APPLICATION OF UNDERWATER PHOTOGRAMMETRY FOR THE DEFORMATION CONTROL OF SUBMERGED OBJECTS

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ABSTRACT :

Various experiments on underwater photogrammetry have been realized to verify the precision of the technique in submerged object reconstruction (Capra, 1992).
Afterwards experiments on the application of underwater photogrammetry for the deformations control of submerged objects have been made, using non metric cameras and non conventional monoscopic photogrammetric systems for the data reduction.
After an accurate camera calibration, an average accuracy between 2-5 mm in deformation entity through photogrammetric measurements was obtained, comparing the position variations obtained fthrough photogrammetric measurements with the known position variations of many signalized points of the object.
The applied technique, characterized by the relatively low cost, assured a precision that could find interesting applications, in off-shore technological fields and in scientific fields also (biology,geology, archaeology).

RESUME' :

Dans le passé on a conduit different experiences de photogrammetrie subaquatique pour verifier la precision de la technique a regard de la recontruction des objets submergès (Capra, 1992).
Par la suite, on a etè conduit des experimentations de application de la photogrammetrie subaquatique au controle de la deformatione des objets submergès, en utilisant appareils photographiques pas metrique et sistemes photogrammetrique pas conventionnels pour la restitution.
Apres avoir soigneusement calibrer l'appareil photographique, on a obtenu une precision moyen de 2-5 mm pour la valeur de deformation avec les misures photogrammetriques, en comparant les mouvements obtenues par les misures photogrammetriques avec le variations de position connu de beaucoup de points de l'objet.
La technique appliqueè, characterisee d'un cout relativement bas, a fournit une precision interessant pour different applications industriels, comme dans l'industrie off-shore, et pour applications scientifiques, comme dans la biologie, la geologie et l'archèologie.

1 Introduction

In a previous work (Capra,1992) the results of underwater photogrammetry experiments were presented.
Non metric cameras and non conventional monoscopic photogrammetric restitution systems were used.
The experiment had the aim to verify the precision of restitution of signalized points. The accuracy resulted of about 1-3 cm in object coordinates. That precision was sufficient for the purpose of a survey and a tridimensional reconstruction of submerged objects.
As a successive step, the application of this technique for the deformations control of the submerged objects was tested. The precision obtained in the old tests is not sufficient for the aim of deformations control, where generally it should be necessary to study movements less than 1 cm. So the aquisition process, the camera calibration and the data reduction were made utilizing some particular devices.
A metallic grid of 3 elements was used as a surface whose deformation must be controlled (figg.1,2 and 3). On the grid were collocated many reference points of known coordinates.
The position of the 3 elements varied, assuming new configurations where the reference points coordinates were known. The photogrammetric restitutions of the grid in the three configurations were made, after the execution of an opportune camera calibration.
Afterwards, the position variations of the control points obtained through photoghrammetric measurements were compared with the known position variations.
The results showed that it is possible to evaluate a surface deformation with a precision of few millimetre through the underwater photogrammetric technique applied.

2 Experiment description

A metallic grid made by 3 elements was used as the surface whose deformation must be controlled. On the grid were collocated 43 control points of 5 mm of diametre, clear visible in the photos (fig.1). The control points positions were measured by a monocomparator with a precision of 0.1 mm.
The figg. 1,2 and 3 show the grid in the 3 configurations called 1, 2 and 3.
The object was photographed in the configuration 1, where the elements are disposed on the same plane. Successively the grid was composed in configuration 2, where the elements formed an angle of 90 degrees each other. In the configuartion 3 the third element was ruotated in opposite direction of configuration 2, obtaining a final position like a box.
The elements were rigidly connected, so the position variations of the control points from the configuration 1 to 2 and from 1 to 3 were known. Five photos of the grid in the three configurations were made, the image distance varied

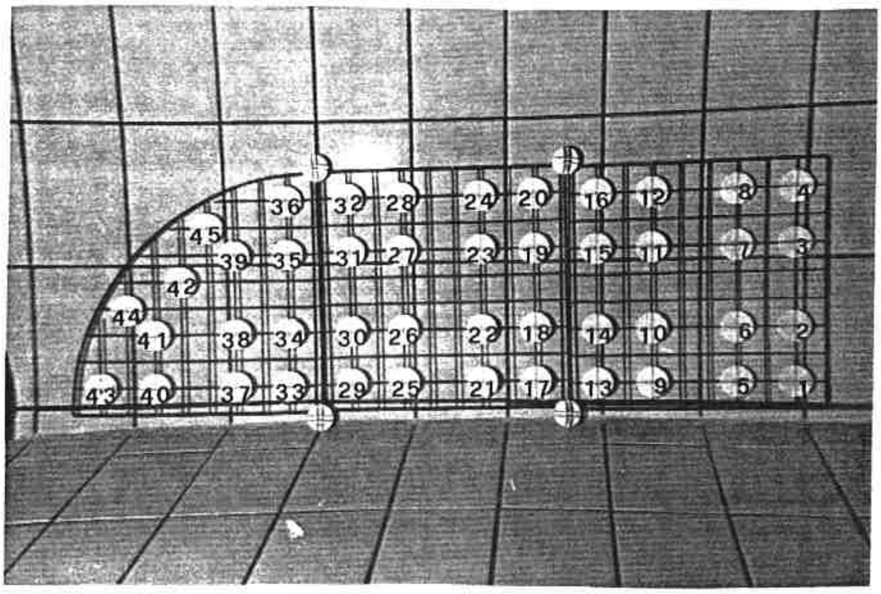

Fig.1 - Grid configuration 1

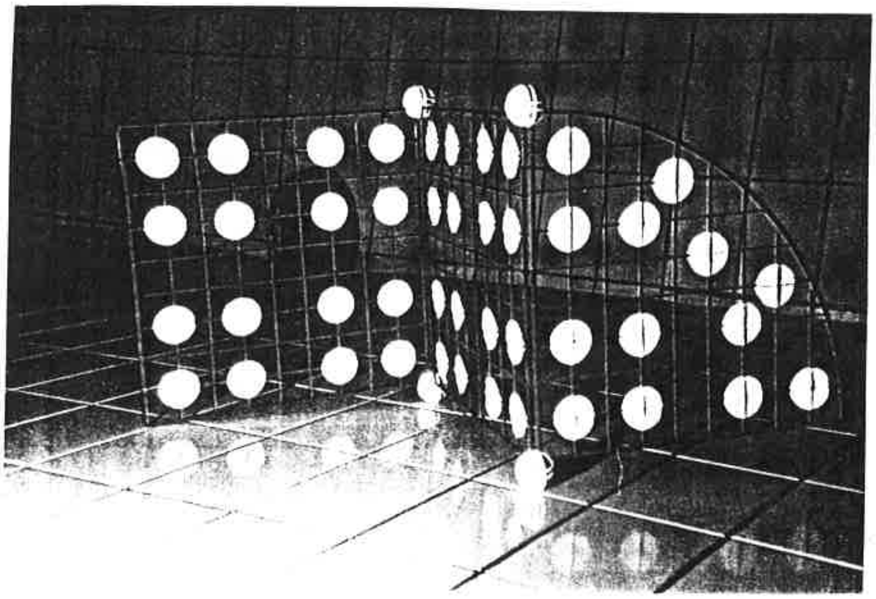

Fig.2 - Grid configuration 2

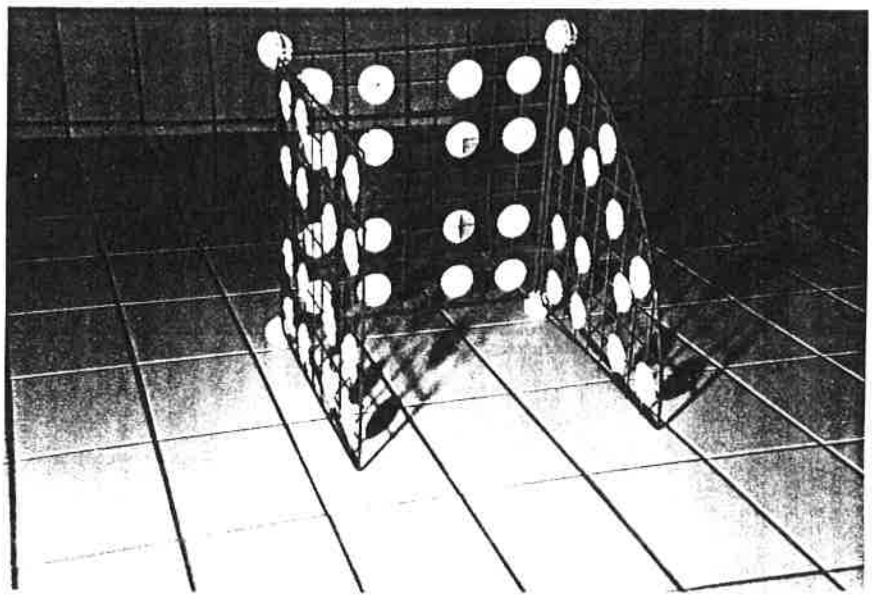

Fig.3 - Grid configuration 3

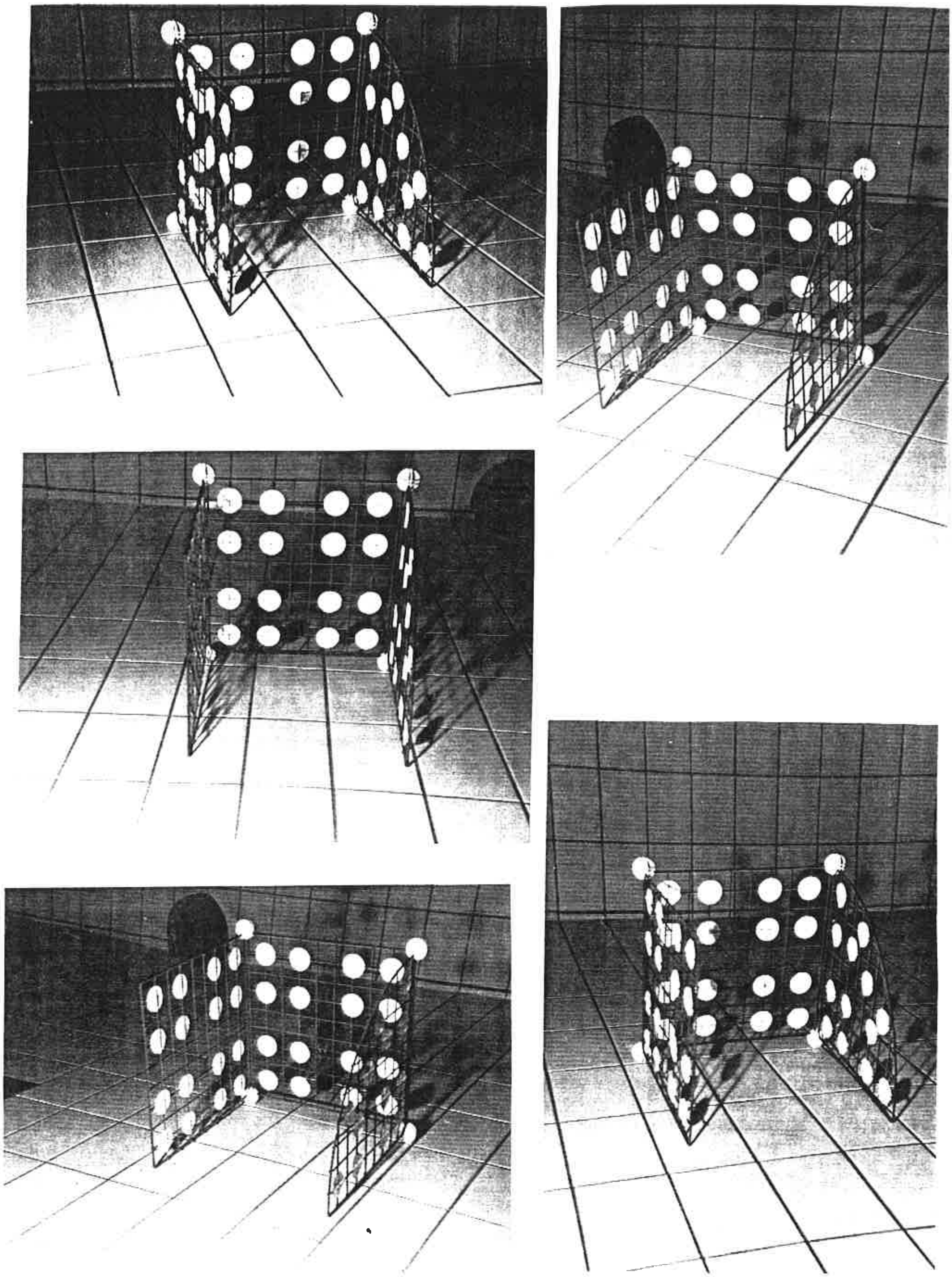

Fig. 5 - Five view of the grid configuration 3

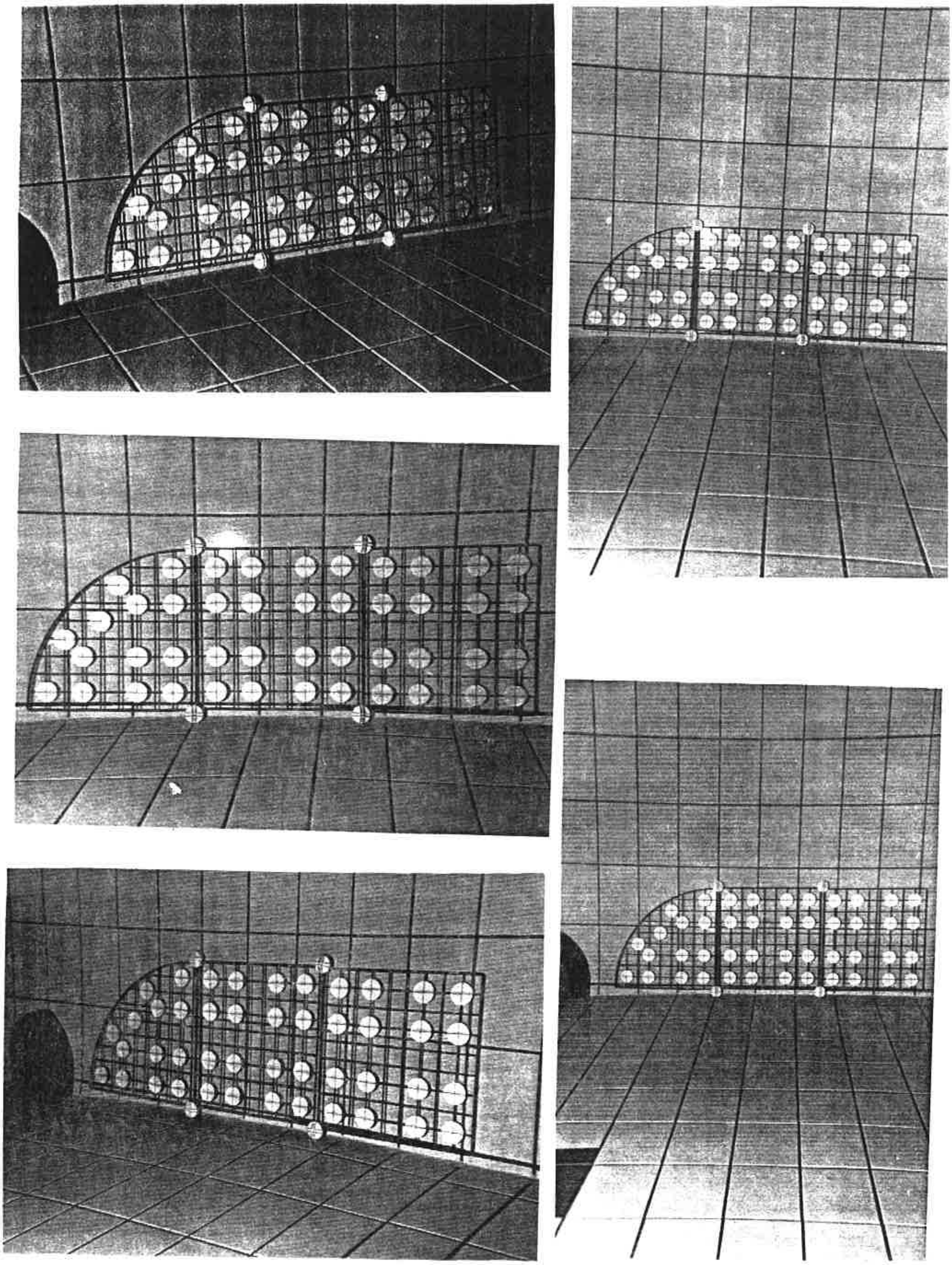

Fig. 4 - Five view of the grid configuration 1

approximately from 2 to 3 metres. The photos were made in fresh water and the light diffusion was particularly accurate. The figg. 4, 5 show the five photograms of the grid configurations 1 and 3.
A non metric Nikonos camerawth 35 mm Nikkor f/2.8 lenswith was uesed. Negative 35 mmcolor film (Gold Kodak) with 100:21 ASA/DIN was used.

3 Photogrammetric restitution and deformation control

The photo measurements of the control points was made monoscopically on a digitizer table (resolution 20 micron).
The camera calibration was made using the "bundle adjustment" program of the MR2 software, as part of the analytical reduction process, in the same procedure utilized in a previous work (Capra,1992).
It was necessary to increase the final precision to apply the technique to deformations control. Some particular attentions were made in photo aquisition and reference frame preparation, so it was possible to obtain a more accurate camera calibration and photogrammetric resitution.
First of all, five photos was used (fig.4), making attention to use at least two photos with the camera ruotated along the axe of view. In this way it is possible to measure the control points from different point of view around the object and to measure the same points on simmetrical disposition with respect to the centre of photograms, so the computation of the parameters of interior orientation and of the distorsion coefficient is more precise.
Moreover a remarkable number of control points was used, making attention to use an appropriate focal length (35 mm) and distance of view for obtain an omogeneous and quiet complete overture of the photos by the object control points (fig1,2,3).
The interior orientation elements Xp,Yp (centre of the plate) and C (principal distance) were recovered with a precision of σ = 0.3 mm. The nominal air focal lenght of 35 mm for omage distance of about 2 m. had a correspondance underwater computed value of 56.36 mm.
Comparing the known coordinates and the photogrammetric measured coordinates of the control points, after the calibration process, , a difference of few millimetres was obtained.
For example the value of differences obtained with the photo set related to object configuration called as 3 (fig.3) is shown in tab.1.
The same procedure was followed for the photos sets related to the object configurations named 1,2 and 3 (figg.1,2,3).
The position variations of the control points from 1 to 2 and to 3 are known with 0.1 mm accuracy. The know movements were compared with the photogrammetric measured movements in term of dX,dY and dZ variations and in term of module of the movemnt recovered. The tab. 2 shows the results obtained passing from object configuration 1 to 3.
Passing from configuration 1 to 2, the mean values (and m.s.e.)of differences between knon position variations and those measured through photogrammetric restitution are, expressed in mm., for dX= 0.6 (m.s.e.= 2.9), for dY= 1.8 (m.s.e. = 3.1),for dZ = 0.3 (m.s.e. = 2.0) and for the Module = 5.1 (m.s.e. = 3.4) are quiet similar, as you can see there are not significantly different from those obtained from configuration 1 to configuration 3.
The results show a little value of about 1 mm, with a m.s.e. of about 2-3 mm, in movement determination through the photogrammetric measurements executed with the technique experimented. There are not present signifiant systematic effects and the precision remains of the same value indipendently by the direction of the vector of movements, as you can see looking at configuration 2 and 3 with respect to the position 1.

4 Conclusions

The results obtained demonstrated that it is possible to know the position variations of many reference points with an accuracy of 2-5 mm, using non metric camera for the data aquisition and a non conventional system for photogrammetric restitution. So it appears possible to control the deformation of a submerged object with this precision, making some photos of the object, at different time intervals, and measuring photogrammetrically the position variations of many reference points distributed on the surface of the object.
The precision is not related to the focal length utilized (see also Capra,1992), but is related to the photo scale, because it is necessary to have a complete and omogeneous distributio of control points on the photos to obtain a very high accuracy in camera calibration and phortogrammetric data reduction.
The automatic photogrammetric measurements is very interesting for the application of photogrammetry in deformations control. Some experiments of the application of Rollei Reseau Scanner RS1 (Luhman, Webster.Ebbinghaus, 1988) in underwater photogrammetric deformations control have been made, using the same data aquisition and data reduction system here descibed. The results will be show in the future.
It could be stated that the applied technique, characterized by the relatively low cost, assured a precision that could find interesting applications, in off-shore technological fields and in scientific fields also (biology,geology, archaeology).

Tab.1 - Mean values of differences between known and measured coordinates of the control points in the tests with different object configurations. Values are expressed in mm.

	Object configuration 1	Object configuration 2	Object configuration 3
Mean value of δX	0.2	- 0.3	-0.2
m.s.e of δX	1.0	1.2	1.4
Mean value of δY	1.0	1.3	1.2
m.s.e. of δY	1.3	1.8	2.1
Mean value of δZ	-0.3	0.4	-0.4
m.s.e. of δZ	1.1	1.1	1.3
Mean value of Module	2.6	2.9	3.0
m.s.e. of Module	1.3	1.5	1.6

Tab.2 - Differences between know position variations and those obtained from photogrammetric measurements, passing from grid configuration 1 to 3. Values are expressed in mm.

Pt	dX	dY	dZ	Module
2	-0.8	0.3	-1	1.3
3	0.6	0.9	-1.1	1.5
5	0.1	-0.6	0.2	0.6
8	-0.3	8.8	-1	8.9
9	2.6	0.1	1.9	3.2
12	-0.2	0.5	0.5	0.7
14	-0.6	0.6	0.3	0.9
15	-1.7	1.4	-2.8	3.6
17	-0.5	-2.4	-1.6	2.9
18	-1.3	3.3	-1.6	3.9
19	-2.4	2.5	0	3.5
20	-1	1.9	-1.6	2.7
21	6	-1.8	0.6	6.3
22	6.2	3.0	-1.1	6.9
23	6.3	2.9	-2.0	7.2
24	6.6	3.0	-2.0	7.5
25	3.2	-2.3	0.4	3.9
26	3.8	3.4	-0.9	5.2
27	3.7	4.6	-1.4	6.1
28	5.2	4.4	-1.3	6.9
29	0.7	-3.1	1.4	3.5
30	1.4	5.4	0.7	5.6
31	1.9	5.4	1.1	5.8
32	2.9	4.9	-1.2	5.8
33	-4.2	-2.9	-2.2	5.5
34	-3.7	2.3	-3.2	5.4
35	-1.6	5.2	-3.0	6.2
36	-0.8	6.7	-2.9	7.3
37	-2.8	4.3	-0.7	5.2
38	-3.7	5.7	-0.4	6.8
39	0.1	6.3	-1	6.4
40	-3.1	-3.1	4.4	6.2
41	-2.2	4.1	3.7	5.9
42	2.0	2.6	1.6	3.6
43	-4.6	-2.8	5.4	7.6
44	-0.1	1.9	4.2	4.6
Mean value	0.4	1.9	-0.2	4.8
m.s.e.	3.0	3.1	2.1	3.1

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