REPEATED OBJECT RECONSTRUCTION OF THE BREMEN HANSE COG

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ABSTRACT:

Today the Bremen Hanse Cog is on display in the German Maritime Museum (Deutsches Schifffahrtsmuseum) in Bremerhaven. The cog was found in October 1962 in the river Weser and was prepared in conservation liquid between 1982 and 1999 (DSM, 2003b; Hoffmann, 1981).
In 1982 the Institute of Photogrammetry and GeoInformation (IPI) used a metric camera SMK 120 to take about 80 analogue images of the cog from several directions. With additional geodetic measurements, signalised vertical lines and tie points the three-dimensional point cloud was calculated and line drawings from three directions of the cog were plotted.
After 17 years of conservation distortions in the range of +/-10 - 25 cm of several parts of the wooden cog were detected. In 2003 over 100 images were taken with digital cameras to carry out the photogrammetric object reconstruction and calculation of a point cloud of the cog again. To reconstruct the profiles measured in 1982 the profile lines have been visualized with white tape comparing the historic analogue drawings with the current surface of the ship. In 1982 the three dimensional data was calculated from overlapping stereo image pairs. Today the point cloud has been calculated by image coordinate measurements in convergent digital images and the application of the adjustment software PhotoModeler 5.0 Pro from Eos Systems Inc. This paper deals with the documentation of the photogrammetric measurement and adjustment process, the visualisation of results and the comparison of the measured profiles of the cog after 21 years.

KURZFASSUNG:

Heute wird die Bremer Hanse Kogge im Deutschen Schifffahrtsmuseum in Bremerhaven ausgestellt. Die Kogge wurde im Oktober 1962 in der Weser gefunden und zwischen 1982 und 1999 in Konservierungsflüssigkeit präpariert. 1982 nutzte das IPI die Messkamera SMK 120 um etwa 80 Messbilder der Kogge aus unterschiedlichen Richtungen anzufertigen. Mit zusätzlichen geodätischen Messungen, signalisierten vertikalen Profilen und Verknüpfungspunkten wurde die dreidimensionale Punktwolke berechnet und Strichzeichnungen der Kogge angefertigt. Nach 17 Jahren in der Konservierungsflüssigkeit wurde festgestellt, dass sich mehrere Bereiche der hölzernen Kogge um +/- 10 bis 25 cm verformt hatten. 2003 wurden über 100 Photos mit digitalen Kameras aufgenommen, um die photogrammetrische Objektrekonstruktion erneut durchzuführen. Um die im Jahre 1982 gemessenen Profile rekonstruieren zu können, wurden diese mit weißem Band auf der Schiffsoberfläche markiert. 1982 wurde das dreidimensionale Objektmodell aus überlappenden Stereoaufnahmen berechnet. 2003 wurde die Punktwolke durch Bildkoordinatenmessung in konvergenten digitalen Bildern unter der Anwendung der Software PhotoModeler 5.0 Pro. der Firma Eos Sytems Inc. berechnet. Dieser Beitrag beschreibt die photogrammetrische Messung und Ausgleichung, die Darstellung der Ergebnisse und den Vergleich der gemessenen Profile nach 21 Jahren.

1. INTRODUCTION

1.1 Historical background

The three dimensional object reconstruction with photogrammetric methods was based in the past on the application of the analogue metric camera SMK 120 and the stereo image measurement with the Stereoplanigraph C8. In 1982 the documentation of the complete Bremen Hanse Cog consisted of line drawings of the wooden surface and plotted profiles in ten locations perpendicular to the main axis of the ship. The line drawings have been used by the museum specialists to reconstruct the wooden body of the cog the profiles were required to control the deformation of the cog while fixing it in the exhibition hall (Weski, 1999; DSM, 2003a; GNT, 2003).

1.2 Current requirements

In the year 2003 several deformations of the cog have been detected in the range of 10 to 25 cm. To ensure a flexible and cost saving solution for the object reconstruction and deformation measurement digital cameras, a free convergent image bundle, and PC-based photogrammetric image measurement and triangulation methods have been used. Depending on local conditions and the applied cameras the image scale was calculated between 1: 929 up to 1 : 114.
The customer again was interested in line drawings of the ten profiles which have been processed and exported in AUTOCAD DXF-format.

2. MATERIAL AND METHODS

2.1 Object description

The Bremen Hanse cog has been fixed under the roof of the exhibition hall with a complex construction with several diagonals made of steel holding the wooden cog together and fixing it with its lower part on the ground floor. The main dimensions are 24 x 8 x 7 m. The location of the cog in the museum allows the positioning of some camera stations on the first floor, all the other stations are on the ground floor and restrictd to a maximum distance of 7 m from the cog. Due to walls and other restrictions most of the camera stations have been used in the range from 2.5 to 6 m. Additional lighting was necessary for most of the images.

2.2 Historical results

The historic line drawings contain information about parts of the wooden surface of the cog as well as the location of the measured profile points. To prepare the imaging process of the photogrammetric survey in the year 2003 about 105 tie points have been fixed on the body of the ship. To compare the deformation of the measured profiles, the location of the profile points have been taken from the old line drawings and marked with white tape on the surface of the cog.

2.3 Digital Camera Application

For the photogrammetric survey two digital cameras have been used. The 6-Megapixel camera Nikon D100 and the 5-Megapixel metric camera Rollei D7 metric[5] had been calibrated before with a three dimensional and a two dimensional calibration field (Wiggenhagen, 2002). For the point signalisation and imaging process about 10 hours were needed. Most of the time was required for the point and profile signalisation on the surface of the cog and the image transfer and image conversion from the compact flash memory cards to the PC.

Due to the different aperture angles of the cameras and local conditions in the museum hall over 100 images were taken. With the Rollei D7 metric[5] camera 60 images and with the Nikon D100 camera 39 images were used for the photogrammetric measurement.

2.4 Coordinate Measurement and triangulation

Prior to the bundle adjustment the achievable point accuracy was calculated (see. Tab. 1).

Camera		Object / Base Distance	Image Scale	Accuracy in x,z,y
ROLLEI	mm	m / m		mm
Sensor width	8.76	6.9 / 1.8	1 : 929	2.8, 2.8, 10.7
Focal length	7.43	2.8 / 1.8	1 : 377	1.1, 1.1, 1.8
NIKON	mm	m / m		mm
Sensor width	23.7	6.9 / 1.8	1 : 280	2.2, 2.2, 8.6
Focal length	24.6	2.8 / 1.8	1 : 114	0.9,0.9, 1.4

Table 1. Reachable point location accuracy

The calculated point location accuracy between 1 mm and 11 mm fulfilled the required accuracy for the project.

The software PhotoModeler 5.0 Pro from Eos Systems Inc. (Eos, 2003) was used for the image coordinate measurement, the bundle adjustment and the preparation of the results. Most of the tie points have been measured in 3 and more images (see Tab. 2). A very stable bundle adjustment resulted from this high redundancy.

Point Type	Number of	
	points	rays/point
Tie point	4	< 3
	12	3
	200	≥ 4
Total	**216**	
Profile point	27	< 3
	213	3
	107	≥ 4
Total	**347**	

Table 2. Number of rays per measured point

After all images have been orientated the points of the signalised profiles could be successfully measured. The point cloud was visualized in the three dimensional view to obtain an overview of the measured points and profiles and to detect points of poor geometry. Most of the profile points could be measured in three and more images

3. RESULTS

To be able to compare the current results with the survey of the year 1982 line drawings of the ten profiles had to be processed at an output scale 1 : 20.

3.1 Coordinates

From the photogrammetric survey 216 tie point coordinates with an accuracy of +/- 0.5 mm could be calculated. The high accuracy depends on the fact that the circular targets have been measured with an automatic point measurement operator calculating the centre of the imaged ellipse with an accuracy of 0.01 pix in image space.

The profile points had to be measured manually. As the image coordinate measurement was carried out in monoscopic mode it was quite difficult to detect the identical points in several convergent images. The epipolar line visualisation ability of PhotoModeler 5.0 was very helpful in this cases.

The point accuracy in object space for the 347 points was calculated with +/- 3 mm in all three coordinate directions.

3.2 Lines

In addition to the photogrammetric survey ten control distances had been measured. The locations of these distances were given in the digital images by their start and end points. The connection between these points have been defined in the photogrammetric bundle to be considered as independent reference lines.

To prepare the result of the whole bundle adjustment for later documentation the different line types were defined in different layers and with different colors.

For the visualisation of the ten profiles the triangulated points have been connected with lines.

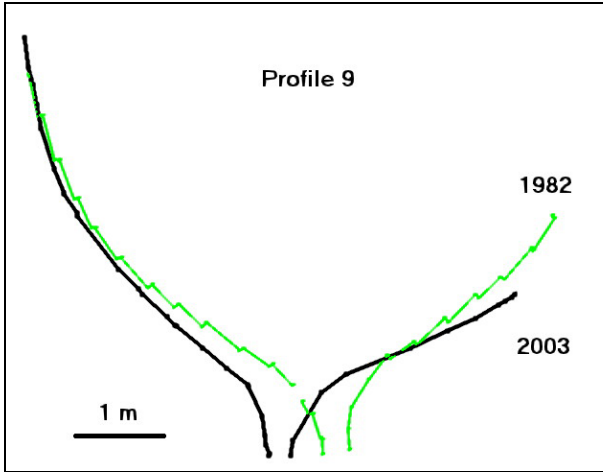A comparison between the two measurements in 1982 and 2003 for profile 9 is shown in figure 1.

Figure 1. Distortions shown in profile 9

The following figure 2 shows one of the digital images with the location of the right part of profile 9. Between the roof of the museum hall and the cog several construction elements made of steel can be detected which allow the wood manufacturer to fix the cog in the desired location of the room. Some of these diagonals have been forced too much. Therefore the ship moved to the rotated location shown in figure 1.
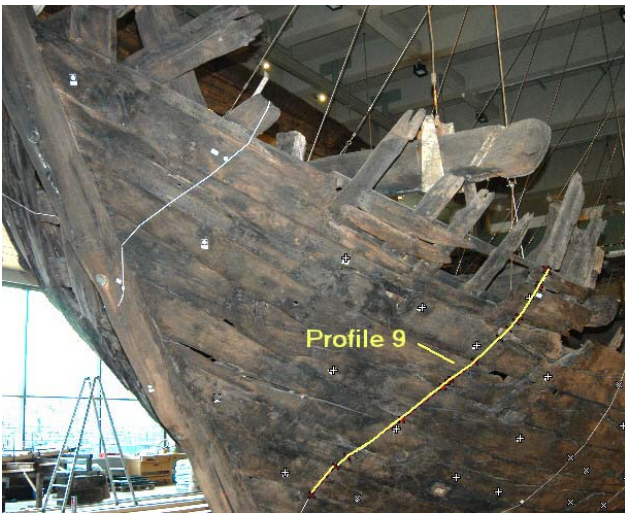

Figure 2. Surface with marked profile 9

The deformations of the cog are caused by several effects. Some local distortions are affected by the different expansion of wooden construction elements. Between horizontal plancs and surface parts differences up to 20 cm could be detected. The main distortion of the whole ship was produced after the wood archeologists tried to repair local distortions with additional steel constructions inside the cog. The whole ship moved with its lower part to one side and rotated in one direction.

This effect can been seen in an oblique visualisation of the cog from the front side to the back in figure 3.
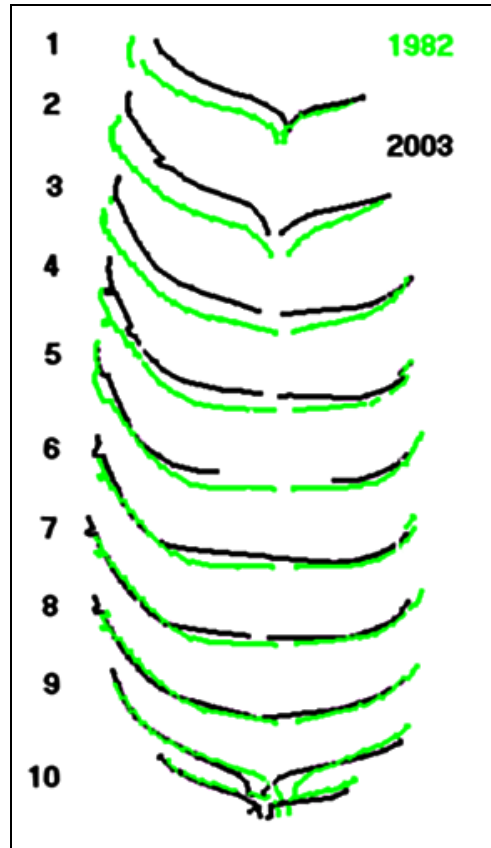

Figure 3. Comparison of profiles

3.3 Surfaces

For visualisation purposes the photo textures of some digital images were used to show the surface of the cog on top of the measured object point cloud. For the resampling of different locations 46 color images of the Nikon D100 were used. Apart of the left side of the cog was processed as a textured model.

The three dimensional view could be examined with the 3D-Viewer of PhotoModeler or with a plug-in for an Internet browser if it was exported in VRML-Format.
An impression of the cog with some of the textured areas is shown in figure 4. The same textures were used for the processing of ortho images of the left side of the cog.
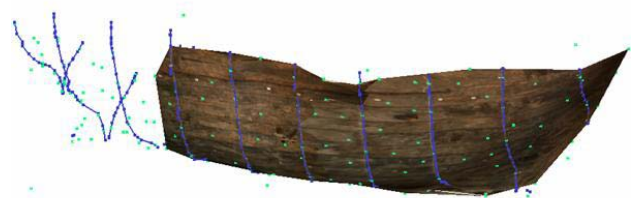

Figure 4. textured surface

3.4 Quality Control Information

To enable a quality control of the triangulated point cloud, several distances in the survey volume have been signalised and

measured. Ten control distances in the range of 1.6 to 6.0 m have been measured and compared with the distances calculated from the photogrammetric survey (see Tab.3). As the geodetic measurements have been carried out only with a measuring tape the accuracy of the distances is to be considered in the area of +/- 5 mm.

	Control Distance	[m]	
		length	difference
1	1208-518	3.590	-0.010
2	1207-528	3.910	-0.020
3	1206-526	3.550	-0.029
4	223-225	6.048	-0.014
5	801-802	2.800	-0.016
6	285-296	3.760	-0.012
7	083-073	2.020	0.011
8	415-053	3.470	0.013
9	445-311	1.590	0
10	310-017	2.201	0.009

Table 3. Calculated distance differences

Depending on poor intersection angles some of the control distances could be triangulated only with low accuracy. The mean absolute difference of 13.4 mm was sufficient for the whole photogrammetric project.

4. DISCUSSION

4.1 Comparing Analogue with Digital Measurement

In comparison to the analogue imaging and photogrammetric measurement process the digital method requires many more images depending on the resolution of the digital cameras and the geometric conditions in the museum hall. In 1982 forty stereoscopic image pairs were necessary for the production of a line drawing of the wooden surface of the cog. For the measurement of the profiles only ten vertical lines had to be projected onto the surface from both sides of the cog (see fig. 5). Those lines were measured in stereo mode with the Stereoplanigraph C8 and were drawn in real time at a mechanical plotting table.
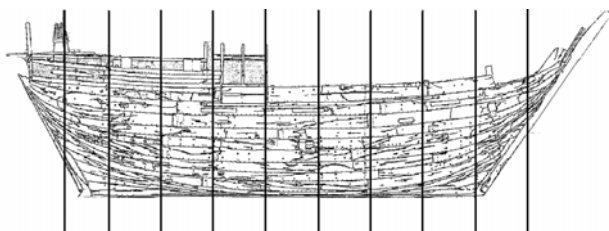

Figure 5. line drawing with profile lines

In the second measuring campaign in 2003 over 99 images were necessary for the triangulation. 227 tie points and twenty signalised profile lines were required to offer enough points for the monoscopic measurement in the convergent images.
The profiles exist of 340 measured points. The image coordinates of these points have been measured in manual mode with the pointing device of the PC.
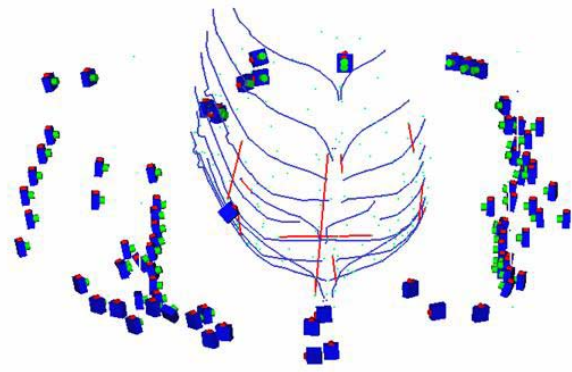An overview of the camera stations, profiles, control distances and measured points is given in figure 6.

Figure 6. camera stations, profiles and control distances

Although the whole object reconstruction could be carried out with a standard PC and without the need of a digital stereo workstation the required accuracy between 10 and 20 mm in object space could be reached. The software PhotoModeler 5.0 Pro from Eos Systems Inc. offered following functions for the photogrammetric data processing:

- Camera calibration,
- Project image administration,
- Manual and automatic image coordinate measurement,
- Epipolar line referencing mode,
- Definition of points, lines, surfaces and textures,
- Photogrammetric bundle adjustment,
- Measurement of three dimensional coordinates and distances,
- Visualisation of three dimensional data,
- Ortho image production,
- Vector and raster data export.

The statistical point reports and the residual display were very powerful for the detection of registration errors and poor intersection constellations.
The ability to consider several project cameras was important for the common adjustment of all images from both used digital cameras.

4.2 Analogue to Digital results

In 1982 line drawings and profile plottings in the scale 1: 20 had been produced. The line drawings were produced for both sides of the cog and also for an inside view. The details shown in the drawings depend on the ability of the operator to do an interpretation of the image material and to select important features and draw them. As this was a very time consuming and expensive method today in most cases ortho image maps will be preferred.
Therefore in 2003 no line drawings were asked from the customer. Only the profiles were delivered on paper as well as digital data sets again in the scale 1 : 20.
For publication purposes additional three dimensional visualisations with textured surfaces and ortho images have been processed. One of the historical line drawings can be compared with a part of an ortho image in figure 7.
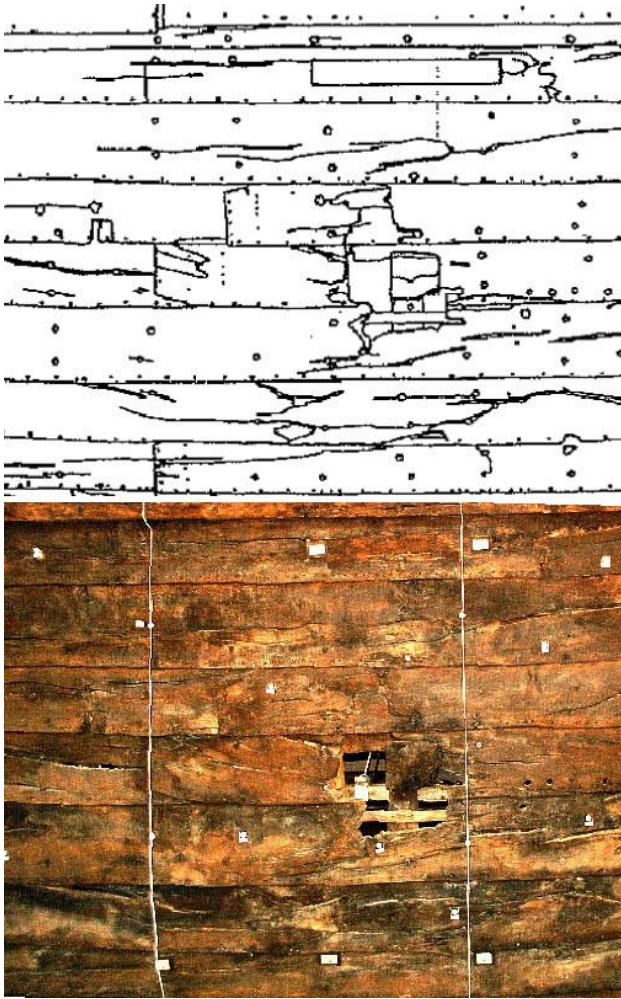
Figure 7. Comparison of line drawing and ortho image

Based on the standard export formats TIF, DXF and VRML the results could be exported to several other applications e.g. AUTOCAD.

5. CONCLUSION

In this project it could be shown that modern digital cameras in combination with flexible adjustment and monoplotting software are capable to reconstruct a large object in short time with sufficient accuracy.

The Bremen Hanse Cog was imaged with over 100 digital images using the digital professional consumer cameras Rollei D7 metric[5] and Nikon D 100. The desired accuracy of +/- 10 to 20 mm in object space could be reached by the measurement of 216 tiepoints and 347 object points in one photogrammetric bundle. The accuracy was checked by ten independent control distances. The mean absolute difference was calculated with 13.4 mm.

With the resulting three dimensional profiles a deformation of the cog could be shown and was documented with line drawings and digital vector data sets.

6. REFERENCES

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7. ACKNOWLEDGEMENTS