SOME SPECIAL CASES OF CLOSE RANGE PHOTOGRAMMETRY APPLICATION

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ABSTRACT:

Photo and video cameras have become irreplaceable in a modern man's life. Millions of these cameras register all important events that happen. From the photogrammetric point of view these are non-metric cameras. Utilization of photos made by these cameras for measurement pupooses can be invaluable in many situations. This has been subject of interest at the Laboratory for Photogrammetry , Institute of Geodesy , Faculty of Civil Engineering Belgrade , since 1987. An experiment and three characteristic examples of photography made by non-metric cameras are presented in the paper.

INTRODUCTION

In various circumstances, a lrage number of photos is made by using ordinary photo camera, without previously planned taking of photographies. On the other side, the standard application of close-range photogrammetry usually assumes:

- utilization of the professional photogrammetric equipment which provides that difference between projection at the moment of film exposure and central projection is as small as possible, and
- calculation of the photography disposition which is going to provide the required accuracy for final results, considering the selected equipment and field conditions.

Introduction of analytical photogrammetric methods enabled the needs of a large number of users who do not use standard photogrammetric methods to be satisfied (Wong 1975, Kager 1976, Fraser 1982). This also enabled utilization of photos made by non-metric cameras for measurement purposes (Waldhaeusl, 1988).

Possession of adequate software and interesting problems that appeared in practice had enabled investigations in this field at the Laboratory for Photogrammetry since 1987. The paper presents a brief overview of few selected experiments and projects where one or both of the above mentioned conditions were not satisfied.

EXPERIMENT

In 1987, Laboratory for Photogrammetry at the Faculty of Civil Engineering in Belgrade and Crime Investigation Service of the Belgrade Police Department have carried out a specially prepared experiment (Mihajlović et al, 1994). A traffic accident was simulated at the street crossing (Figure 1). The aim of the experiment was to confirm possibilities of utilization of non-metric photos for traffic accident investigation. It should be an alternative method of investigation in cases where the standard photogrammetric procedure failed for any reason, or it could not provide all the necessary information. The traffic scene accident was registered using the following methods:

1. precise geodetic surveying (electrooptical tacheometer Carl Zeiss EOT 2000),
2. standard photogrammetric procedure (camera Wild C120, autograph Wild A40),
3. photography using non-metric cameras (Mamia 6x6cm, Yashica 6x6cm, Practica 24x36mm, Minolta 24x36mm i Mamia 24x36mm).

Precise surveying measurements were carried out to serve as control measurements, since they provide considerably higher accuracy of object coordinates then photogrammetric methods. Using precise tacheometry, the positions of 100 object points were determined from specially developed geodetic network. The same points were measured on photos made by non-metric cameras and by the Wild photogrammetric camera. Photo measurements were carried out on monocomparator, and the data were processed using software packages BINGO and FotoSoft. The photos were processed in series, where one series included all photos made by one camera and with the same photo material.

Coordinates for object points from five independent series, acquired by photography using different types of non-metric cameras, different format and different photo material, have been compared with the results of the geodetic survey and shown in Table 1. General information on data adjustments, important for drawing conclusions, have been presented in the same table. The results and conclusions were encouraging. Only those which concern the achieved accuracy will be herby emphasized:

1. All camera types, regardless of format and photo material, provide the required accuracy. For the realised

experiment it is 4-8 cm in XY plane and 1-3 cm in Z-axis.

2. The accuracy of Z coordinate is up to three times accuracy of X and Y coordinate.
3. Regardles of theoretical accuracy of image coordinates measurement which is 1mm, the achieved accuracy is considerably lower (8-13mm). The reason is found in the errors of geometrical projection which are not eliminated, and partially in the errors of point definition.

Table 1 : The results of photogrammetric adjustments compared with the results of geodetic survey

Camera Film Format	Photo no	σ [mm]	N U N-U	c [mm] ξ [mm] η [mm]	m_x [mm] m_y [mm] m_z [mm]
MAMIA black &whit 60x60 mm	5	0.013	204 153 51	90.163 -0.409 0.139	0.064 0.076 0.013
YASHICA colour 60x60 mm	6	0.013	237 162 75	90.295 -0.226 0.125	0.043 0.064 0.013
PRACTICA black&white 60x60 mm	5	0.012	202 141 61	52.481 -0.151 0.548	0.047 0.080 0.024
MINOLTA black&white 24x36 mm	5	0.014	212 156 56	51.623 -1.451 0.373	0.046 0.037 0.013
MAMIA colour 24x36 mm	3	0.008	131 117 14	54.454 0.012 -0.012	0.032 0.020 0.030

At the end of 1993, this experiment was extended (Mihajlović, 1994). The task was to take photography of the same scene accident by using camera RolleiFlex 6006 and to measure photos and process data with the RolleiMetric MR2 system. It was also planned to use that system for photo measurement and data processing for all previously made photos within the experiment. The purpose of this extension of the experiment was to answer to the following questions:

1. *Is it possible to replace comparator measurements (which are rather expensive) with tablet digitizer measurements (which are inexpensive)?*
2. *To what an extent is the accuracy improved (in this particular experiment) by using metric camera RolleiFlex 6006 comparing the accuracy achieved by use of non-metric photos made in 1987 ?*
3. *Is there a difference between the results of data processing carried out in 1987 and the results of data processing using the ROLLEIMETRIC MR2 system ?*

In addition to other useful experiences and observations, the following answers have been obtained:

1. The loss of accuracy deriving from measurements of photos using tablet digitizer is insignificant. The explanation is in the fact that comparator measurements, as the most accurate photogrammetric measurements, cannot significantly improve the overall accuracy because very often, the measured points are not precisely defined. This enables more freedom in planning and implementation of future projects.
2. With regard to accuracy, the results achieved within the experiment extension are almost identical to the results of the experiment that was realised in 1987. The explanation is to be found in the fact that the increase of the overall accuracy obtained by use of semi-metric camera has been neutralised by the lower accuracy of image coordinates measurements.
3. The results obtained by data processing by use of two independent software systems are identical. That was to be expected, considering the same mathematical model being applied.

In the 1972-1995 period, the experts of the Police Department in Belgrade were using camera Wild C-120 for photography of the traffic scene accidents accompanied with heavy injuries and damages and also for homicide cases. Restitution of photos was being carried out using Wild A-40. In the middle of 1995, this equipment was replaced with the RolleiFlex 3003 camera and the RolleiMetric MR2 photogrammetric system.

1. TRAFFIC SCENE ACCIDENT ANALYSIS

For court investigation requirements, expertise of the traffic scene accident that happened in November 1990 was carried out using available photo documentation (Mihajlović, 1994). Laboratory for Photogrammetry at the Faculty of Civil Engineering was appointed to conduct the expertise. The direct task of the expertise that was to be based on information contained in documents and available photo documentation was to determine the following:

- *"if traces on the street which are noticeable on photos from photo documentation belong to the vehicle driven by the accused,*
- *direction and speed of the vehicle driven by the accused need to be determined using the acquired data,*
- *using available photo documentation investigate all the facts that are important for the time and spatial analysis of the traffic accident.."*

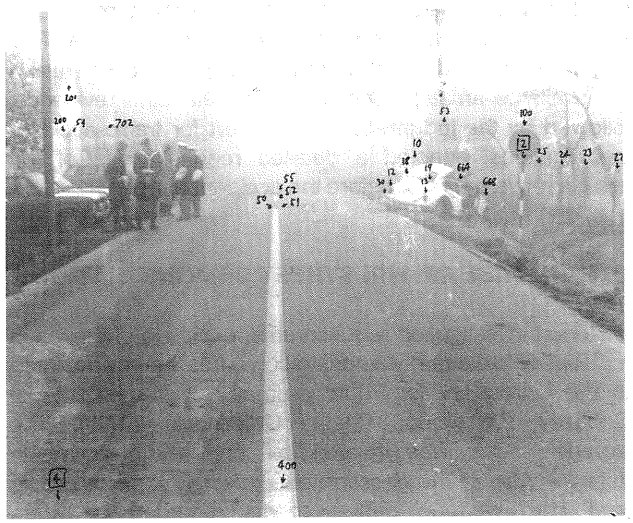

Figure 1: Photo of the traffic scene accident

This is the case of dealing with photos (Figure 1) that were made for photo documentation purposes only. As it will be seen from photography disposition, they were not made to serve as a basis for measurement, but as a visual documentation.

The position and geometry of traces that have been under investigation were determined by photogrammetric intersection using the available photo documentation and the additional field measurements. Comprehensive photogrammetric measurements and analysis have been carried out (Table 2). In addition to the traces in question, other relevant details have been shown on the drawing of the traffic scene accident such as: unquestionable traces, the found position of the vehicle, traffic signs, etc.

Table 2: Some characteristics of the traffic scene analysis project

Data acquisition	
control points	spatial intersection method ($m_x = m_y = m_z = 2cm$)
photo material	non-metric photos - Leica type
Data processing	
software	RolleiMetric MR2
number of cameras	1
number of photos	1 (2-6)
camera - objects distance	2 - 25 m
photography disposition	bad
data adjustment	bundle adjustment
accuracy of image coordinates	0.2 mm
achieved accuracy for object coordinates of the trace in question	2-3 cm in direction normal to the street axes; 5-10 cm in street direction

Comprehensive photogrammetric observations were necessary to provide the required accuracy and to connect questionable traces with other details important for the spatial and time analysis of the traffic scene accident. Two traces determined by photogrammetric intersection using the available amateur photos and all the other evidence, followed by the judgment of the expert for traffic accident investigations, enabled a detailed reconstruction of the vehicle movement just before the accident happened.

2. EXPERTISE OF THE STREET DEMONSTRATIONS

For court investigation requirements, expertise of the video material of the street demonstrations, has been appointed to the Laboratory for Photogammetry at the Institute of Geodesy (Mihajlović, 1994b, Cvijetinović, 1996). The expertise task was related to the photogrammetric determination of the direction and possible path of bullets fired from weapon during events recorded by video cameras. Video images of the event made by video reporters of several TV stations were given at the disposal of the Institute of Geodesy at disposal.

The expertise has been divided into several characteristic stages (Table 3).

Figure 2: One of the framed images

Table 3: Characteristic stages and the time taken by the expertise

	Description	h
1.	Conversion of the video material in a computer acceptable form and printing on paper	2 h
2.	Photogrammetric registration of the scene in front of the Federal Assembly building	1 h
3.	Inspection of the scene accident, field measurements	6 h
4.	Photogrammetric process. (orientation)	13 h
5.	Photogrammetric processi. (calculations of 3D coordinates)	3 h
6.	Creation of drawings by use of CAD tools	15 h
		Total : 40 h

The elements of the interior and exterior orientation of thirteen framed video images (Figure 2) have been determined by use of photogrammetric measurements and positions of control points determined by precise geodetic survey. Some of the most important characteristics of the project are presented in Table 4.

Calculations of coordinates for the top of the gun and the eye of the shooting person were necessary for the determination of the bullet direction. Mean square error of the X and Y coordinates wa 6.5 cm, and 1.7 cm for Z coordinate (Table 4).

Three dimensional coordinates and exterior orientation elements calculated by geodetic survey and photogrammetric methods were transported to AutoCAD where editing of final drawings was carried out. Wire frame drawing was generated for the scene in front of the Federal Assembly building (Figure 3). Drawings with vertical and horizontal profiles set in bullet direction, and perspective views from camera positions were also created.

Table 4: Some characteristics of the project - expertise of the events in front of Federal Assembly building

Data acquisition	
Control points	spatial intersection method ($m_x = m_y = m_z = 3cm$)
photo material	original video images printed on paper additional photo material made by RolleiFlex 6006 camera
Data processing	
used software	BINGO, *DigiSoft*, AutoCAD
number of cameras	1 (2)
number of photos	1 (2)
camera - objects distance	8m from the first camera, 20m from the second camera
photography disposition	bad
data adjustment	bundle adjustment
accuracy of image coordinates	0.2mm
achieved accuracy (exterior orientation)	$m_x=6cm$; $m_y=7cm$; $m_z=3.5cm$; $m_\varphi=m_\omega=m_\kappa=0.25$ grad
achieved accuracy (bullet direction)	$m_x=6.3cm$; $m_y=7cm$; $m_z=1.7cm$

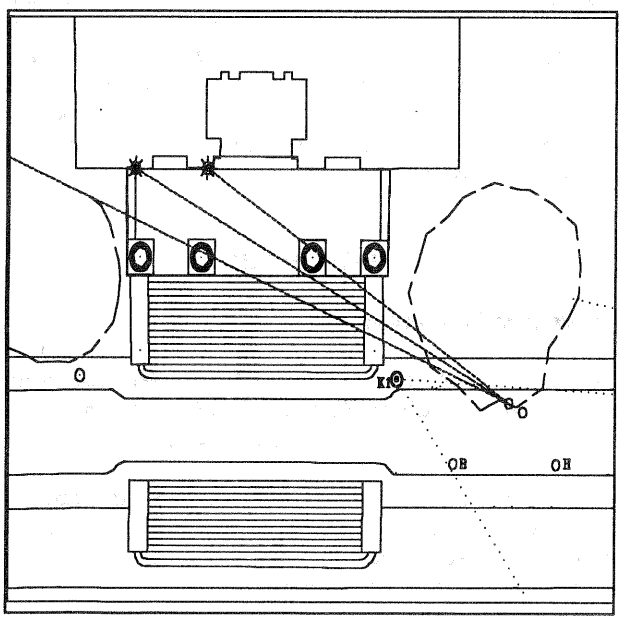

Figure 3: 2D drawing of the accident scene in front of the Federal Assembly building

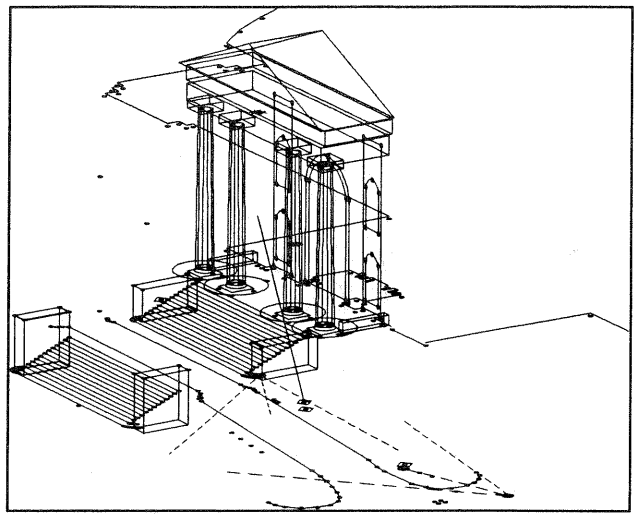

Figure 4: 3D drawings of the accident scene in front of the General Assembly building

Expertise had prevailing influence on the court investigation.

3. SURVEY OF THE INACCESSIBLE TERRAIN

Topography of the terrain which is hard to access accessible is very specific and complex. The problem of surveying of such a terrain can be very successfully solved using non-contact methods such as photogrammetry. However, the standard photogrammetric method (photography using professional camera, measurements on analog stereoplotter) is very limited in such cases. The procedure presented in this paper (Joksić et al, 1994) has been based on photography using non-metric camera and data processing using the RolleiMetric MR2 photogrammetric system.

The test area typical for the for the design of structures on communications (bridges, tunnels, viaducts) was chosen. Th photos made by use of the non-metric camera and coordinates of five control points were the only field measurements. Data processing was carried out using the RolleiMetric photogrammetric system. Photo images were reproduced using ordinary photo paper with the 5 times enlargement.

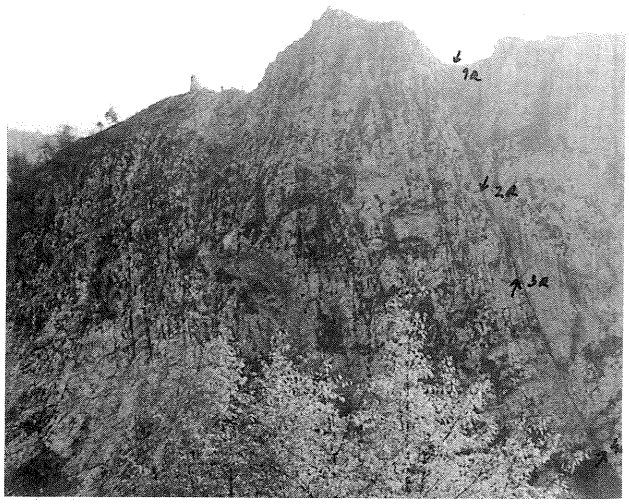

Figure 4: Photo of the test area

Coordinates for several hundreds of points on the terrain were determined for the project requirements. The achieved accuracy was about one decimeter (Table 5).

Table 5: Some characteristics of the project - survey of the hard to access terrain

Data acquisition	
control points	spatial intersection method ($m_x = m_y = m_z = 3cm$)
photo material	non-metric photos - Leica type
Data processing	
software	RolleiMetric MR2, Surfer
number of cameras	1
number of photos	5
camera - objects distance	100 m approx.
data adjustment	bundle adjustment
accuracy of image coordinates	0.2 mm
achieved accuracy (3D terrain coord.)	$m_x=6cm$; $m_y=6cm$; $m_z=12cm$

Data of this experiment were used within general project of the railroad bridge.

OBSERVATIONS ON FURTHER DEVELOPMENT OF THE PHOTOGRAMMETRIC SYSTEMS

During the implementation of the presented experiments and projects, some observations concerning further development of the close-range photogrammetric system could be made. As far as hardware is concerned, a monocomparator has been used for the first experiments, and tablet digitizer for succeeding ones. Today, it is possible to measure photo coordinates without these instruments. For data processing (adjustment, presentation) it was necessary to use several software packages and to provide a link between them. In the last few years, revolutionary changes took place in photogrammetry. Only few components of the classical hardware have remained. The gravity of the development has been moved to the software area. Digital image processing and computer graphics are particularly interesting fields. Digital photogrammetry has practically become a special application of these two fields. These changes have influenced close-range photogrammetry very fast, since it is the area that doesn't require extremely heavy computer support. Such a digital photogrammetric system can be realised even on the standard PC configuration, extended with a camera and a scanner or tablet digitizer. Of course, a special software for the support is also required. This has provided a great interest of a large number of potential users.

CONCLUSIONS

Using concrete examples, possibilities of utilisation of non-metric photo and video images, made for measurement or any other purpose, have been demonstrated. Experiences acquired in dealing with these problems have enabled mastering of the whole technology and its application in some other areas. In addition to the professional photogrammetric organizations, many other users that require interpretation of photo images emerge.

Inexpensive and simple photogrammetric systems based on standard PC platform offer to their users a very promising motto : *"Everything that can be seen on the photo can be measured and drawn also"*. Considering the trend of the development, it can be expected that photogrammetry is going to become a standard extension of the graphics workstations very soon.

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