# THE EMPRESS MANOR A PIONEER PHOTOGRAMMETRIC PROJECT IN BRAZIL USING THE 3X3 RULES

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# ABSTRACT

Key words: 3x3 rules, preservation, restoration, photogrammetry, cultural heritage

This is the first architectural photogrammetric survey undertaken in Brazil applying the 3x3 rules proposed by Prof. Peter Waldhäusl, University of Technology, Vienna.

One of the main goals of this work is to disseminate and popularize in Brazil low-cost methods already in use in countries where the preservation of the cultural heritage is well developed.

Relevant aspects having fundamental importance on the 3x3 rules method when compared with the conventional architectural photogrammetric procedures are the reduction of costs and time necessary to produce models.

Being more efficient (less money and time consuming) this measurement method presents an accuracy compatible with the requirements of historical documentation and restoration projects.

Calculations have been done comparing the internal geometry of the non-metric camera used, a Mamiya RB67 Pro S with a 50 mm wide angle lens, with the P32 Wild metric camera (64 mm lens) as a parameter.

With the results obtained it is possible to conclude that this method is an invaluable tool that ought to be widespread in Brazil, a country that possesses a great architectural heritage requiring documentation.

The building belongs to the Rio de Janeiro Botanical Garden. Its origin goes back to 1575 when it was the manor of the farm known as D'El Rey and later Nossa Senhora da Conceição da Lagoa Farm, erroneously called Empress Manor.

# 1 - INTRODUCTION

This project is part of a series of investigation the authors are undertaking in search of means and methods to survey Brazilian historic heritage at low cost and under modern techniques. Integrates the "Anteprojeto of Brazilian Historic Monuments" (Gomes et al, 1995).

This project also integrates the Master Degree thesis in Architecture of one of the authors, in the field of Preservation and Restoration of the Cultural Heritage, at the Faculdade de Arquitetura e Urbanismo of the Universidade Federal do Rio de Janeiro.

#### **1.1 - A brief history of the Empress Manor**

The building situated at 2040, Pacheco Leão Street has been erroneously called "Empress Manor" for more than two decades due to a misinterpretation that led to the conclusion that it was the house that Pedro I gave to his wife the empress Dona Amelia of Leuchtemberg. In fact, it has been the manor of the Fazenda dos Macacos (Monkey's Farm). The reason why the misinterpretation occurred is the similarity of names to different places, establishments or geographic accidents in Rio de Janeiro.

There are at least two known Fazenda dos Macacos: the one situated at the side of the Macacos River, and another one that belonged to the empress, situated between the Boa Vista Palace in São Cristóvão and the Andaraí community, area that originated the Vila Isabel borough. Donated by D. Pedro I to the empress in 1829, has been sold to the Baron of Drummond in 1872.

The history of this house is intimately attached to the history of the Nossa Senhora da Conceição da Lagoa Mill, established in 1575 by the Governor D. Antonio Salema. It was then called D'El Rey Mill (king's mill). Is remained in the hands of the crown only till 1589 when it was sold and became private property. At the end of the XVIII century the lands of the farm comprehended the area nowadays occupied by Jardim Botânico, Horto, Gávea, Leblon, Ipanema, Arpoador, Lagoa, part of Humaitá and a big part of the Tijuca National Park boroughs. The original building focused by this project was a small house that belonged to Manuel da Rocha Vieira, constructed at the "Chácara do Macaco" where he, his wife and five children lived. The house has been built over wooden blocks and had adobe walls covered with tiles. It measured 36,5 x 53 palms in the back (each palm measures 8 inches or 22 centimeters; so the house measured about 8 x 12 meters).

It has been rebuilt many times and received various additions during its existence, caused by the many and successive changes in its use.

#### 1.2 – Selection of the building

This building has been selected because its origins goes back to the XVI century, has been modified and addicted during its long history and was to be restored. According to Gonçalves and Carvalho (1993), in one way or another, the addictions have incorporated the construction of the building we see today. The option of the Restoration Project was to keep the visibility of the various moments of the history of the group of buildings that testifies its evolution.

To document the situation of the building before the restoration by a photogrammetric method never used in Brazil was a rare and interesting opportunity.

# 2 - MATERIALS AND METHODS

#### 2.1 - Adopted method

Herbig and Waldhäusl (1994) presented an extremely simplified method to produce photogrammetric documents for Architectural use named "3x3 Rules", which the characteristics was: the use of non-metric cameras and the simplification of the photographic method. Once the object of this project has been chosen the "3x3 Rules" have been defined as the photogrammetric method to get knowledge and to evaluate its applicability, as well as the degree of precision we would find under our operation conditions.

# 2.2 - 3x3 Rules for simplified restitution of facades

The rules that give name to this method are defined under three chapters:

- three geometrical rules;
- three photographical rules and
- three organisational rules.

Resuming the major points we have:

- the use of non-metric cameras, that is, simple non-calibrated cameras;
- the photographic stereo pair is taken with the camera in orthogonal position to the object, and camera positions separated by a distance called "base" and parallel to the façade;

- there is no need to determine control points for intersection;
- however, distances have to be measured on the object to determine the restitution ratio. It is also possible to use stadias to be photographed;
- plans, horizontal and vertical lines (yardsticks) are defined on the object.

#### 2.3 - Preparing the model

The façade of the manor house was divided in 6 (six) models due to the irregularity of the ground, like its inclination and the presence of trees that could obstruct the coverage of the façade according to the "normal case". The first step was to fix 7,5 cm diameter targets on each of the 6 models. Distances between them have been measured. Scales and yardsticks to help establish control points are present in each of the models. In this paper only the results of model 1, Chapel, will be presented.

# 2.4 - Defining the camera-to-object distance, angle of shooting and base

Camera-to-object distances have been calculated for each model according to its width. Base of the stereo pair has been defined as 1/10 of the camera-to-object distance. The angle of shooting was about 90°.

#### 2.5 - Photographic equipment

Photographic equipment used was a Mamiya RB 67 ProS camera, medium format 6x7, with a Sekkor C 50 mm lens.

#### 2.5.1 - Camera's characteristics

Focal distance f= 50 mm Aperture 1:4.5 Format a x b mm =  $68 \times 56$  mm Coverage angles a:  $68.4^{\circ}$  b:  $58.5^{\circ}$ Diagonal:  $82.8^{\circ}$ 

#### 2.5.2 - Camera calibration

Measurement of the coordinates of the chosen fiducial marks has been made at the Wild AVIOLYT BC2 analytical restitution equipment of Aerofoto Cruzeiro S.A., at Rio de Janeiro.

As the camera used is non-metric thus not having fiducial marks, the four corners of the negatives has been chosen as fiducial marks as per Kraus (1997).

Focal Distance = Principal Distance (mm) = 50.00

| FM               | Coord. (mm)                            | Origin PP                              |  |  |  |  |
|------------------|--|--|--|--|--|--|
|                  | Х                                      | Y                                      |  |  |  |  |
| 1<br>2<br>3<br>4 | 33.994<br>-33.994<br>-33.994<br>33.994 | 28.149<br>28.149<br>-28.149<br>-28.149 |  |  |  |  |

Camera MAMIYA Fiducial Marks (µm) Origin PP

| MF | Х        | Y        |
|----|----------|----------|
| 1  | -35053.0 | -34199.0 |
| 2  | 32974.0  | -32477.0 |
| 3  | 31406.0  | 23722.0  |
| 4  | -36605.0 | 21970.0  |



Fig. 1 – Negative format and Chosen fiducial marks

| [mage | Points  | (um)    |
|-------|---------|---------|
| inage | 1 Onico | (perir) |

| Seq.N°                               | Pt.N°  | Х  | Y  |
|--------------------------------------|--|--|--|
| 1<br>2<br>3<br>4<br>5<br>6<br>7<br>8 | 501<br>502<br>503<br>504<br>027<br>028<br>029<br>016 | 22818.0<br>- 25101.0<br>20004.0<br>- 18255.0<br>- 19002.0<br>11359.0<br>20895.0<br>32218.0 | - 15218.0<br>- 17578.0<br>14162.0<br>13292.0<br>- 8293.0<br>- 7970.0<br>- 7514.0<br>- 9291.0 |
| 10<br>11<br>12                       | 032<br>031<br>032<br>030                             | 6999.0<br>19816.0<br>- 18775.0   | - 515.0<br>1241.0<br>- 1062.0  |

#### 2.6 - Photometry

We used a Minolta IV flash meter, with spherical diffuser to measure incident light.

#### 2.7 - Film

ILFORD FP4 120,125 ISO black & white negative film was used. It is a panchromatic fine grain film, high resolution and high definition. Four films were used, producing 10 (ten) negatives each. Two shots have been made at each camera position generating two different negatives under different time settings and maintaining the same aperture.

#### 2.8 – Shooting

According to the photogrammetric principles and following the 3x3 Rules, several camera positions have been chosen for taking the pictures as follows:

> <u>Façade n<sup>0</sup> 1</u> (Figure 2) Object's width : L = 9.3 m Distance to object : Y = 11.00 m

Photo ratio : 1 : 220 Restitution ratio : 1 : 50 Enlarging factor : 4.4 x (recommended for ortophotos between 4 and 6 times) Base length : B = 2.00 m

Y/B ratio : 5.5 (possible between 4 and 20, recommended between 5 and 10) Photograph's superposition

Formula :

$$p\% = \frac{Y_{\cdot}(\frac{a}{f}) - B}{Y_{\cdot}(\frac{a}{f})}.100$$

p = 86.6 %

Approximate precision in the *Y* direction of the object

Formula :

$$dy = \pm Y.(\frac{Y}{B}).(\frac{dpx}{f})$$

 $dpx = \pm 0.007 \text{ mm}$ 

 $dy = \pm 8.47 \text{ mm}$ 

Approximate precision in the X and Z directions

Formula: dx = dz = 0.5 dy

Graphic precision of the plant 
$$1:50:\pm 10$$
  
at

mm

object Photograph's width 220 x a = 14.96 m Model's width Formula :

$$S_{ST} = Y \frac{a}{f} B$$

 $S_{ST} = 12.96 \text{ m}$ 

Object's width : L = 9.30 m

#### 2.8.1 – Applying 3x3 Rules

According to the rules the steps above have been followed:

- 7,5 cm diameter targets have been fixed on the façade;
- horizontal length between targets have been measured;
- 2 (two) graduated stadia, one vertical, one horizontal (4 m long each) for control of the ratio of restitution were used;
- 2 (two) yardsticks were used to define plumb lines;
- distances between targets, yardsticks and stadia have been measured.

#### 2.9 - Restitution

#### 2.9.1 - First steps

Due to budget limitations we decided that only the stereo pair of the chapel of the manor (façade #1) would be used for the production of the orthophoto and the restitution. The restitution process began with the measurement of the image coordinates of both negatives that constitute the stereo model of the façade. Measurement has been made with the help of an analytical restitutor Wild AVIOLYT BC2, in monocomparator mode.

# 2.9.2 - Production of the orthophoto at the Vienna University of Technology

The Institute of Photogrammetry and Remote Sensing of the Vienna University of Technology have processed the negatives of façade # 1 and its coordinates by steps:

- a) measurement of points at the object by means of the ORPHEUS software;
- b) adjustment of these measurement by means of the ORIENT software, using distances and vertical and horizontal lines defined at the object. The vertical surface of the façade was mainly considered in the calculations;
- c) rectification of the façade was made by means of the IDL software. The result is an analytical orthophoto at 1: 50 ratio (Figure 3).

# 2.9.3 - Restitution of the plan of façade 1 at 1:50 ratio

# **2.9.3.1** - Calculations of the control points coordinates

First of all, we defined a coordinates system for the restitution of the stereoscopic model of façade # 1, as follows:

> Axis X: from left to right Axis Y: from down to up Axis Z: from the object ahead (heights) Origin of the system: target # 27

| <u>Point 27</u>   | Point 28                                    |  |  |  |  |  |
|---|---|--|--|--|--|--|
| $X_{27} = 1000.000 \text{ m}$<br>$Y_{27} = 100.000 \text{ m}$<br>$Z_{27} = 500.000 \text{ m}$ | $X_{28} = 1006.525 \text{ m}$<br>$Y_{28} =$ |  |  |  |  |  |

Next, well-defined points at the façade have been chosen as follows:

- points at vertical lines : X = constant
- distances approximately horizontal :  $\Delta X$
- points at horizontal lines : Y = constant

- points at the surface of the façade :  $\mathbf{Z}$  = height = constant

These points have been measured at the AVIOLYT BC2 after the relative orientation performance. After that were processed by means of

the Prof. Ackermann PAT-M43 software. The result is a list of coordinates (X, Y, Z) consisting of 33 points.

#### 2.9.3.2 - Restitution of the façade at the DVP of the Instituto Militar de Engenharia – IME, in Rio de Janeiro

We also chose to perform the digital restitution far from the normal architectural photogrammetric procedure to analyse the results and to compare it with the orthophoto produced by the Vienna University of Technology.

To have the digital images necessary to perform the restitution at the DVP we used a Sharp JX-610 scanner with a special lamp for transparencies.

Negatives have been digitalized at 600 dpi, maximum optical resolution of the scanner. Then they have been transformed in positives using the Pstyler 2.0 software and stored in the memory as noncompressed tif format. This way we obtained a model according to the requirements of the DVP. At 600 dpi each pixel measures 42.3  $\mu$ m.

The inner orientation of the model was performed using a focal distance of 50.00 mm and the corners of the negatives as fiducial marks measured by a comparator, as per 2.5.2. The relative orientation was performed as usual, employing six points of Gruber. After the absolute orientation made, in which twelve of the thirty-three control points have been used, the restitution of the façade details began. Vertical and horizontal stadia can be used to verify the restitution ratio.

The vectorial archive of the restitution obtained at the DVP have been exported in dxf format and later edited and printed at the MicroStation 95 software.

# **<u>3. DISCUSSION AND RESULTS</u>**

The final result of these procedures is a plan of the façade at a 1:50 ratio (Figure 4).

Annexes 1, 2 and 3 show data referring to the model orientation at the DVP. It is possible to verify that even without the use of fiducial marks that exists in metric cameras the results obtained presents medium quadratic errors of the order of centesimals of millimeters that are similar to the error met in surveys undertaken under conventional photogrammetric conditions. Consequently, compatible with the margin of error accepted in projects of restoration of the architectural heritage.

Using the formulae of planimetric precision described at the DVP manual we have as planimetric precision of the restitution:

 $\tau_{XY} = PS * P * 0.7 * 10^{-6}$ 

$$\tau_{XY} = 220 * 42.3 * 0.7 * 10^{-6}$$
  
 $\tau_{XY} = 0.01 \text{ m} = 1 \text{ cm}$ 

where PS = photo ratio

P = dimension of the pixel in  $\mu m$ 

# **4. CONCLUSIONS**

Every state of the art technology generates controversies and interesting technical discussions till it is accepted and put into practical effect. It couldn't be different with this job. But the interaction of technician of different countries, of three universities – the Instituto Militar de Engenharia, the Universidade Federal do Rio de Janeiro and the University of Technology of Vienna, was rewarding and gratifying. In addition to the academy, a genuinely Brazilian society having great technical capability, pioneer in Architectural Photogrammetric project, also participated in this job: Aerofoto Cruzeiro S.A.

Many parameters have been analysed. The results obtained authorize the following conclusions:

- photogrammetric procedures according to the 3x3 Rules are simpler, faster and less expensive than the traditional methods;
- it is an excellent tool to produce archival documents of surveys of the nation historic building stock, in view of its ability to produce fast and precise results with low cost and the restricted physical danger to which the agents may be subject. So rapid is this process that decisions can be taken when the building been surveyed is under imminent danger;
- even if it collapses, it is possible to rebuilt in its original shape and volume, preserved by the stereo pair;
- errors are perfectly compatible with the architectural requirements for preservation and restoration;
- there is no need to restitute the photographs immediately, that is the more expensive part of the process, as the negatives can be well archived for long periods;
- negatives and positives can be digitally produced, thus generating archives easily transported and manipulated, accessible and usable on site or at a remote location, far from the origin of the original documents;

- the orthophoto has no inclination and its ratio is constant, allowing direct and highly precise measurement, with a maximum planimetric error of centimeters or less;
- it allows following of the work during all its steps;
- doubt that arise during the work can be solved putting the stereo pair on the DVP for observation;
- the orthophoto allows the comparison between the restoration work carried out with the original plan of the building, if any;
- it allows calculation of the volume of the materials to be incorporated, as it measures height, width and depth;
- the object is rarely touched during the work and this represents safety to the building against possible damages and security to the group during the work in the field.

Giving publicity of these results to the Brazilian photogrammetric community, we intend to demonstrate that it is possible to preserve the cultural heritage of the nation economically and precisely. Undoubtedly, Architectural Photogrammetry is a powerful tool to this end. The participants of this research fill themselves fulfilled with their contribution to help to put into practical effect and disseminate these techniques in Brazil.

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# Annex 1

| RESUL | JTS OF  | INT  | 'ERIOR ORI | ENTAT | ION : SO | LAR2 |         |     |        |
|-------|---------|------|------------|-------|----------|------|---------|-----|--------|
| (06-1 | 5-199   | 9 08 | :19:45 )   |       |          |      |         |     |        |
| Focal | leng    | th = | 50.000     |       |          |      |         |     |        |
|       | 2       |      |            |       |          |      |         |     |        |
| Ortho | gonal   | tra  | nsformati  | on    |          |      |         |     |        |
| LEFT  | IMAGE   |      |            |       |          |      |         |     |        |
| 1     | 1       | x=   | 33.994     | vx=   | 0.213    | y=   | 28.149  | vy= | -0.176 |
| 2     | 2       | x=   | -33.994    | vx=   | -0.158   | y=   | 28.149  | vy= | -0.254 |
| 3     | 3       | x=   | -33.994    | vx=   | -0.203   | y=   | -28.149 | vy= | 0.208  |
| 4     | 4       | x=   | 33.994     | vx=   | 0.148    | y=   | -28.149 | vy= | 0.223  |
| RIGHT | IMAG    | E    |            |       |          |      |         |     |        |
| 1     | 1       | x=   | 33.994     | vx=   | 0.266    | y=   | 28.149  | vy= | -0.220 |
| 2     | 2       | x=   | -33.994    | vx=   | -0.181   | y=   | 28.149  | vy= | -0.335 |
| 3     | 3       | x=   | -33.994    | vx=   | -0.286   | y=   | -28.149 | vy= | 0.263  |
| 4     | 4       | x=   | 33.994     | vx=   | 0.202    | y=   | -28.149 | vy= | 0.293  |
| Affin | le trai | nsfo | rmation    |       |          |      |         |     |        |
| LEFT  | IMAGE   |      |            |       |          |      |         |     |        |
| 1     | 1       | x=   | 33.994     | vx=   | 0.005    | y=   | 28.149  | vy= | 0.016  |
| 2     | 2       | x=   | -33.994    | vx=   | -0.005   | y=   | 28.149  | vy= | -0.016 |
| 3     | 3       | x=   | -33.994    | vx=   | 0.005    | y=   | -28.149 | vy= | 0.016  |
| 4     | 4       | x=   | 33.994     | vx=   | -0.005   | y=   | -28.149 | vy= | -0.016 |
| RIGHT | IMAG    | E    |            |       |          |      |         |     |        |
| 1     | 1       | x=   | 33.994     | vx=   | -0.010   | y=   | 28.149  | vy= | 0.021  |
| 2     | 2       | x=   | -33.994    | vx=   | 0.010    | y=   | 28.149  | vy= | -0.021 |
| 3     | 3       | x=   | -33.994    | vx=   | -0.010   | y=   | -28.149 | vy= | 0.021  |
| 4     | 4       | x=   | 33.994     | vx=   | 0.010    | y=   | -28.149 | vy= | -0.021 |
|       |         |      |            |       |          |      |         |     |        |

### Annex 2

| RESUL                                | TS (mm                  | ) 0                                  | FRI  | ELATIVE O  | RIEN                                   | TATION :  | SOL  | AR2  |   |  |
|--------------------------------------|-------------------------|--------------------------------------|--|--|--|---|--|--|---|--|
| (06-1                                | 5-1999                  | 08                                   | :29  | :30)   |  |   |  |  |   |  |
| 1<br>2<br>3<br>4<br>5<br>6<br>7<br>8 |                         | 1<br>2<br>3<br>4<br>5<br>6<br>7<br>8 | x=<br>x=<br>x=<br>x=<br>x=<br>x=<br>x=<br>x= | -2.03<br>-3.48<br>3.89<br>6.61<br>6.93<br>6.21<br>3.09<br>2.74 | y=<br>y=<br>y=<br>y=<br>y=<br>y=<br>y= | -2.06<br>6.09<br>6.13<br>6.64<br>1.68<br>-2.69<br>-2.94<br>1.36 | Z =<br>Z =<br>Z =<br>Z =<br>Z =<br>Z =<br>Z =<br>Z = | -14.42<br>-16.36<br>-16.48<br>-16.72<br>-15.50<br>-10.91<br>-10.21<br>-15.41 | ру=<br>ру=<br>ру=<br>ру=<br>ру=<br>ру=<br>ру= | 001<br>.002<br>004<br>.007<br>004<br>.001<br>.001<br>004 |
| Standa<br>bx=<br>om=                 | ard er:<br>2.65<br>0.25 | ror<br>by<br>fi                      | :<br>=<br>=                                  | py =<br>0.07 bz<br>7.05 ca                                     | 0.0<br>=<br>=                          | 004<br>0.07<br>2.80   |  |  |   |  |

# Annex 3

RESULTS OF ABSOLUTE ORIENTATION : SOLAR2 (06-15-1999 09:28:25 )

| 27       | X=    | 999.99  | dX= | 0.00   | Y=   | 99.60 d  | =Y£ | -0.00 | Z = | 500.00 | dZ= | 0.01  |
|----------|-------|---------|-----|--------|------|----------|-----|-------|-----|--------|-----|-------|
| 28       | X=    | 1006.53 | dX= | 0.00   | Y=   | 99.51 d  | lY= | 0.01  | Z = | 500.00 | dZ= | -0.00 |
| 29       | X=    | 1008.60 | dX= | 0.01   | Y=   | 99.56 d  | lY= | -0.01 | Z = | 500.11 | dZ= | -0.01 |
| 30       | X=    | 1005.71 | dX= | -0.01  | Y=   | 101.22 d | lY= | 0.01  | Z=  | 500.01 | dZ= | -0.03 |
| 31       | X=    | 1008.59 | dX= | 0.03   | Y=   | 101.55 d | lY= | -0.00 | Z=  | 500.10 | dZ= | 0.02  |
| 603      | X=    | 1003.68 | dX= | -0.02  | Y=   | 101.11 d | lY= | -0.01 | Z = | 500.03 | dZ= | -0.01 |
| 702      | X=    | 999.93  | dX= | 0.01   | Y=   | 103.98 d | lY= | -0.01 | Z=  | 500.01 | dZ= | -0.01 |
| 703      | X=    | 999.93  | dX= | 0.05   | Y=   | 101.17 d | lY= | 0.02  | Z=  | 500.02 | dZ= | 0.01  |
| 801      | X=    | 1002.40 | dX= | -0.03  | Y=   | 104.80 d | lY= | 0.02  | Z=  | 499.99 | dZ= | -0.04 |
| 802      | X=    | 1004.99 | dX= | -0.01  | Y=   | 104.80 d | lY= | -0.05 | Z = | 500.00 | dZ= | 0.04  |
| 803      | X=    | 1007.57 | dX= | 0.01   | Y=   | 104.80 d | lY= | 0.01  | Z = | 500.00 | dZ= | -0.01 |
| 805      | X=    | 1006.37 | dX= | 0.00   | Y=   | 104.81 d | lY= | 0.02  | Z = | 500.00 | dZ= | -0.01 |
| 808      | X=    | 1003.77 | dX= | -0.01  | Y=   | 104.81 d | lY= | -0.02 | Z=  | 499.99 | dZ= | 0.04  |
| 809      | X=    | 1002.57 | dX= | -0.02  | Y=   | 104.81 d | lY= | 0.01  | Z = | 499.98 | dZ= | -0.02 |
| 901      | X=    | 1002.17 | dX= | -0.03  | Y=   | 98.62 d  | lY= | 0.01  | Z=  | 500.04 | dZ= | 0.00  |
| Standard | erroi | c: mX=  | 0.0 | )2 mY= | 0.02 | mZ= 0.0  | )2  |       |     |        |     |       |



Fig. 2 - Stereo pair of the façade  $\,\,1\,\,rest ituted at the DVP$ 

Fig. 3 - Digital attaphoto of the Empress Manor (ratio 1:50) produced by the Technical University of Vienna





Fig. 4 - The Empress Manor (1:50) digitally restituted at the DVP in the Department of Cartogrphy of the Military Institute of Engineering



Fig. 5 - Comparison between the ortophoto and the restitution