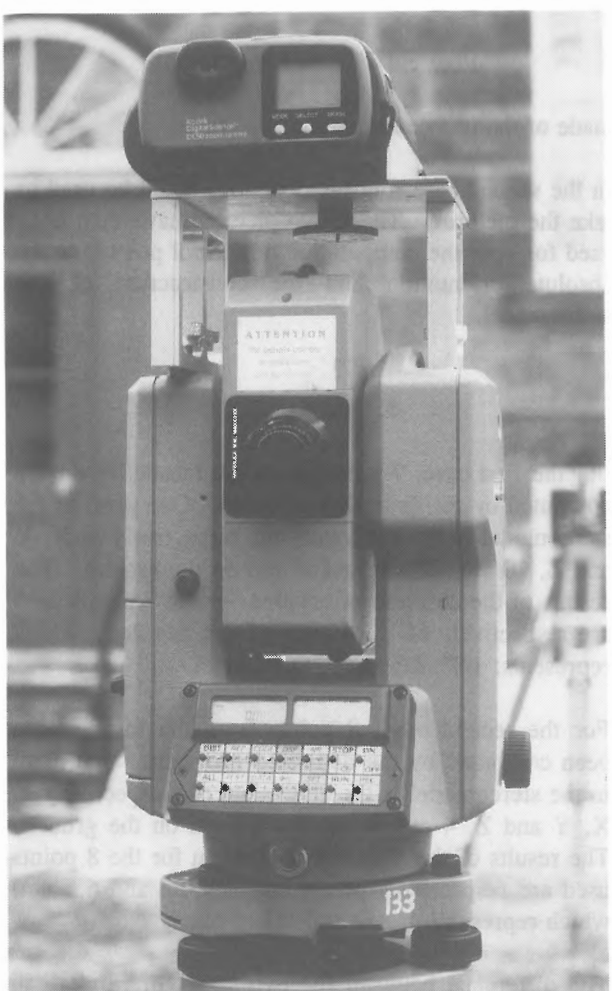

Figure 2 - The Camera Installed

3. CALIBRATION

In order to obtain georeferenced pictures, we have to know several physical parameters related to the system: the ΔX, ΔY and ΔZ offsets between the perspective center of the camera lens and the center point of rotations of the Total Station, the difference of azimuth between the optical axis of the camera lens and the one of the Station and also the difference of site between the optical axis of the camera lens and the horizontal plane. We need also to know the calibration of the camera itself: the calibrated focal length and the offsets in x and y of the principal point on the CCD sensor.

A special calibration site (Figure 3) available at our Lab of Metrology has been used (Savopol *et al.*, 1996). Made with six special steel wires, the extremities of which are dipping in an oil container for stability, supporting balls of different sizes, this site has been used many times with success for the calibration of several cameras. The three sizes of balls available are used for different distances of the cameras to the site. Mounted with a specific sequence of balls with different sizes, the wires can be easily recognized, even with only a small part of them visible, the sequence being unique for each of them. The site occupies a volume of 4m by 2m by 5m of height. The calibration is made with four different points of view using the auto-calibration technique (Kenefick *et al.*, 1972). Besides computing the internal camera calibration, the program gives the ground coordinates of the perspective centers. Compared with the ground coordinates of the center of the Total Station used and computed at the same time, the three offsets ΔX, ΔY and ΔZ are deduced.

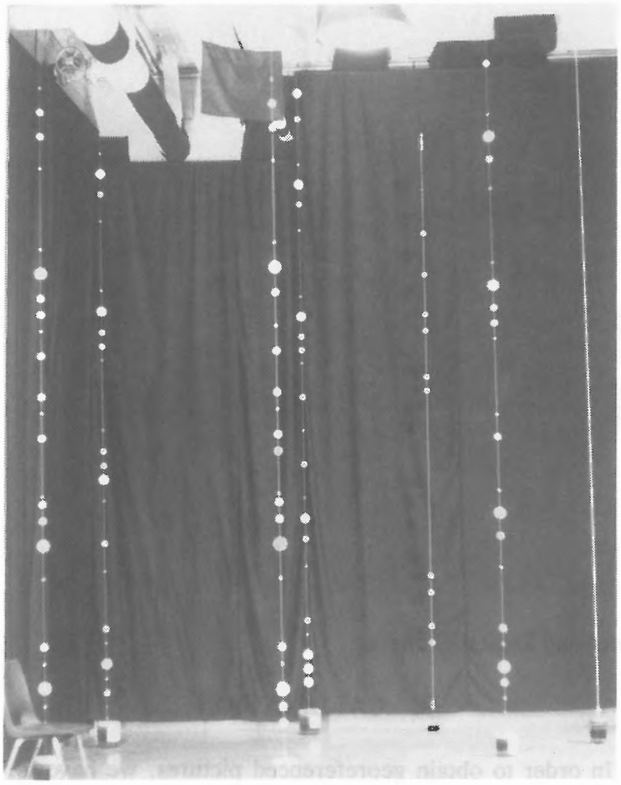

Figure 3 - The Calibration site

4. GROUND EXPERIMENTS

Two different cases have been experimented: the case where there is enough space in front of the building permitting sightings from points with up to 90° intersections (Figure 4), and the more common case in urban areas where intersections close to 10° are only possible (Figure 5).

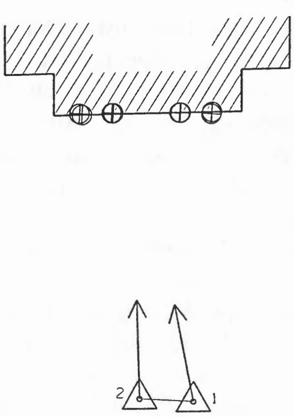

Figure 5 - Poor Intersections

In the first case, four station points were used. The four were used to take pictures of the building, the two extreme ones have been used for the computations of the ground coordinates of some points on its facade to be used for the absolute orientation of the model

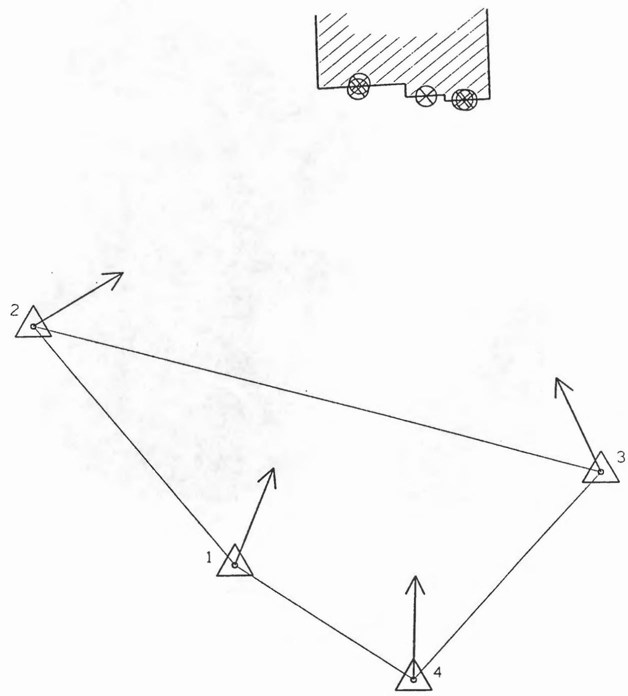

Figure 4 - Good Intersections

made of the two central-stations pictures.

In the second case, only two stations could be used to take the pictures. These two pictures have then been used for both the computation of control points for the absolute orientation and the construction of the stereomodel.

5. RESULTS

For the first case, 7 points from the facade have been computed by the dedicated program. One pixel in the stereomodel is the equivalent of, respectively in X, Y and Z, 10 cm, 10 cm and 17 cm on the ground. The results of the absolute orientation for the 7 points used are respectively of : 1,4 cm, 1,9 cm and 2cm, which represents: 1/7^e, 1/5^e and 1/9^e of pixel.

For the second case, 8 points from the facade have been computed by the dedicated program. One pixel in the stereomodel is the equivalent of, respectively in X, Y and Z, 4 cm, 4 cm and 20 cm on the ground. The results of the absolute orientation for the 8 points used are respectively of : 4 cm, 1,9 cm and 6,5 cm, which represents 1, 1/2 and 1/3 of pixel.

The difference between the two series of results can certainly be explained by the better definition of the ground coordinates for the first case due to the better intersection.

6. DISCUSSION

The results obtained show that the coupling of a cheap digital camera with an expensive Total Station is neither absurd nor unworkable (Gravel, 1997). Of course, some minor improvements will eventually be brought, the most important being the possibility of a site movement for the camera itself. To have the camera axis always horizontal is a handicap when you have not enough backward distance to see the top of the building (this is why the last phototheodolites had their optical axis decentered with the photographic plate). When it is difficult to fix it to have it interdependent with the theodolite telescope, the old Wild P-30 phototheodolite solution with several predetermined site angles seems to be the best possible solution. These site positions of the camera can be easily calibrated in lab.

Another improvement, for increasing the precision of the results, which are in direct relationship with the size of the pixel on the buildings, is to use a digital camera with more pixels as has been done in the system described by Kasser (1998). This is what we are doing now with the Nikon-Kodak DC-420 with 1.5 millions of pixels (1500 x 1000), but we are facing then the price problem we have raised before. With a cost of $ 10 000.00, we come back to the same problem of cost for surveyors that we had before. But, the prices of digital cameras being in constant fall, we are confident that in a few years, this present problem will be solved by itself (what to say of the recent 25 millions pixels Leica camera?).

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