VALUATION OF ORTHORECTIFICATION BY USE OF PHOTOMODELER SOFTWARE

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ABSTRACT:

Within the project "Initiation to Research" students and their tutors had to produce an orthophoto at scale 1:200 of the main façade of the institute as a training project. The dimensions of the object are 107m long and 23m high.
The available equipment of the institute was:

- Digital Camera KODAK DC 265
- Digital Camera SONY DSC P-71
- Total Station LEICA Model TCR 307
- Software PhotoModeler, version 4.0 d
- Software DVP with Orthophoto Module.

In the planning stage of the project, it was decided that the façade had to be divided into three parts, due to the rather large dimension of the object, short camera–to–object distances, obstructions (trees, parked cars, etc).
The chapter Ground Control is treated with high emphasis and may be of special interest.
The spatial coordinates of 30 well distributed targets and 12 more points in the object were determined by forward intersection and polar measurement by use of an electronic distancer (EDM) in reflector-less mode and simultaneous trigonometric levelling.
The results are compared and discussed. Two coordinate systems with different characteristics, but with the same vertical datum were used:
- An arbitrary local survey system served as the purpose for calculation of the results of measurements in the field.
- The object system, defined in the object, represents the final values of coordinates for processing within the program PhotoModeler.
Various methods of transformation between the two systems, such as:

- plane similarity coordinate transformation with 2 identical points
- plane similarity transformation with over-determination (HELMERT-Transformation).
- plane affine transformation with over-determination (HELMERT-Transformation).

were employed and compared. Having the same origin in altitude, the two sets of coordinates could be treated as plane coordinates.
Furthermore, some values of transformed coordinates could be checked in the field by use of the program "Determination of Free Station Coordinates" of Total Station LEICA TCR 307.
The achieved precisions of the ground control coordinates are adequate to the scale 1:200 of orthophoto.
Summarizing the chapter Ground Control, it can be stated that a simplified ground control could be useful for small objects within the 3 x 3 Rules. Also the way to get an efficient ground control for large objects is shown.
A large number of orthogonal and oblique images were taken.
An orthophotomosaic, composed of various orthophotos produced by PhotoModeler, served for the plot of the façade.

1. INTRODUCTION

Within the project "Initiation to Research" students and their tutors had to produce an orthophoto at scale 1:2oo of the main façade of the institute as a training project. The dimensions of the object are 107 m long and 23 m high.

The available equipment for this project was:

Digital Cameras	:	KODAK DC 265
		SONY DSC P-71
Total Station	:	LEICA model TCR 307
Softwares	:	PhotoModeler, version 4.0 d,
		DVP with Orthophoto Module

The orthophotos produced by different methods and different software have to be compared. The purpose of this didactic project was to orient the students to experiment theory and practice of terrestrial photogrammetry. Inspired by the 3x3 Rules, see (8, Waldhäusl / Hanke / Ogleby / 6, Herbig), some years ago, we in Brazil are very concerned about the divulgation of projects with simplified ground control and low-cost software, such as PhotoModeler. We require that this IME-Project gives some useful information to the community, like the project for the Documentation of Monuments and Architectural and Archeological Sites: The Tower Castle Garcia D' Avila see (3, IPHAN - Fundação Ricardo Franco / IME).

2. PROJECT PLANNING

In the initial stage of the project only the Digital Camera KODAK DC 265 with the following characteristics was available:

- focal distance: 38 mm
- approx. format : 26mm x18mm

Considering the camera characteristics and also the large dimensions of the object, short camera-to- object distances, obstructions like trees, parked cars, etc., it was decided:

- The main façade had to be divided into three parts, to be processed independently in PhotoModeler.
- the mean orthogonal image scale should be about 1: 1000
- the scale of the orthophoto should be 1: 200
- the tolerances for the coordinates of the ground control should be :
- in x- and z-direction : ± 15 mm
- in y-direction : ± 45 mm

furthermore the approximate camera stations were selected.

3. GROUND CONTROL

3.1 Distribution of the targets

As we were not very familiar with PhotoModeler software, we expected some difficulties during processing regarding absolute orientation of models. Therefore we fixed the rather large number of 34 targets at the object, distributed in lines and rows. 4 of these fell down during the interval between the taking of images and the topographic measurements. (see Appendix)

3.2 Coordinate systems

In accordance with the methodologies adopted in Industrial Measuring Systems we used two different coordinate systems with different characteristics for the ground control:

- the object system , defined in the object
- an arbitrary local survey system, approximately parallel to the object. Both systems have the same origin in altitude. Therefore the transformations between the two systems can be treated as plane transformations.

3.2.1 The object system

(see figure 1).

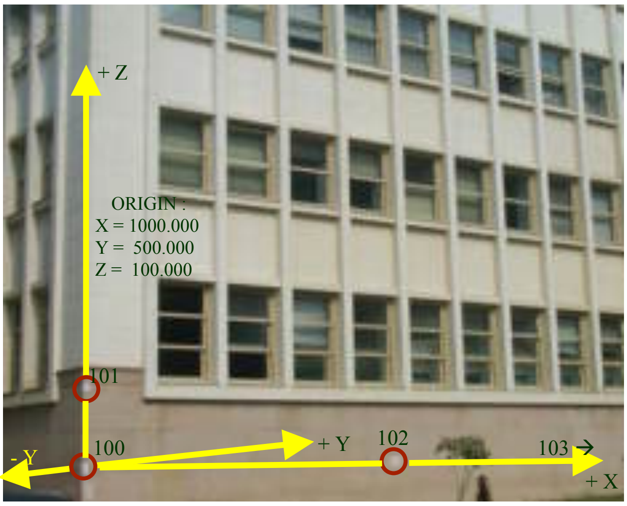

Figure 1 - Definition of the Object Coordinate System see (7 Luhmann, page 28)

Exploiting the geometric properties of a vertical plane in plane objects like façades and walls, the object system offers considerable vantages such as:

- points in vertical lines : x = constant
- points in horizontal lines : z = constant
- points in the same vertical plane : y = constant
- approximately horizontal distances : = Δ x

In many cases of small objects the above mentioned coordinate system is sufficient for a simplified ground control, which permits the absolute orientation of the model and therefore the generation of an orthophoto:

- some horizontal distances between targets measured by a tape define the scale of the model.
- one vertical line between two targets defines the z-axis
- the y-planes are defined in the object
- some altitudes of approx. horizontally distributed targets, obtained by a level , define the horizontal x – axis.
- some more distances between targets (diagonal, vertical and horizontal) improve the geometry of the system.

In this way we performed some projects such as :

- The Empress Manor, Rio de Janeiro, CIPA 1999 (stereo), see (5, Gomes). The ground control was completed later by densification (see 3.2.2)
- The Chapel Santa Bárbara, Santa Cruz, RJ, CIPA 1999, (PhotoModeler), see (4, Gomes).
- About 15 isolated façades of the Tower Castle Garcia D' Avila, Praia do Forte, Bahia, 2001, (PhotoModeler), see (3, IPHAN - Fundação Ricardo Franco / IME)

- A monument, located at Praia Vermelha, Rio de Janeiro, 2000, (PhotoModeler), see (2, Barbosa)
- Rock Art Photogrammetry – The Bear at Fonte Grande II Canyon – Uibaí, Bahia, Brazil, CIPA 2001,(PhotoModeler), see (10, Gilson D. Koatz)

3.2.2 Completion of Simplified Ground Control

However, in the case of large objects, one needs to complete the simplified ground control by densification. This can be done in different ways:

- by **processing with software** like ORPHEUS and ORIENT of the Institute of Photogrammetry and Remote Sensing , Vienna University of Technology, see (4, Gomes: The Empress Manor-Project). An orthophoto of the façade was produced by IDL-Software.

- **by photogrammetric measurements;**

Almost simultaneously to processing with ORPHEUS and ORIENT in Vienna, the same stereopair of the Empress Manor -Project with incomplete (poor) ground control was introduced in the AVIOLYT BC 2 of AEROFOTO CRUZEIRO S/A. In the relatively orientated model about 33 points were measured.

Later on, the single model was adjusted by the program PAT -M. Author: Hanns J.C. von Studnitz, AEROFOTO CRUZEIRO S/A, Rio de Janeiro.

A digital restitution of the same façade was executed in the Digital Video Plotter-DVP of IME.

- **by additional topographic measurements.**

In this case, one needs a coordinate system outside the object system, the so-called

3.2.3 Arbitrary local coordinate system

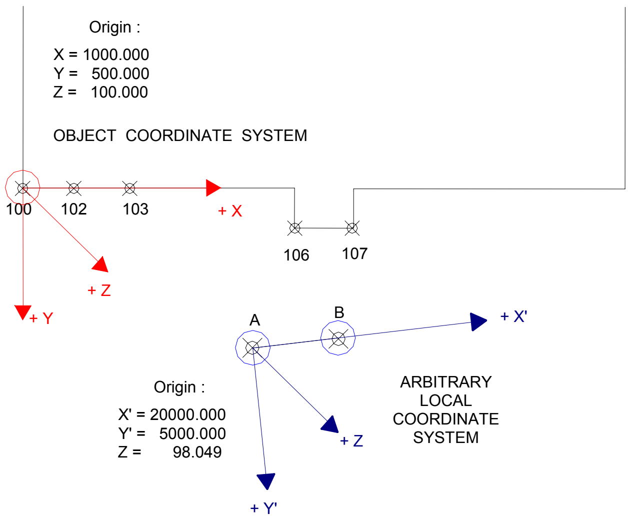

Figure 2 - Definition of the two coordinate systems

3.3 Topographic Measurements

3.3.1 Polar measurements by use of a Total Station

Initially it was planned to use a Total Station LEICA TCR 307 in reflector-less mode with simultaneous trigonometric levelling from a baseline of two stations in order to determinate polar coordinates of control points. But it turned out that due to very oblique pointings, the return signal to EDM was too weak and thus the distance measurements failed in about of 40 % of instances.

Therefore we decided to use the intersection method for all points of the project and to consider the polar coordinates for comparison purposes only.

3.3.2 Forward intersection

The spatial coordinates to a total of 42 points (mostly targets) were determined by forward intersection in the x–y-plane with simultaneous trigonometric levelling. In the beginning from two stations in the arbitrary system, in later stages from three stations directly in the object system (see 3.6.2).

For safety reasons we strongly recommend a double forward intersection using two baselines, for example B-A and B-C, (see figure 3).

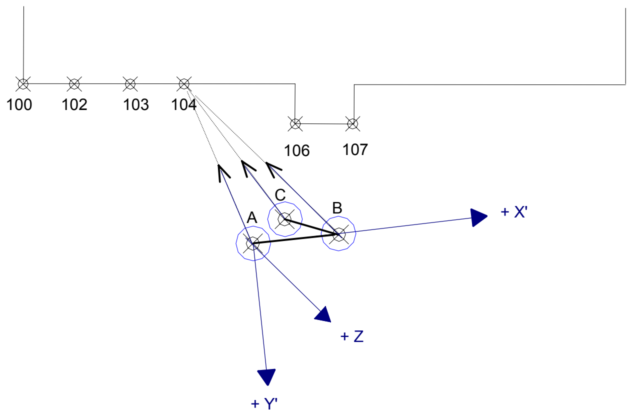

Figure 3 - Double Forward Intersection

3.3.3 Comparison between polar and intersection method

Coordinate differences for 15 determinations were compared and showed the following standard deviations:

± 6.61 mm in x-coordinates (1 point out of tolerance)

± 8.26 mm in y-coordinates (2 points out of tolerance)

3.4 Computations

The spatial coordinates (x,y,z) were computed by use of a program developed based on manual calculations for plane forward intersection combined with trigonometric levelling by the author Walter da Silva Prado, (see fig. 4).

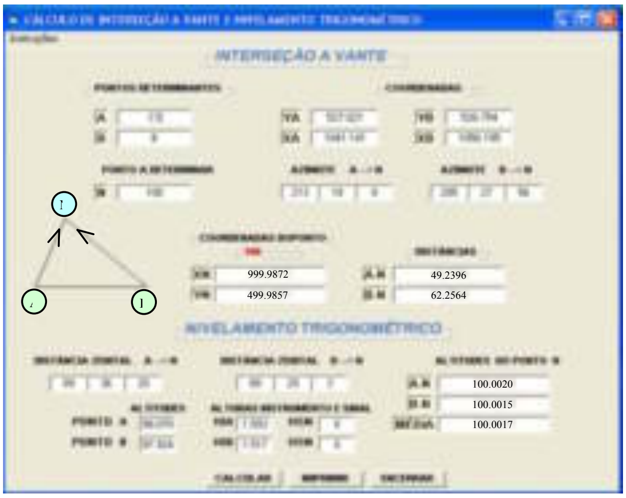

figure 4 - Forward Intersection Combined with Trigonometric Levelling

3.5 Coordinate transformation

The coordinates computed in the arbitrary local coordinate system have to be transformed into the object system.
As already stated, both sets of coordinates can be treated as plane ones- this arrangement simplifies transformation calculation. Different types of plane transformations were used. see (1, Albertz / Kreiling - 7, Luhmann):

- similarity transformation with 2 identical points
- similarity transformation with over-determination (HELMERT - Transformation with 5 identical points)
- affine transformation with over-determination (HELMERT -Transformation with 5 identical points)

Based on manual calculations the three transformations were programmed by the author Walter da Silva Prado, (see figure 5).
We suggest the similar transformation with over-determination to be the most adequate solution. Affine transformation is not necessary, because both systems are at the same scale.
The comparison of the two similarity transformations shows insignificant differences.

TRANSFORMAÇÃO PLANA DE SEMELHANÇA COM EXCESSO						
TRANFORMAÇÃO DE HELMERT						
SISTEMA DE CAMPO				SISTEMA OBJETO (FACHADA)		
PONTO	Y	X		Y	X	PONTO
PONTOS IDÊNTICOS				PONTOS IDÊNTICOS		
103	4969,552	19981,197		500,000	1019,067	103
106	4979,605	20009,715		507,067	1048,443	106
100	4967,584	19962,213		500,000	1000,000	100
102	4968,524	19971,280		500,000	1009,110	102
107	4980,654	20019,866		507,067	1058,639	107

PONTOS A TRANSFORMAR				PONTOS TRANSFORMADOS		
PONTO	Y	X		Y	X	PONTO
100	4967,584	19962,213		499,997	1000,000	100
101	4967,638	19962,285		500,044	1000,077	101
102	4968,524	19971,280		500,000	1009,108	102
103	4969,552	19981,197		500,004	1019,069	103

figure 5 - Similarity Transformation with Over-determination

3.6 Final comments about the two coordinate systems

3.6.1 During the first days of the project, all measurements and computations were executed in the arbitrary local coordinate system.

3.6.2 However, once having transformed the station coordinates of A, B and C into the object system, all further measurements and computations were carried out in the object system. The horizontal circles of theodolites and total stations were oriented in the object system; therefore we were able to measure azimuths in the field.

3.6.3 A further check for two of the transformed station coordinates were obtained in the field by use of the program "Determination of Free Station Coordinates" of Total Station LEICA TCR 307.

3.7 Precisions of ground control coordinates

Derived from coordinate differences we calculated the standard deviations for the ground control coordinates as follows:

standard deviations (mm)		Tolerances (mm)
± 8.8	In x	± 15
± 8.3	In y	± 45
± 3.4	In z	± 15

These precisions are adequate to the scale 1:200 of orthophoto.

3.8 Artificial points in the object coordinate system

During processing orthophotos by PhotoModeler software we had to create about 16 artificial points in order to mark the edges of the orthophoto areas. These points, so-called QG (quebra galho), were defined in the y-plane by the intersection of horizontal lines (z = const. of known points) with vertical lines (x = const. of known points). In order to proof such procedure, some coordinates were checked by field measurements.

4 TAKING IMAGES

A total of about 28 orthogonal and oblique images were taken with both cameras.
Due to some obstructions such as trees, leaves, traffic, parked cars, etc, the cameras could not be placed in

appropriate positions and therefore some images are very oblique.
This is the case of the upper part of the central façade, which is very high – no hydraulic lifting device for the cameras was available.

5 PROCESSING WITH PHOTOMODELER

The two cameras were calibrated according to the instructions of the PhotoModeler user manual.
In the course of processing very oblique images for the purpose of the absolute orientation of models, we had to make use of additional auxiliary points (see 3.8).
For the assembling of the five orthophotos to a mosaic we employed the software ALDUS PHOTOSTYLER 2.0.
This orthophotomosaic served for the plot in AUTOCAD. (see Appendix)

6 PROCESSING WITH DIGITAL VIDEO PLOTTER (DVP)

At the present moment, only a rectified image of one façade, produced by DVP-software, is finished.
Orthophoto production is still in progress.

7 CONCLUSIONS

For small plane objects (façades, walls, etc) a simplified ground control - using tape and level only - is sufficient for the orthophoto generation. In case of large objects, however, the ground control has to include topographic measurements i.e. the employment of theodolites or total stations is a must.
The PhotoModeler –Software showed to be very useful for the generation of orthophotos as a base for the plot. i

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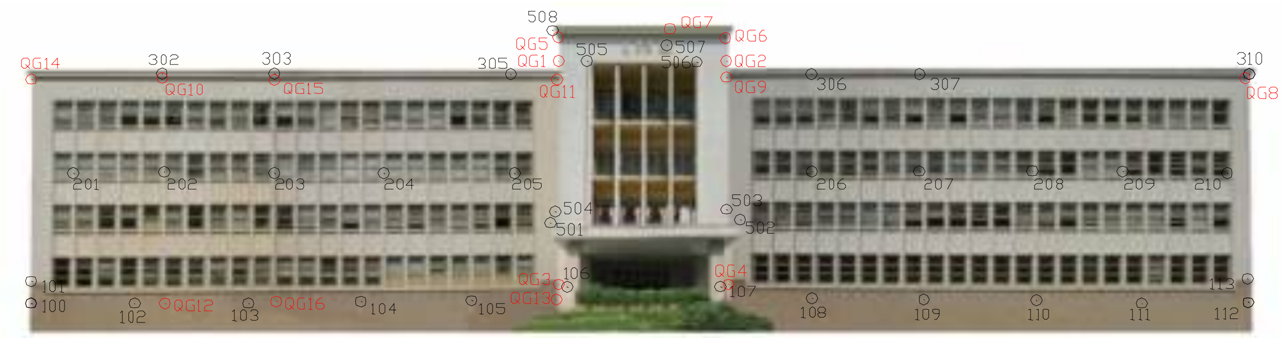
Captain Justino Francisco Pires de Oliveira, of Departamento de Engenharia de Fortificação e Construção, (IME) – for plotting the main façade in AUTOCAD.

APPENDIX

1 - Distribution of Targets and Auxiliary Points.
2 - Orthophotomosaic.
3 – Plot of the Main Façade.

APPENDIX



1 - DISTRIBUITION OF TARGETS AND AUXILIARY POINTS

2 - ORTHOPHOTOMOSAIC

3 - PLOT OF THE MAIN FAÇADE