PHOTOGRAMMETRY ON MARINE STRUCTURES

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Abstract

The research program FOMAKON (Photogrammetry on Marine Structures) has been worked out in Norway during the last 4 years. As a part of this project, several photogrammetric test measurements on marine structures have been done. The paper briefly describes some of the conditions occuring at industrial dimension control. It then presents one of the test measurements, and shows how the experiences may be used when making an improved system for photogrammetric control at yards.

Introduction

Photogrammetry has for years been used as a measuring method in industry. Results achieved by photogrammetrists have generally fulfilled the requirements set by customers. In spite of this, photogrammetry has never been accepted as a competitive measuring method compared to traditional geodetic methods used in industry. Until now photogrammetry has been isolated events for specific measuring situations.

In this paper we will try to explain some of the reasons for this situation. In addition we will look at how photogrammetry can improve its position and competitiveness. This will be illustrated by means of measurements done on a marine structure.

Characteristics of photogrammetry used in industry

Industrial measurements in general, and measurements done on marine structures in particular, are very different from traditional photogrammetric tasks. It is not sufficient to consider if it is possible to solve a particular task at a shipyard by means of photogrammetry. It is also necessary to judge if this measurement can be realized within the demands set by the yard. Here are some of the factors that have to be considered:

The geometry of the object. Marine structures extend considerably in all directions. It is therefore difficult to achieve stereoscopic view except for limited areas of the structure within a stereoscopic model. Normal case of photography will result in too many pictures.

The surroundings of the object. One of the factors that characterizes a marine structure under construction is limited space. Photogrammetrists may not freely choose the ideal locations, but must make use of available areas.

The accessibility of measuring points. Points that need to be measured will often be shielded by scaffoldings and tarpaulins. The photogrammetrist must therefore adjust the positions and directions of photography according to the visibility of targets.

Time consumption. Time consumption is probably the main bottleneck in connection with photogrammetric measurements. In the traditional use of photogrammetry one is free to spend the time required both for field work and calculations. However, this cannot be accepted as far as production is concerned. Results must be presented within a short period of time to prevent a halt in production.

Knowledge about object and production. A control scheme cannot be realized in a proper way without sufficient knowledge about product, sequence of operations, and product specifications. One must be able to specify the control scheme in relation to the production stages, and be aware of production methods and work schedules.

Use of data. Nominal data of the mapped points should be available on a computer readable medium in order to facilitate quick and reliable computer based comparison. If CAD systems are used, these requirements may easily be met. But if not, the data have to be recorded on the computer before the control measurements. Results from the photogrammetric adjustment must also be available in a form which makes further processing possible. This implies interfacing between the block adjustment program and the different analysis programs. Deviation reports should be produced by computer programs. Comparison of measured points to specified planes, straight lines, and nominal distances should be implemented, since this often is the form of the specified data. The data should also be available for analyses and prognoses (for instance stuctural analysis).

The FOMAKON Project

The research project FOMAKON (Photogrammetry on Marine Structures) has been carried out at the University of Trondheim, The Norwegian Institute of Technology. The aim of the project was to develope photogrammetric procedures suited for the specific demands and problems met at shipyards.

Experiences gained during the project show that present technology wihtin photogrammetry can satisfy all requirements put forward by the yard industry, except that of time consumption. Photography, film processing, and digitizing are so time-consuming that it represents considerable limitations in the use of this technique. However, the technological development within these areas is progressing fast and it may therefore be expected that tomorrow's photogrammetric techniques to a large degree will fulfil all requirements.

A pilot version of a photogrammetric system for shape and dimension control in industry has been developed through the FOMAKON project (Holm, Østbye, 1982).

Control of a floating dock

Approach

One of several test measurements done in the FOMAKON project was the control of a floating dock built by A/S Nye Fredrikstad mek. Verksted for Senegal. The length of the dock was 225 metres, and because of its size it was built in five sections. The sections 1, 2 and 3 (see figure 1) were to be joined at sea. Consequently the joint edges had to be concordant with respect to plane, height, and length before the various sections were launched. With respect to welding, gaps up to 10 mm could be accepted..

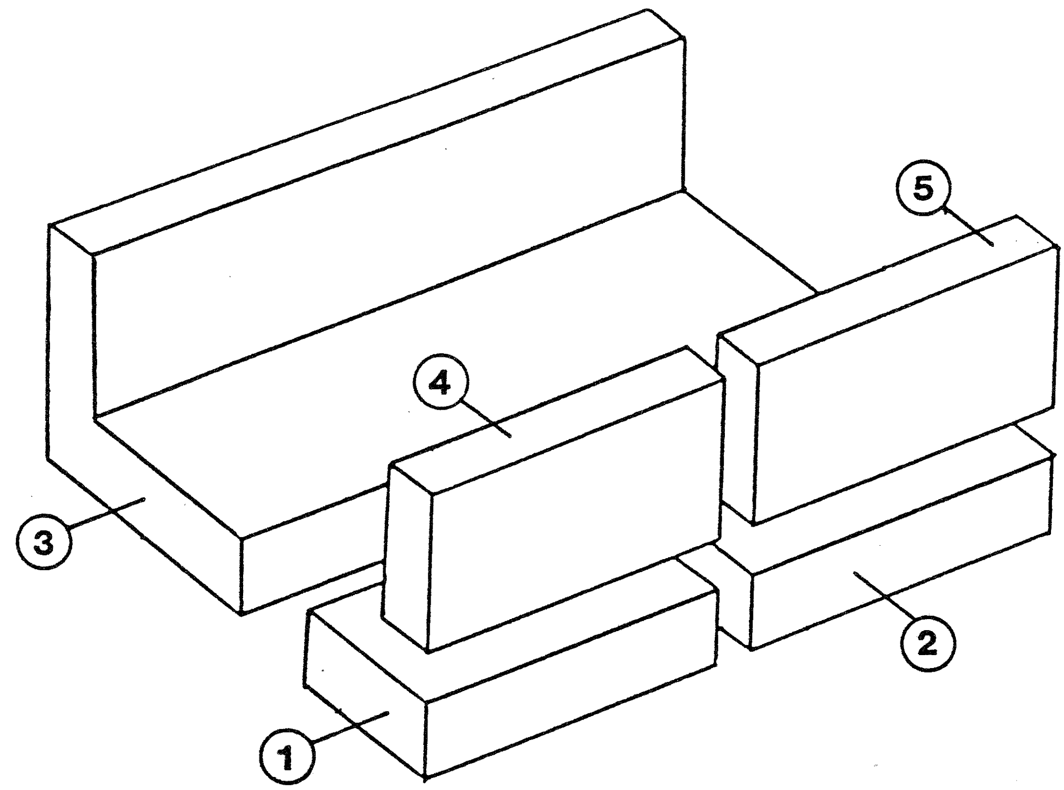

Figure 1. The main sections of the Senegal floating dock.

The described measurement was done on the main part of the dock, section 3. This section was built in dry dock. The joint edge, that should be perpendicular to the deck and parallel to the longitudinal axis, was located only 30-40 cm away from the dry dock wall (see figure 2). In this particular case, the real control task was to set out marks for the cutting of the edge. Photogrammetry was not supposed to be suited for this purpose. Instead, the test was carried out as an "as built" mapping of the cutting marks under the actual environmental conditions. The cutting marks had been set out by the operators of the shipyard control department.

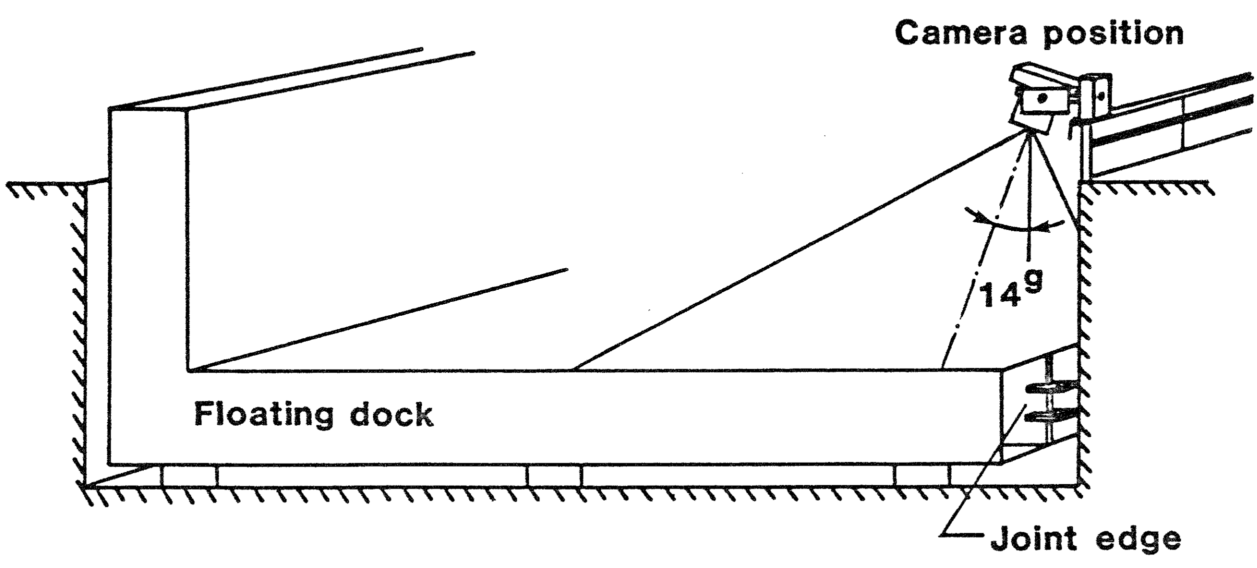

Figure 2. The measuring situation.

Time consumption

As an as-built control the photogrammetric measurement would have been the final stage of the production work before launching. From the yard's point view, the restrictions of time consumption were not very strong. 3-7 days could be accepted. It was planned to spend one day for targetting and object control measurements, one day for photography, and two to five days for film processing, digitizing, calculations, and preparation of reports.

Reports

The yard was not content with results given in lists with x, y and z-coordinates for the various measured points. Graphic visualization of deviations was necessary to make it easy to simulate the assembly of the different sections and to estimate maximum gaps.

Targetting

One half of the dock's lenght was mapped. About 200 targets were mounted on floorplates, frames, in the bottom, and on the deck in the joint area. Most of the points were located in dark areas because of the narrow space between the structure and the wall of the dry dock. Furthermore the points were marked on planes nearly parallel to the directions of photography. Because of these circumstances special targetting had to be arranged.

Targets made of reflex tape were mounted on special holders which were attached to the joint edge by means of wedges. The distance from the centre of the target to the cutting mark was fixed (see figure 3).

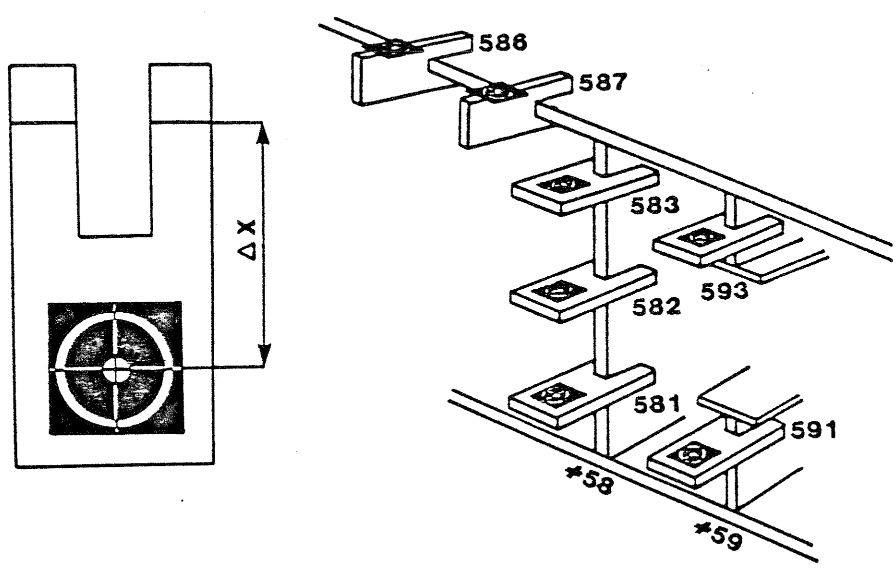

Figure 3. Mounting of targets.

Object control

The FOMAKON-system will normally use a minimum number of 3 dimensional coordinate values as object space control. However, since this was a test measurement, it was desirable to have an additional control network. Points were laid out on the deck in two profiles, one near the centreline of the dock, and one close to the joint edge. In addition, four points were laid out between these two profiles in one part of the dock.

The profiles were set out by theodolite. Calibrated tape measure was used between the profile points, and all points were levelled. 28 control points were laid out. Figure 4 shows the point distribution.

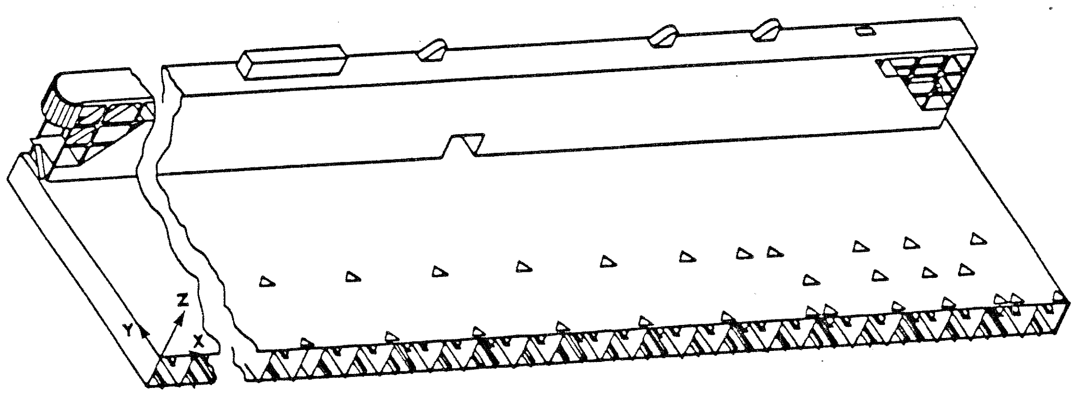

Figure 4. Object control points.

Photography

The photography was done in overcast weather without any additional lighting. Test exposures had shown that the daylight provided sufficient reflex from the targets to make measurements possible. Pictures were taken with a Wild P31 super wide-angle camera from 16 locations. The photography was done as a strip with the camera axis at 14^{g} angle to the plumb line.

It was not possible to bring the camera in the wanted positions with an ordinary tripod. Therefore a specially designed adapter had to be used. This adapter could easily be mounted on the railing on the edge of the dry dock (see figures 2 and 5) so that the camera mount was almost horizontal. The photographing lasted six hours.

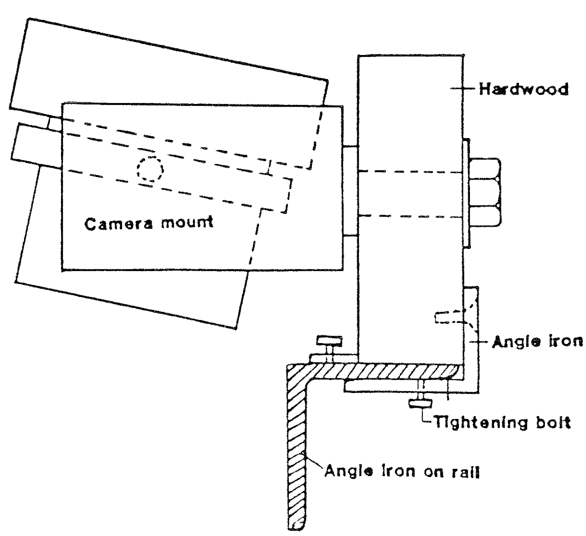

Figure 5. Camera with adapter.

Digitizing

The image points were digitized in a simple and direct way in a mono comparator. The coordinates were recorded on magnetic cassette tapes and transfered to the computer later. Each target was pointed and recorded two times. After digitizing of the fiducial marks, the control points were measured. Finally all the measuring points at the joint edge were recorded.

The targets with reflex tape appeared to be well readable on the pictures. However, because of the darkness in the narrow space between the wall of the dry dock and the structure, it was somewhat difficult to judge which frame each target was attached to. Therefore the operator har to pass through the points in a structured way. The points were read frame by frame, starting at the middle of the image, where the connections were most obvious.

Computations

The final coordinates were computed by bundle adjustment.

Since the photographs were taken in one strip, the preliminary computations for producing approximate values for the bundle adjustment, might have been carried out with a strip forming program made for aerotriangulation purposes. However, the typical shipyard control task will have more arbitrary camera orientation, and consequently a more general computer program was used in this case. The program PRECOMP was developed during the project to produce preliminary values for image orientation and point coordinates for arbitrary orientations of pictures.

Resection was performed for all pictures, based on available coordinates of the object control points on the deck. Since all available coordinates represented points on a flat body, it was necessary to give approximate values for the camera positions. In images with less than 6 coordinated points, the orientation angles ν and κ were given as well. These additional values were used in linear constraints to the 11-parameter solution, according to Hådem (1981).

Two images had insuficcient control. Therefore a few measuring points were coordinated by intersection. Then the two pictures were satisfactorily resected.

Finally all the measuring points were intersected, using all available images for each point. During visual inspection of the results, concerning both the RMS values and the object coordinates themselves, a few points were picked as suspicuous for gross errors. By several intersections on each point, based on different selections of images, a couple of gross errors in image coordinates could be pointed out.

The bundle adjustment was carried out as consecutive resections and intersections as described by Hådem (1981). The available program had no statistical tools for detecting gross errors. Error detection was performed by the old time-consuming procedure: Residuals on image coordinates is examined, and the operator has to judge whether or not the size implies a gross error. A few image points were rejected. Some of these proved later to be results of identification errors. But some seemed to be just big random errors, and should consequently not have been rejected.

The object space control in this task was supposed to be given as auxiliary data, and not by three dimensional coordinates. As the lay-out of the control points was very regular, the data was however given to the program in the form of coordinates as indicated in figure 6.

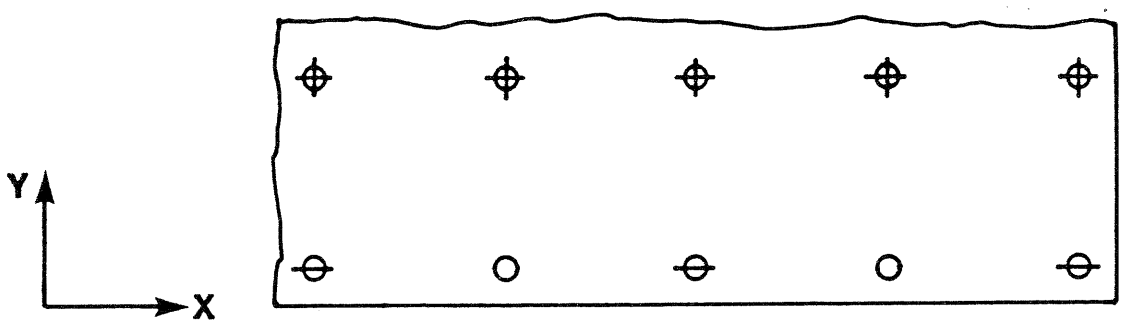

Figure 6. Object control lay-out.

Instead of four tape measured distances along the centreline, X-values of five points were given (vertical dash in figure 6). Transverses from the profile along the centreline were given as Y-values in five points (horizontal dash). Three Y-values near the edge represented three distances between the profiles. Finally the circles indicate 10 levelled Z-values given.

Results

The bundle adjustment was performed with an estimated accuracy of 7 μm in image coordinates, and with estimated accuracy on the object coordinates of 3 - 5 mm.

The computed Y-values on the measuring points were compared with nominal values of the cutting marks. The computed values approximates a plane with an RMS value of 2 mm. The results were visualized using an interactive graphic system designed for presenting 2-dimensional data. An example is shown in figure 7.

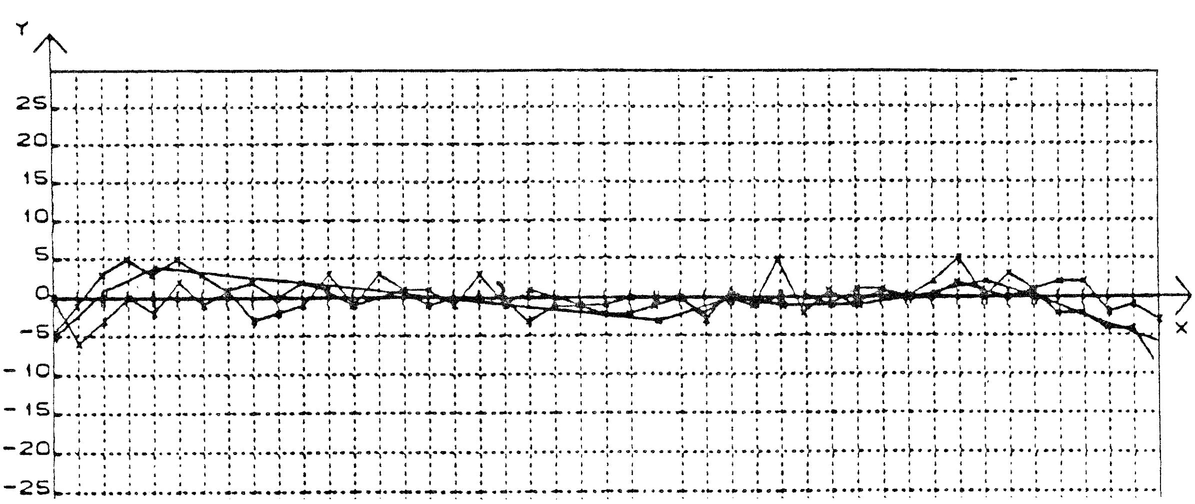

Figure 7. Example of graphic visualizing of discrepancies.

Concluding remarks

The test measurement was a success in the sense that it showed some important positive properties of the photogrammetric method, and it pointed out some phases of the process where certain improvements had to be done to make it competitive to traditional control methods. Some of the improvements are later implemented in the FOMAKON system.

The test showed that with specially designed targets and camera adapter, photogrammetry was able to provide results with sufficcient accuracy. However, the time limits were exceeded.

It appeared to be difficult to carry out all the planned object control measurements with sufficient care, within the available time. This problem may be eliminated to a certain extent if the photogrammetry is integrated in the control program of the yard. In that case, some of the targetting and other preparations may be done during the production process.

The time consuming film processing and digitizing of image points can hardly be avoided until digital cameras and suitable software are available for this kind of use. 1-2 days earlier results may then be expected.

During digitizing of image coordinates the two readings of each point should be done in two separate passes in order to discover identification errors. This is later taken care of in the FOMAKON digitizing system MONO-DIG.

The need for gross error detection by objective procedures such as statistical testing was clearly shown, as well as the need for a flexible software with possibilities for interactive testing on smaller parts of the block. This will not only increase the reliability of the coordinates, but also cut down the time needed for producing results.

As one can see in figure 7, interpretation of the results is improved by graphic presentation. It was therefore strongly recommended to implement a 3-dimensional graphic system for visualizing deviations on structures. Graphic presentation should be a part of any control report.

It should be noted that this particular kind of measurement was totally dependent on the use of a calibrated metric camera because of the lack of object control distances in Z direction.

Litterature

Holm, K.R., Østbye, B., 1982. The FOMAKON Project, Photogrammetry on Marine Structures. ISPRS, Commision V, York.

Hådem, I. 1981. Bundle Adjustment in Industrial Photogrammetry. Photogrammetria, 28: 45-60.

Østbye, B. et al 1983. Fotogrammetri på marine konstruksjoner. Report UR-83-31. The norwegian Institute of Technology.