

NON-CONVENTIONAL SYSTEM IN UNDERWATER PHOTOGRAMMETRY

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Abstract

The non-conventional monoscopic photogrammetric systems have been recently developed: they permit a low cost acquisition and data reduction, with an adequate accuracy in object coordinates in terrestrial and close range photogrammetry.

The results of experiments with one of these systems in underwater photogrammetry are here presented with particular attention to obtainable accuracy.

Key words : Non-conventional Monoscopic Analytical System Non-metric cameras Underwater Photogrammetry

Introduction

The employment of non-conventional monoscopic photogrammetric systems of data reduction has been remarkably developed in the latest years.

These systems have a low cost of acquisition (are utilizable with metric and non-metric cameras) and a low cost of data reduction (they cost about 10 times less than a classical analytical reduction system). They are photogrammetric multi-image restitution systems that permit 3-D measurements of an object or of a structure. The system is composed by a PC computer (a good configuration is with microprocessor 386), a digitizer and a reduction software (fig. 4).

The photograms are measured on a digitizer tablet in monoscopic way. We know or we can determine the interior parameters of the cameras. Using these parameters and some known points in the photograms it is possible to make the relative and the absolute orientation.

We obtain the 3-D coordinates of the real points of the object through a projective transformation by pointing out on the digitizer the homologous points in the different photograms.

It is possible with these systems to reconstruct an object in 3-D coordinates with a good accuracy (few centimetres) in object

coordinates at different photographic scales in terrestrial and close range photogrammetry.

The author made some different applications of one of these systems with non-metric cameras in underwater photogrammetry using an appropriate methodology.

The aim was to determine the accuracy of the method, that has been tested comparing the coordinates obtained through photogrammetric measurements and the known coordinates of the control points of a reference frame

The experiments have been executed with an apparatus manageable and relatively easy to use. Underwater non-metric cameras Nikonos with three different focal length (15 mm, 28 mm and 35 mm) were utilized. So it would be possible to control the accuracy of the results versus the lens also used. A reference frame of reduced sizes containing the control points of known coordinates was used. The non-conventional monoscopic photogrammetric system was the Rollei Metric MR2 .

The accuracy obtained could show the possible fields of underwater applications of the particular adopted method.

Data acquisition

Photos have been taken at depth of about 15 m. and in different environments (sea bottom and sea cave, fig. 5,7,8) where the illumination conditions are quite different and the refractive index variation is different for the variation of physical parameters (pressure, temperature and salinity).

A nadiral photograph and two lateral convergent photographs have been taken to permit a better convergence of the multi-image orientation algorithm. (fig.5,7,8). A favorable relationship could be obtained between stereobase and photographs distance (1:3- 1:4).

The imaging distance to the test frame for the three cameras position was approximately 2 m., resulting in an average photoscale of about 1:100 (15 mm.), 1:50 (28 mm.) and 1:40 (35 mm.).

Photographic equipment

The camera are two Nikonos III with 15 mm. Nikkor-UW f/ 2.8 lens and 28 mm. Nikkor -UW f/3.5 lens and a Nikonos IVA 35 mm. Nikkor f/2.8 lens (fig.3). The light sources was furnished by electronic flash Nikonos SB 102 (150 watts) and Sea &Sea 200 (150-200 watts) (fig. 3).

Negative 35 mm color film (Gold Kodak) with 100:21 ASA/DIN was used .

Reference frame

The frame is used for two purposes: to furnish the known points for the orientation elements of the photograms and to execute the cameras self-calibration .

The reference frame is made of PVC bars which form approximately the edges of a parallelepiped of about 0.9 x 0.2 x 0.15 m. in size and of about 3 kg in weight (fig. 1,2).

The known points are signalized with white circular discs , each of 30 mm. diameter with within a black cross printed, that were affixed to the structure to serve as targets.

The positions of the targets were determined with an high accuracy (< 0.1 mm.) in a reference system fixed on the frame .

The PVC thermal dilatation coefficient is about 7 ppm for C°. The variation of temperature from the surface to the working area at a depth of 15 m. was about 5 C° (13 C° versus 18 C°) that produces an eventual length variation of about 0.35 mm. for the 1 m. maximum length of the bar. This variation is less than the expected accuracy target obtainable through photogrammetric measurements.

Fig. 1 - Frontal view of the reference frame utilized.

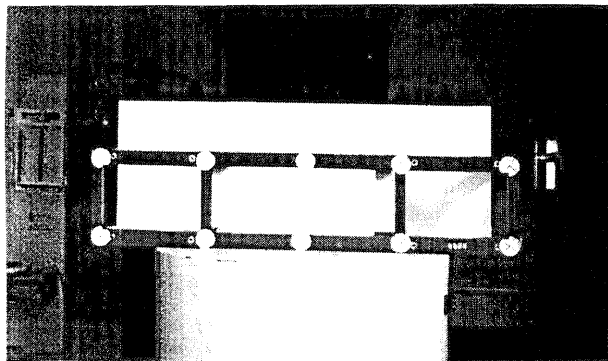
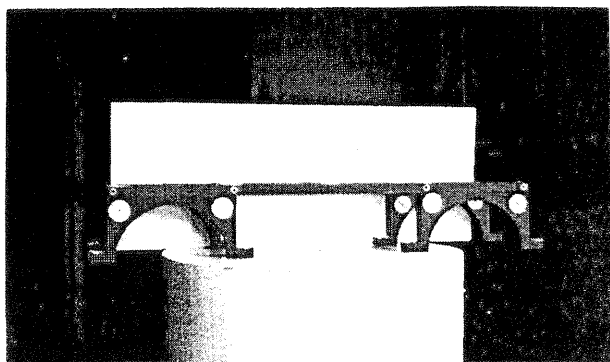


Fig. 2 - Lateral view of the reference frame utilized.



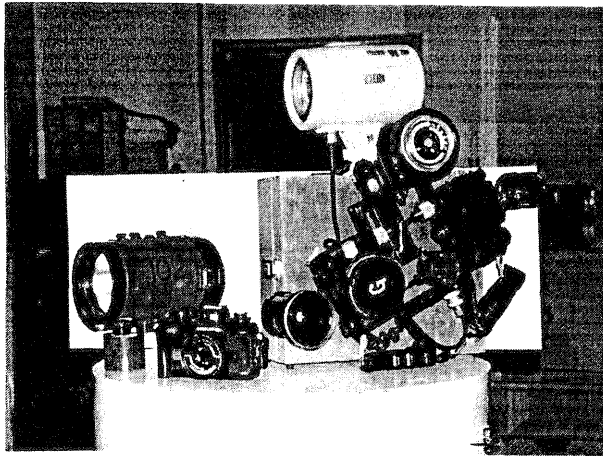
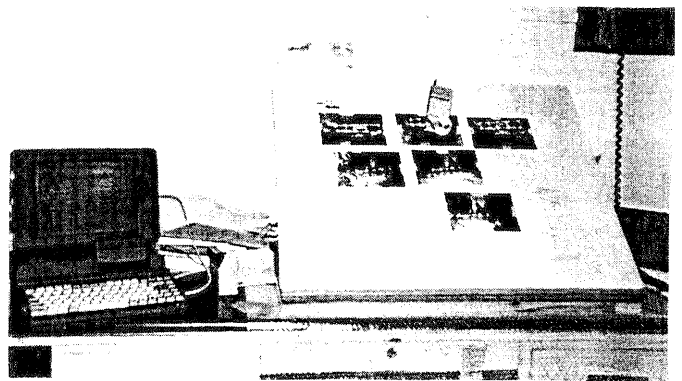


Fig. 3 - Photographic equipment: from left to right th flash Nikonos 102 SB, the Nikonos IVA with 35 mm, the Nikonos III cameras with 15 and 28 mm, the flash Sea & Sea 200.

Fig. 4 - The Rollei metric MR2 system.



Self-calibration and data reduction

A self-calibration technique has been used for the camera calibration procedure (Torlegard, 1974, Fryer 1986, Kotowski, 1988).

Using the "bundle adjustment" program of the MR2 software the camera is calibrated as part of the analytical reduction process. The camera calibration parameters (parameters of interior orientation) are recovered simultaneously with the known points x, y, z coordinates and the elements of exterior orientation in the least squares bundle adjustment.

The physical self-calibration model contains the distortion coefficients regarding the effects of medium (water) and the interior orientation elements (X_p, Y_p co-ordinates of the principal point and C principal distance).

Using non-metric cameras Nikonos the position of principal point has been measured on the photograms, while the focal length is introduced as the principal distance .

The bundle adjustment program was utilized introducing in input a very high variance (100 mm.) for the previous parameters of

internal orientation. Contemporarily eight points of the reference frame were collimated in the three photograms and their known coordinates and relative distances were introduced with low variance (0.1 mm).

The homologous points of different photograms have been collimated in a monoscopic way with a pointer on a digitizer (fig. 4).

Through a projective transformation the bundle adjustment program permitted to compute the correct internal parameters of the camera and furnished the orientation elements for the photograms also.

The interior orientation elements X_p, Y_p and C were recovered to a precision of $\sigma = \pm 0.04$ mm (for 28 e 35 mm lenses) and $\sigma = \pm 0.03$ mm (for 15 mm lens).

The nominal in air focal length of 15 mm for image distance of about 2 m. had a corresponding underwater computed principal distance of 19.8 mm while the 28 mm was 39.2 mm and the 35 mm was 49.3 mm .

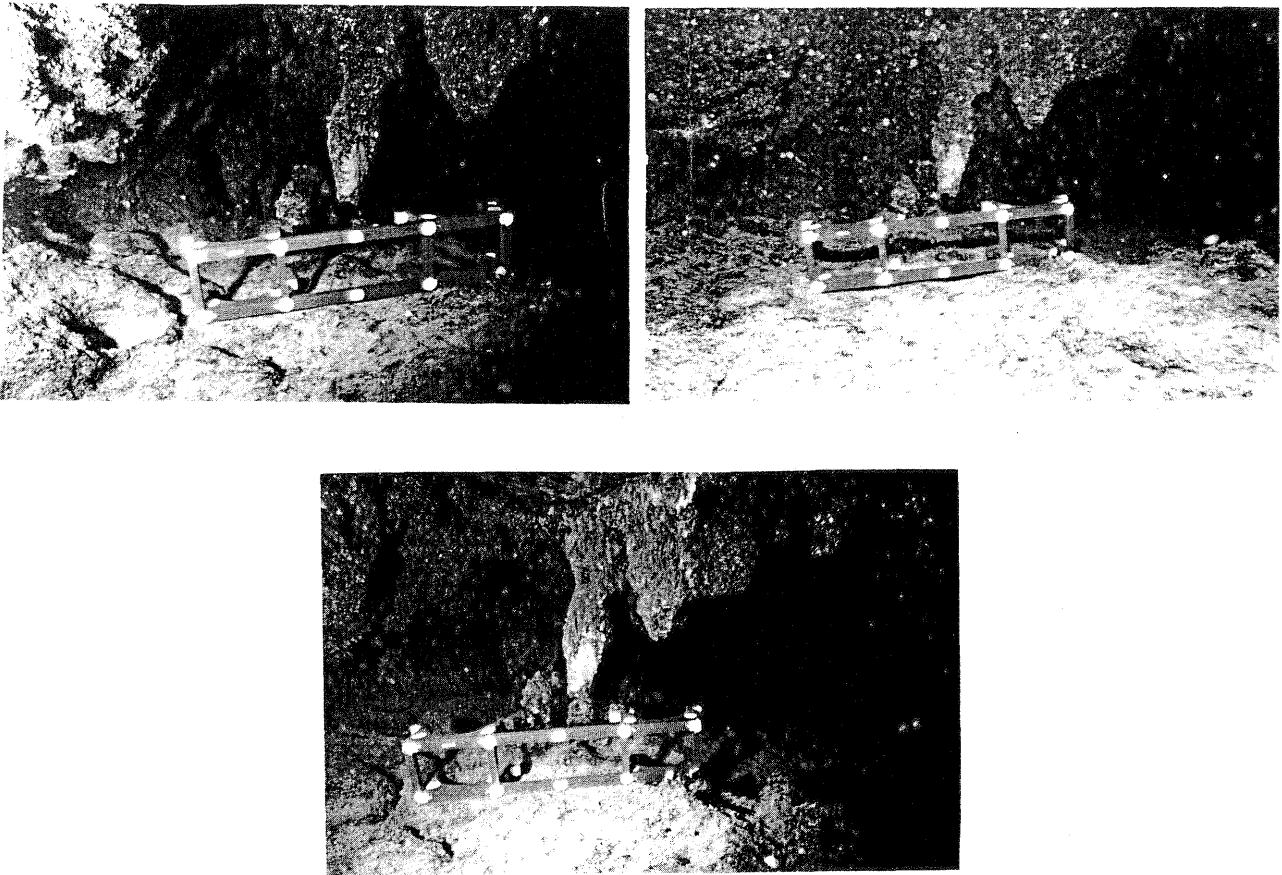


Fig.5 - Photograms with 15 mm

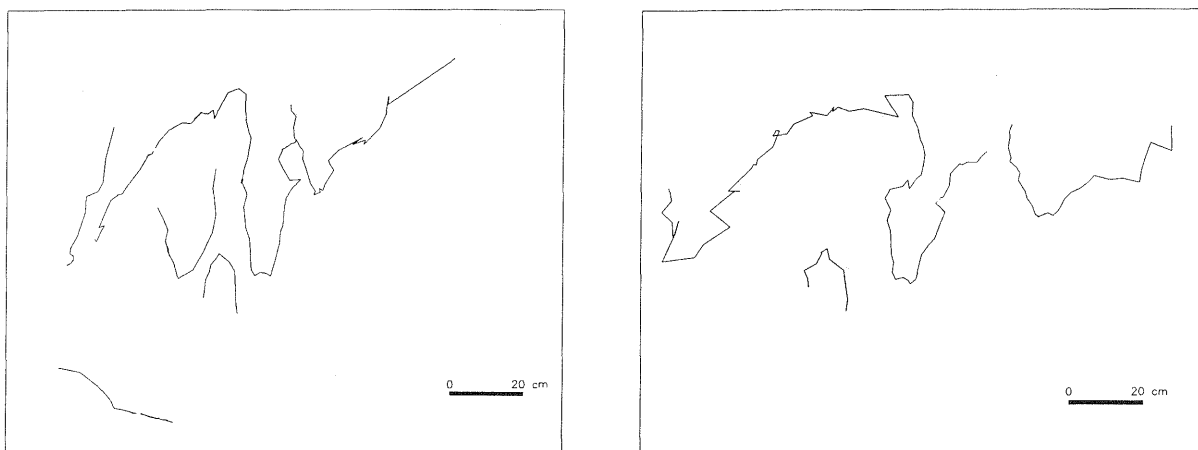


Fig. 6 - A particular frontal and lateral view of a profile of the cave photographed in fig. 4. Obtained through Autocad software.

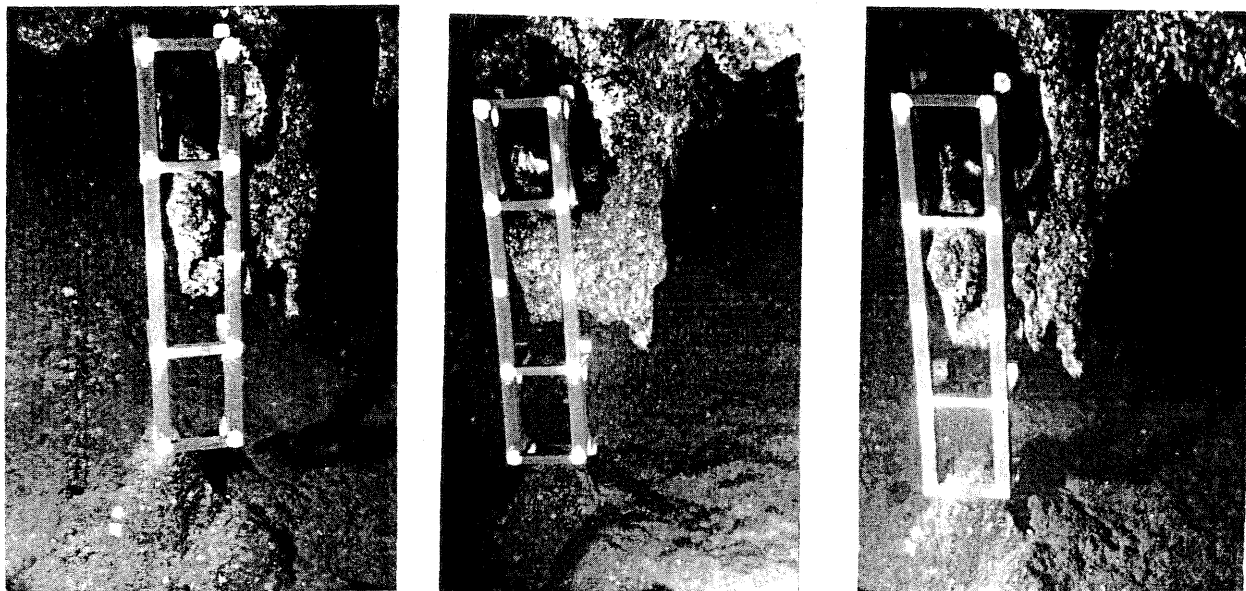


Fig. 7 - Photograms with 28 mm

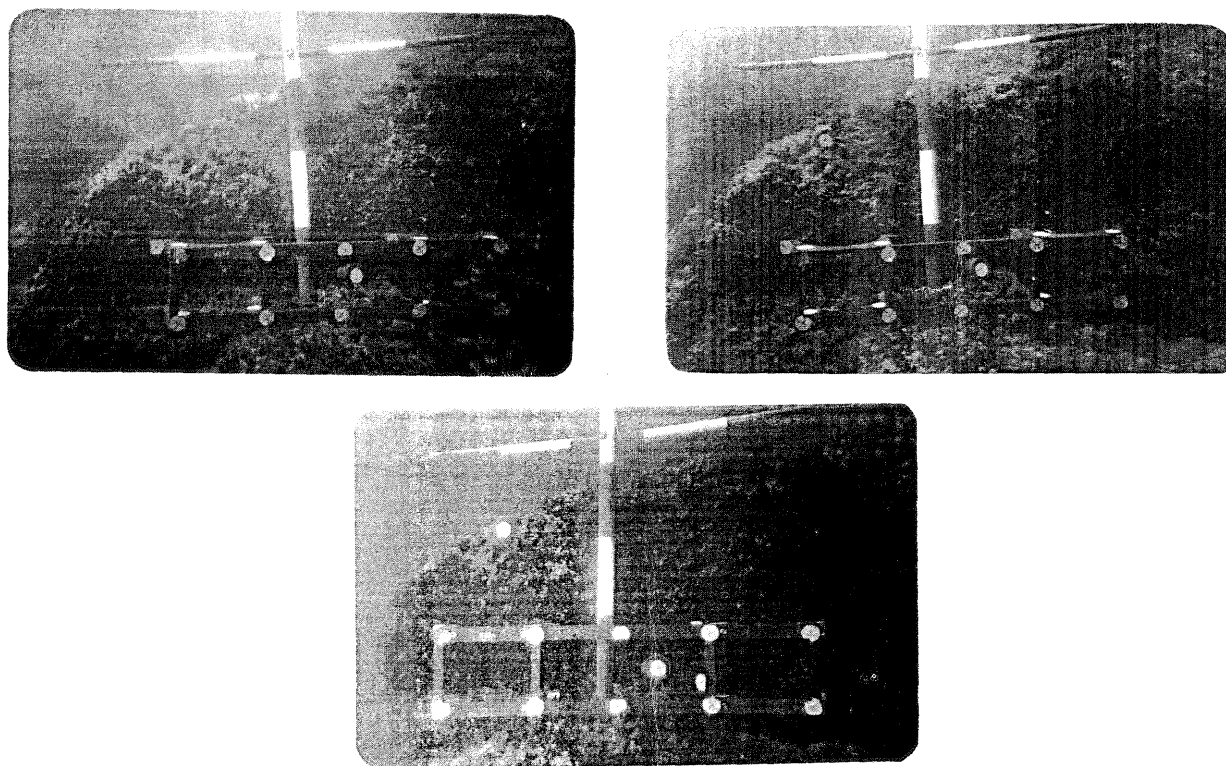


Fig. 8 - Photograms with 35 mm.

The new computed parameters of interior orientation were re-introduced in the multi-image orientation program with the known and measured coordinates of control points to make relative and absolute orientation. Then digitizing the homologous points in the three photograms, it was possible to obtain the 3-D coordinates of the real points by a spatial intersection .

The comparison between the known coordinates and the measured coordinates of the signalized control points on the frame with three different focal length is shown in tab. 1 .

We observe that the average value of the difference in the three coordinates varies between about 8 mm and 32 mm and the standard deviation of $\Delta X, \Delta Y$ and ΔZ varies from 7 to 23 mm. The vector differences are 22 (for 15 mm), 37 (for 28 mm) and 43 mm (for 35 mm), while the corresponding standard deviation are 19, 23 and 19 mm.

Table 1 - Differences between known and measured coordinates of the points of reference frame. Values are in mm..

POINTS	$\phi = 15 \text{ mm}$				$\phi = 28 \text{ mm}$				$\phi = 35 \text{ mm}$			
	ΔX	ΔY	ΔZ	Vector (*)	ΔX	ΔY	ΔZ	Vector (*)	ΔX	ΔY	ΔZ	Vector (*)
1	12	6	2	14	10	2	40	41	35	37	11	52
2	13	3	2	13	14	0	1	14	6	7	2	9
3	2	0	4	4	11	0	20	23	30	20	8	37
4	16	3	2	16	15	1	19	24	21	13	16	29
5	3	7	1	8	7	2	24	25	48	20	2	52
6	22	3	7	23	12	1	27	30	21	31	26	46
7	12	2	1	12	10	1	42	43	9	4	2	10
8	21	1	4	21	10	2	71	72	96	43	20	60
9	43	30	22	57	5	63	44	77	24	61	14	67
10	20	7	10	23	34	38	23	56	30	63	13	51
11	66	27	13	72	4	63	34	72	59	45	60	65
12	0	16	2	16	15	3	32	35	46	10	34	58
13	17	13	6	22	6	2	22	23	11	5	19	23
14	12	4	16	20	10	1	4	11	37	40	1	54
15	2	1	4	5	11	0	1	11	40	29	59	36
Mean	16	8	8	22	11	12	27	37	32	28	19	43
Stand. Dev.	17	9	6	19	7	15	18	23	23	19	22	27

$$(*) \text{ vector} = \sqrt{\Delta X^2 + \Delta Y^2 + \Delta Z^2}$$

We can see that the results become worse increasing the focal length.

The result contrasts with expected value in relation to the lenses distortion : a reduced focal length presents usually a major lens distortion. In fact the front plane ports produce a less relevant chromatic aberration and geometric distortion only in a narrow angular field of view on the diagonal ($<40^\circ$). The maximum field of view on the diagonal for the 35 mm is 46° , while for the 28 mm is 59° and for the 15 mm is 90° .

We should hypothesize that the effects of increasing lens distortion is probably adjusted by the fact that the eight known points of the frame are contained in a central portion of the photo for the 15 mm.(fig.5) ,

while for a same image distance the same eight points are located at the border of the photograms for the 28 mm and the 35 mm (fig.7,8), where the effects of lens distortion is more relevant and not negligible.

The radial distortion evaluation of the used lenses is not the aim of this work, for this particular study see Hohle, 1971 and Fryer, 1986.

The self-calibration parameter model is not useful to describe film deformation and unflatness effects because a metric or semi-metric camera were not used. But these effects in most cases , like this application, yield no improvements in accuracy over the physical model (Fryer, 1986).

Conclusions

The method applied allowed to obtain an accuracy of 1-3 cm in object coordinates at the photographic scale from 1:40 to 1:100. The image distance and the scales used are the most significant in sea water where in average conditions of visibility the very high adsorption and scattering, that reduce the light transmission, do not permit an appropriate illumination and resolution for an object distance more than 3-4 m.

The accuracy obtained is good, in fact the values are near those declared in terrestrial photogrammetry standard application with non-conventional systems.

The data acquisition is relatively simple. It is sufficient to use non-metric cameras and a reference frame at a low weight and of reduced sizes. Using only few points (8 in the experiments) self-calibrating and bundle adjustment reduction program it is possible to obtain the tested accuracy.

There was not a significant difference in accuracy using different focal length. The cameras did not take photos exactly at 2 m. distance and the photograms with different cameras had not been taken in the same environmental conditions, but with different refractive index.

So we should conclude that we can reconstruct in 3-D coordinates an object at image distance approximately fixed, using a number of variable photograms and changing the focal lengths and the sea water conditions. The variation in accuracy is not very significant (1-3 cm.), relatively to standard underwater applications. We have only to collocate a reference frame in the field of the photograms without using control points on the object or on the structure.

The method presented could be employed to reconstruct the form and the dimensions of particular undersea object or structure. In particular it is interesting when the subject has a long extension in one dimension, for example to survey an archaeological site or to map the sea bottom.

The fig. 6 shows some indicative profiles in a frontal and in a lateral view of the cave and of the stalactite of photograms of fig. 5.

These profiles have been obtained in Autocad utilizing the X,Y,Z coordinates of the photogrammetric reduced points.

This paper showed the results of first experiments of the method, some others experiments with different systems and methodology are going to execute, which results will be published successively.

Acknowledgements to Geotop s.r.l. (Ancona , Italy) for Rollei MR2 photogrammetric reduction system loan.

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