Optik 127 (2016) 3964–3968

Contents lists available at ScienceDirect

Optik

journal homepage: www.elsevier.de/ijleo

Underwater visual position measurement system for high-accuracy beam installation

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ARTICLE INFO

Article history:
Received 5 December 2015
Accepted 15 January 2016

Keywords:
Position measurement
Bi-camera vision system
Super resolution
Feature extraction

ABSTRACT

In order to improve the efficiency of an underwater beam installation process, a computer-controlled position adjustment system is established. High accurate underwater position measurement is required in the system to ensure the fitting accuracy of two beams in the fine adjustment. This paper presents a visual measurement method using two pairs of underwater bi-camera vision system. Because the beams are of large size, appropriate markers as the measuring objects are coated on the rails fixed on two beams. A tank filled with clear water is put in front of each underwater camera to reduce the backscattering effect caused by turbid water. In order to solve the inaccuracy of position measurement due to blur edges and unclear contours on the images from the underwater cameras, super resolution as well as other image processing methods has been applied. By analyzing the extracted features from some interest lines and points of the processed images of markers, the position of the beam can be obtained. Results have shown that the position measurement errors are acceptable and the method can be used practically.

1. Introduction

In an underwater beam installation process, a computer-controlled position adjustment system is established to improve the efficiency of the construction process. In order to ensure the fitting accuracy of two beams in the fine adjustment and to achieve automatic control of the system, high accurate underwater position measurement is required. Among the various available solutions, underwater visual measurement provides higher accuracy and resolution compared with those based on radio and ultrasonic sources that cannot be adequately focused [1]. Monocular visual methods have been used for position measurement to reduce the computation time and operation cost but the depth information is unable to be obtained from one image [2]. Estimation of the depth will require extra information provided by a second image acquired through a known camera motion or by a priori knowledge related to geometric information extracted from the 2D image [3]. However, camera motion will cause greater variations in camera calibration parameters in underwater measurement because of radial distortion, which will affect the measurement accuracy. Moreover, radial supporting ways for moving cameras are a challenging issue [4]. Besides, underwater imaging always suffers from low contrast, non-uniform illumination or diminished colors, which makes feature extraction and object recognition from underwater images very difficult [5–7].

Compared with mono-vision, stereo vision can obtain the depth information directly from the images based on the measurement of parallax [8]. Ishibashi [9] described a stereo vision system to calculate three-dimensional position data of an object in the underwater working environment. Zheng et al. [10] presented an underwater stereo vision system to measure the distance between the target and the camera as well as the 3D information of the target. Nevertheless, it's very challenging to catch homologous points in the stereo pair of underwater images because of many interference factors such as photometric distortions and noise, occlusions and discontinuities, etc.[8]. Bruno et al. [11] used a Gray-code technique to solve the correspondence between the points in the underwater stereo pairs. In addition, stereo vision requires precise previous calibration for the extrinsic parameters of the stereo pair to achieve high accurate position measurement [12,13].

This paper employs two pairs of bi-camera vision system to measure the position of a large-size cross beam to be installed referring to an installed one in an underwater operation. The bi-camera vision system rather than stereo vision can overcome the homologous point correspondence problem with stereo-based system and precise previous calibration for the extrinsic parameters of the stereo pair is no longer necessary. As it's difficult to extract feature points from the underwater image due to blur edges and unclear contours on the image, which results in low accuracy of position measurement underwater, super resolution as well as other image

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http://dx.doi.org/10.1016/j.ijleo.2016.01.128
0030-4026/

enhancement technique has been applied in this research to solve the problem.

2. System and procedure of underwater position measurement

2.1. Overall underwater position measurement system

As shown in Fig. 1, the overall underwater beam installation system employs two pairs of bi-camera vision system on both sides of the beam to measure the relative position of the beam to be installed referring to an installed one. Since the beams are of large size, it's difficult to obtain a full view of the underwater beams. Rails are fixed on the beams and appropriate markers, as the measuring objects, are coated on them, as shown in Fig. 2. In the bi-camera vision system, one camera faces toward the top of the rails while the other faces toward the side of the rails, as shown in Fig. 3. The two cameras are placed at a right angle and mounted on the frame connected with the beam to be installed, so the distances between the markers of the beam to be installed and the two cameras are fixed. Here, the distances between the markers and two cameras are both set to 1000 mm. A tank filled with clear water is put in front of each underwater camera to reduce the backscattering effect caused by turbid water. Without the tank, markers with high contrast and strong reflection can't be seen very clearly within a short distance because of backscattering effect, which makes it very difficult

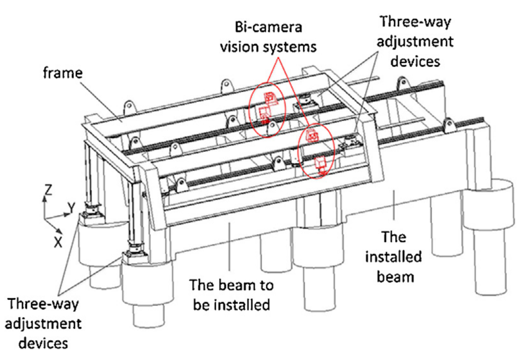

Fig. 1. The overall underwater beam installation system.

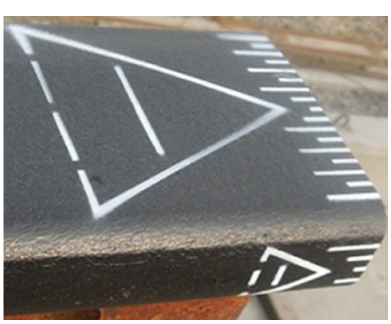

Fig. 2. Markers on the rail.

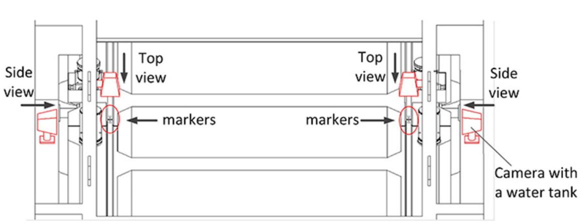

Fig. 3. The enlarged view of bi-camera vision systems.

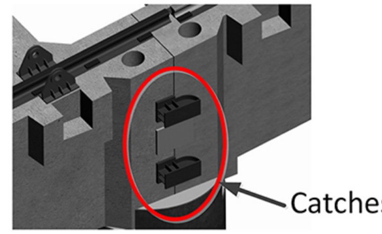

Fig. 4. Catches on the beams.

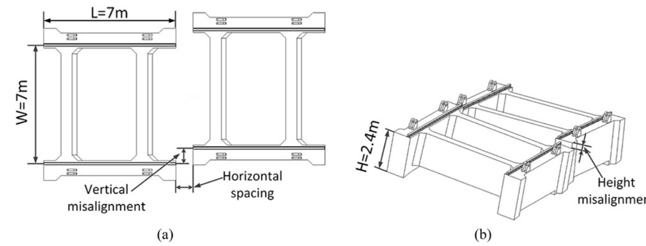

Fig. 5. The size of the beam and three measurement factors: (a) the length and vertical spacing of two rails on the beam, vertical misalignment and horizontal spacing; (b) the height of the beam and height misalignment.

for high accurate position measurement. By extracting geometric information from the images of the four cameras using monocular algorithms, the position of the beam to be installed referring to an installed one can be obtained. There's no need for precise previous calibration for the extrinsic parameters of the stereo pair in this system.

In the installation system, four three-way adjustment devices are connected to the frame and each device consists of three cylinders to adjust the position of the beam in three directions (e.g. X/Y/Z directions, as shown in Fig. 1). The devices are first controlled by the operator onshore to ensure that the markers are within the observability range of the cameras (the coarse adjustment). Then devices are controlled automatically to rectify the position of the beam according to the visual measured data (the fine adjustment). The successful installation of the beams is determined by reliable connections of two catches on the beams as shown in Fig. 4. Compared with the length ($L = 7$ m) and the vertical spacing ($W = 7$ m) of two rails (shown in Fig. 5), the horizontal spacing, vertical misalignment and height misalignment between two beams are relatively insignificant in the fine adjustment, so the tilt angle of the beam is negligible and the fitting accuracy of two beams mainly depends on the measurement errors in the above three factors. The vertical misalignments between two beams on both sides are detected by two top-view cameras, while the height misalignments on both sides are detected by two side-view cameras. The horizontal spacing between two beams on one side is detected both by the top-view and side-view cameras and the measured data are the average of the distances obtained from two images. The position of the beam is obtained from the measured data of these three factors. In order to ensure the successful installation of two beams, the measurement errors in horizontal spacing, vertical misalignment and height misalignment should all within 5 mm.

2.2. Procedure of underwater position measurement

The four cameras are first calibrated underwater using Bouguet's camera calibration toolbox [12] to compensate for the distortion induced by the presence of water before the measurement. Then the measurement is applied according to the procedure shown in Fig. 6. (a) Images of markers are taken by the calibrated underwater cameras and transferred to a visual signal processing module