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# THE STILL PICTURE CAMERA AS A TOOL FOR ANGULAR MEASUREMENTS OF SURFACE OBJECTS IN AN OFF-SHORE AREA

## ABSTRACT

This article presents investigations conducted for the purpose of assessing the possibility of using still picture cameras to fix the positions of surface objects in an off-shore area. The first part describes the research methodology relating to the accurate assessment of angular measurements made with a still picture camera. The second part includes the method used to calculate horizontal angles using photos, and the method of calculating horizontal angles, based on three points whose geographical coordinates are known. The final part contains the results of the investigations, which justify using a still picture camera as a tool for angular measurements.

Key words:
marine photogrammetry, digital camera, photo-based measurement.

## INTRODUCTION

Technological progress, observed over several years, has already revolutionized each aspect of life, facilitating the work and lives of many people. A variety of electronic equipment is used in present day navigation to monitor the situation in off-shore areas including among others active radar. Use of the still picture camera for angular measurements makes it possible to conduct passive observation of the situation in off-shore areas, which reduces the probability of detecting observation posts. Owing to the technological progress in digital camera production there

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exists a wide choice regarding their characteristics, dimensions and functions. The most popular cameras used for professional applications are, of course, those which offer the highest resolution of pictures taken and the quality of lenses. In the computing process, most often, computer systems are used which offer high output and have the capability of processing pictures in real time.

This paper presents the results of investigations aimed at finding evidence to prove the usefulness of still picture cameras in monitoring situations in an off-shore areas.

## THE INVESTIGATION METHOD

The aim of the investigations was to evaluate the accuracy of angular measurements derived from photos. The photos were taken using a camera located on the seashore, at a point whose position was known and unchanged. The measurements related to a horizontal angle measured between a reference on-shore / off-shore object whose position was also known and unchanged, and another surface object (e.g. a floating vessel) in the off-shore area. To conduct the investigations two high class reflex digital cameras a Nikon 60D and a Canon EOS 400D (fig. 1) [2, 7].


Fig. 1. Cameras: a) Nikon 60D, b) Canon EOS 400D

The results, obtained using the photogrammetry-based method, of measuring horizontal angles were compared with the specimen results obtained using analytical methods. The analytical calculations were based on three known points. Two unchanging ones, corresponding to the position of the camera and

the reference object, which were selected, using a receiver GPS TOPCON working in the system ASG-EUPOS (the average error not exceeding 2 cm). The third changing one, corresponding to the position of the floating vessel (mapped on the observed part of the hull), which was obtained using a transponder SAAB R4 from the system AIS. This position was mapped using very simple calculations, based on the known gyrocompass course and the known position of the GPS antenna in relation to the hull of the floating vessel. Thus it can be assumed that the mean error of the third, unchanging, mapped point was within 10 m (obviously for floating vessels transmitting in the AIS, the position marked — accurate position).

## CALCULATING ANGLES USING PHOTOGRAMMETRY AND ANALYTICAL METHODS

Attempting to verify the justification for employing the proposed solution it was necessary to calculate the values of the angles obtained from the measurement photo taken. To this end it was necessary to choose observation points, from which it was possible to observe floating vessels present in the area of our concern, as well as the reference points. Three measurement configurations were chosen (consisting of an observation point and reference points), for which six pictures were taken.

Each of the pictures from the digital camera accepted for the investigations was processed for removing deformations caused, among others, by:

- radial and tangential distortion of the mirror and lens in the camera;
- affinity and unorthogonality of the coordinate system on the CCD matrix.

To this end a matrix of intrinsic parameters was used. It was obtained as a result of calibration of cameras (calibration was performed using a graphic library 'OpenCV') [1, 3, 5]. The rectified and not rectified photos were used to determine horizontal angles (fig. 2).

To determine the horizontal angle $\alpha$ between points $P_A$ and $P_B$ the formula used is:

$$\alpha = \operatorname{arc\,tg}\left(\frac{x_1}{f}\right), \tag{1}$$

where:

$f$ — length of focus in optical system of camera;

$x_1$ — coordinate derived from product of number of pixels and size $r$ of single pixel.

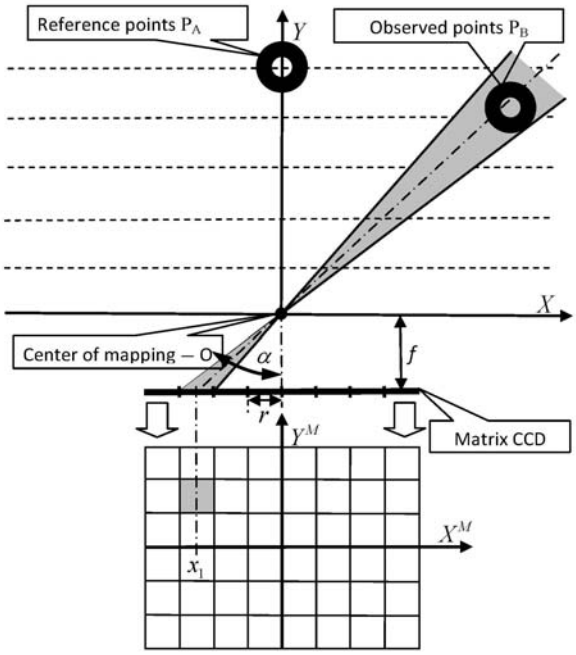


Fig. 2. The idea of measuring a horizontal angle with a camera

In the investigations it was assumed that the optical axis of the camera runs through the reference point $P_A$ (i.e. the point $P_A$ is in the center of the photo / matrix CDD) and the axis $\alpha$ in the matrix CCD is parallel to horizon line (fig. 3).

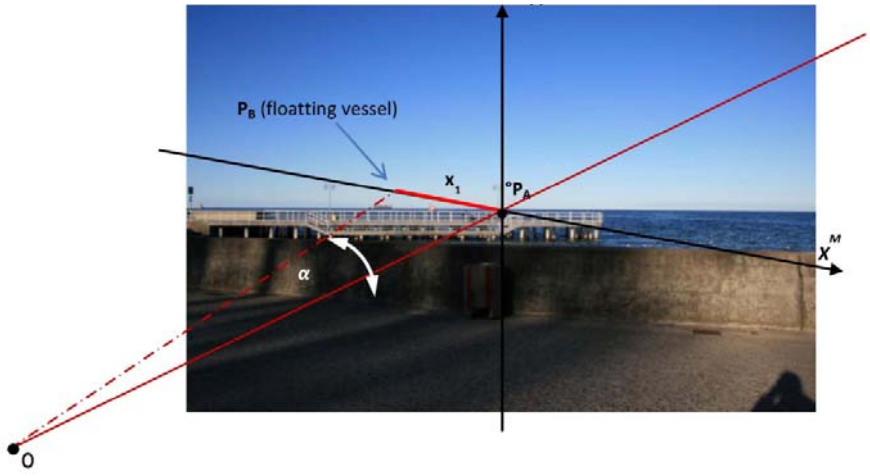


Fig. 3. Measuring a horizontal angle from a photo

The values of the horizontal angles between the measurement points observed in the photos were compared with the values calculated with the analytical method. This was based on the known geographic coordinates for the camera $O(\varphi_0, \lambda_0)$, the reference point $P_A(\varphi_A, \lambda_A)$ and the surface object $P_B(\varphi_B, \lambda_B)$.

The commonly known in marine navigation interdependencies relating to a navigational triangle were used in the calculations. They were employed to calculate the model horizontal angle $\alpha_r$:

$$\alpha_r = \operatorname{arctg}\frac{(\lambda_A-\lambda_0)\cdot\cos\frac{\varphi_0+\varphi_A}{2}}{\varphi_A+\varphi_0} - \operatorname{arctg}\frac{(\lambda_B-\lambda_0)\cdot\cos\frac{\varphi_0+\varphi_B}{2}}{\varphi_B+\varphi_0}. \quad (2)$$

## THE ANALYSIS OF THE RESULTS

In order to carry out the investigations six photos were used. They had been taken from land in the area allowing for observation of floating vessels in the Bay of Gdańsk. Both distorted (original) and rectified photos were considered. The results obtained are presented in table 1.

Table1. The investigation results [8]

| Measurement number | $\alpha_r$ | $\alpha$ from rectified photo | $\alpha$ from original photo | Relation $\alpha_r$ to $\alpha$ from rectified photo | Relation $\alpha_r$ to $\alpha$ from original photo |
|---|---|---|---|---|---|
| 1 | 8.275° | 7.771° | 7.732° | 1.065 | 1.07 |
| 2 | 10.094° | 12.690° | 12.672° | 0.795 | 0.797 |
| 3 | 12.931° | 11.596° | 11.540° | 1.115 | 1.121 |
| 4 | 14.477° | 13.832° | 13.746° | 1.047 | 1.053 |
| 5 | 25.698° | 24.911° | 24.353° | 1.032 | 1.055 |
| 6 | 4.179° | 4.408° | 4.408° | 0.948 | 0.948 |

Following the investigation results presented in table 1, it can be claimed that:

- the angle values determined using the camera after rectifications differed from the angle values determined analytically on average by 1.016°;
- the angle values determined using the camera from the original photo differed from the angle values determined analytically on average by 1.136°;

- in four out of six measurements the angles determined using the photo were lower than those determined analytically;
- any simple interdependence between the obtained values $\alpha$ and the realtion $\alpha_r$ to $\alpha$ were not recorded;
- the angle values determined in the course of the investigations were never lower than 4° and higher than 26°, therefore they can be regarded as sharp, which can also be a cause of decrease in measurement accuracy [8].

However, it must be born in mind that the angle measurement accuracy depends mainly on the length of the focus *f* of the optical system in the camera and the pixel size *r* on the matrix CCD (see fig. 2). Knowing the mean errors of independent variables $f, x_1$ in function of the single measurement (1), applying low of mean error transfer, it is easy to write a mean error in angle measurement equation:

$$m_\alpha = \left[ \left( \frac{\partial \alpha}{\partial f} \cdot m_f \right)^2 + \left( \frac{\partial \alpha}{\partial x_1} \cdot m_{x_1} \right)^2 \right]^{1/2}, \tag{3}$$

where:

$m_f$ — mean error in measuring focus length;

$m_{x_1}$ — mean error in measuring range on matrix CCD.

The detailed, theoretical accuracy-focused analysis of horizontal angle measurement using dependences (3) can be found in [4]. The real investigations described in this article can supplement it.

## CONCLUSION

To monitor a situation in off-shore areas requires focusing attention on possibilities of ma king use of various ways of observation. Using digital devices for image recording can be used as an additional (supplementary) way of monitoring vessel traffic. The main use of the system based on digital cameras could be a clandestine operation situation in which each kind of wave received by an opponent would probably end up with a damage to the transmitter.

Owing to the use of high quality technical devices determining data relating to surface objects could be possible in real time. However, it would require additional funds to develop a processing and surface object acquisition system. This article presents possibilities of using still picture cameras for determining an angle between a surface vessel and an observed reference point. It contains the results of the investigations aimed at finding out the usability of such a solution with regard to accuracy. Following the data obtained it was possible to make a claim that the proposed solution would make it possible to determine horizontal angles and then, using the angles, to fix floating vessels in off-shore areas [8].

Discrepancies recorded in the course of the analysis of the results do not have a systemic nature. These errors could have been caused by imperfections of the optical systems used in cameras, picture processing methods or other unrecognized factors. Their origins and inter-dependencies should be given more detailed analysis of a different kind.

## REFERENCES

[1] Bernasik J., *Podstawy fotogrametrii*, AGH, Kraków 2006 [*Fundamentals of photogrammetry* — available in the Polish language].

[2] *Digital Photography Review DPREVIEW*, [online], http://www.dpreview.com/reviews/nikond60, [access 20.04.2014].

[3] Kulisiewicz T., *Zmierzch fotochemii*, „Wiedza i Życie", 1997, No. 4, [online], http://archiwum.wiz.pl/1997/97042700.asp, [accesss 20.04.2014], [*Twilight photochemistry* — available in the Polish language].

[4] Naus K., *Accuracy in fixing ship's positions by CCD camera survey of horizontal angles. Geomatics and Environmental Engineering*, 'Geomatics and Environmental Engineering', 2011, No. 5/4, pp. 39–46.

[5] *Open Source Computer Vision*, [on;one],http://www.opencv.org, [access 20.04.2014].

[6] Sitek Z., *Fotogrametria z fotografią techniczną*, PWN, Warszawa 1981 [*Photogrammetry with technical photography* — available in the Polish language].

[7] *The-Digital-Picture.com*, [online], http://www.the-digital-picture.com, [access 20.04.2014].

[8] Turek P., *Aparat fotograficzny jako narzędzie pomiarów kątowych obiektów nawodnych w strefie przybrzeżnej*, AMW, Gdynia 2014 [*A still Picture camera as a tool for measuring surface object angles in an off-shore area* — available in the Polish language].

# APARAT FOTOGRAFICZNY JAKO NARZĘDZIE POMIARÓW KĄTOWYCH OBIEKTÓW NAWODNYCH W STREFIE PRZYBRZEŻNEJ


## STRESZCZENIE

W artykule przedstawiono badania mające na celu ocenę możliwości zastosowania aparatów fotograficznych do określania pozycji obiektów nawodnych w strefie przybrzeżnej. W pierwszej części opisano metodę badań związaną z oceną dokładnościową pomiarów kątowych wykonanych aparatem fotograficznym. W drugiej części przedstawiono sposób obliczania kątów poziomych na podstawie zdjęć fotograficznych oraz sposób obliczania kątów poziomych na podstawie trzech punktów o znanych współrzędnych geograficznych. Część końcowa zawiera wyniki z przeprowadzonych badań, które potwierdziły zasadność stosowania aparatu fotograficznego jako narzędzia do pomiarów kątowych.



Słowa kluczowe:

fotogrametria morska, aparat cyfrowy, pomiar kąta ze zdjęcia.