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The Performance Evaluation of Two Different Distance Estimation Tools Under Unclean Water Using Stereo Vision

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Abstract

Stereo vision is one of the best methods for distance estimation of underwater object. In this research two pairs of cameras were used as stereo image acquisition to estimate the distance of underwater object. The stereo vision system in this project consists of calibration of camera, rectification of images, segmentation of images, finding of centroid and localization of object. Edge-based segmentation, Mathematical morphology and largest area selection are used to perform image segmentation. As a result, it is proved that the curve fitting tools method is more dependable than triangulation method to evaluate the coordinates. The final experiment results illustrate that the overall error of curve fitting tools method in the unclean (muddy) water conditions is 0.2 cm, while by using triangulation in the same condition is around 1.5cm.

Keywords

Stereo Vision, Under Water Range Estimation, Image Segmentation, Curve Fitting Tool

1. Introduction

Three-dimensional information of environment is essential for robot movement and object inspection as well in automation applications. Stereo vision is one of the ways to extract the depth information [1]. Stereo vision is based on comparing two view of the same scene that leads to range estimation [2, 3]. According to the comprehensive research carried out by Atsushi Yamashita of Shizuoka University, Reconstruction of object shape and its movement have implemented [4, 5]. However, the technique used in this research, is used to estimate the location of the object. Sensor fusion is an application in vision technology in which, robot movement defined as a function that the operation of the robot controlled by vision system [6, 7].

Aforementioned system estimated the distance of the object using an ultrasonic sensor [8]. However, comparing stereovision accuracy with using an ultrasonic sensor indicates that stereo vision achieve better accuracy [9].

Adoption the stereovision performed by Radhakrishnamurthy et al. in purpose of pin picking up application. The proposed method includes two main steps that are object segmentation module and object localization module [4]. By comparing the result of segmentation, it is clear that segmentation performed better in this paper as the partial noise in localization has removed. The accuracy of segmentation directly influences the image localization negatively [4, 10, 11]. In addition, in this paper the resent growth of stereo vision system in the underwater applications by SVS [12, 13] is covered.

2. Stereo Vision System (SVS)

Stereo vision is a best method to extract data of depth from image [14]. This technique is based on human vision. SVS is a method which gets the 3D information from 2D images. On the other hand, SVS is a method for retrieving depth from images of camera by comparing the same picture from two views. Hence, stereo vision system often consists of programmable computer and a pair of camera to calculate the disparity. Disparity is difference in the position of object image which is taken by stereo cameras [11]; Disparity is reversely proportional to depth. It is a remarkable parameter in the stereo vision system. Following two popular methods are used to estimate disparity value: Triangulation method and Curve fitting tool method. Curve Fitting Tool Method in which x and y of the object are given by the centroid coordinate obtaining by left camera. The coordinate positions are in the pixel values. It is necessary to use convertor unit to convert pixel to centimeter which will be further used in underwater application. The experiment must be performed in the various positions (12 positions in this research) in the work-space by left camera. In this procedure, pixel value is the input which will be converted to real centimeter values as an output. After this step, the value of input and output as x and y coordinate should be estimated. Following step is using curve fitting tools to estimate and create automatic formula to convert the pixel value to real value. Therefore, curve fitting tools estimate the coordinate of x and y in real value from pixel value.

3. Methodology

Camera calibration must be performing before the main steps of procedure, because the loss of the calibration negatively affects the final results. Both intrinsic and extrinsic parameters are numerated via camera calibration process [12]. These parameters are used in rectification section of the process. The first step of the main procedure is to take color pictures (RGB) using stereo cameras. These color images are then converted to grayscale. Alignment of the object in images in horizontal direction is performed after image acquisition. These parameters are used in rectification sector of the procedure [13, 14]. Image segmentation based on offer method is one of the main steps that performs after alignment of the pictures. Mathematical morphology procedure is felt out into three sections to dilate the captured the pictures. Figure 1 shows the graphical representation of the suggested methodology in this paper.

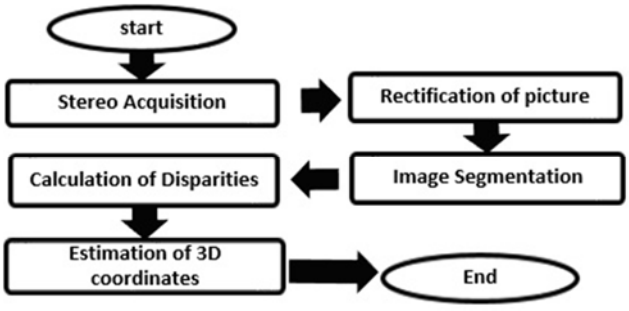

Figure 1. *The graphical representation of the suggested methodology.*

3.1. Camera Calibration

The pre-step in this process is camera calibration. This process is an act that has to be done before starting the main process. Camera calibration is one of the most important parts that affect the final result strongly. Calibration process contain the computation of camera parameter either internal or external or both of them. These parameters are used in the rectification process of the project.

The implementation of the process begins when the color images are taken by the two cameras and then converted to the grayscale images. In the rectification section the process made the object to align in the horizontal direction. In the next step the segmentation is implemented in the rectified image using the proposed technique. Then the process is to find the disparities of the image and it is not possible unless the centroids of the image are calculated.

3.2. Image Segmentation

Image segmentation in this research is a combination of three methods. Edge base segmentation, selection of the largest area, and mathematical morphology are combined to perform the image segmentation. Image segmentation starts exactly after rectification process. The mathematical morphology process is divided into three parts which dilate the captured images, filling the interior gaps and smoothing the object using image eroding.

3.3. Centroid Computation

After finishing the segmentation of the image, calculation of the centroid of the image is next step. Following equations calculate the segmented images coordinates (both left image and right image):

$$\overline{\mathrm{X}} = \frac{1}{\mathrm{A_t}} \int_{\mathrm{area}} \mathrm{xdA} \tag{1}$$

$$\overline{\mathrm{Y}} = \frac{1}{\mathrm{A_t}} \int_{\mathrm{area}} \mathrm{ydA} \tag{2}$$

Where (x) and (y) are the centroid of the coordinates and AT is the total area in the region.

3.4. Disparity

The Difference in two corresponding points in the images must be calculated in order to set the initial condition for the curve fitting tools. This following Equation 2.4 calculates the disparities of two corresponding points in the images.

$$d = \sqrt{(\overline{x_l} - \overline{x_r})^2 - (\overline{y_l} - \overline{y_r})^2} \tag{3}$$

3.5. Curve Fitting Tool

The Z coordinate that is the distance of the object from the stereo cameras calculated using the disparity value found between two images by using curve-fitting tool. The CF tool is graphical user interface (GUI) that lets the user to explore the data and correspondence fits visually. GUI enables exploratory data analysis, pre-process and post process data,

removing of outliners and compression of candidate models

3.6. Segmented Object

Captured color images using stereo cameras read by Matlab and converted to grayscale. Calculation of threshold values performed by Soble operator.

3.7. Curve Fitting Tool

A number of stereo images in various heights were captured. The higher disparity values lead to least error in range estimation from stereo cameras. Curve fitting tool calculated the correspondence graph by considering that the disparity values are in pixel while the actual distance is in centimeters.

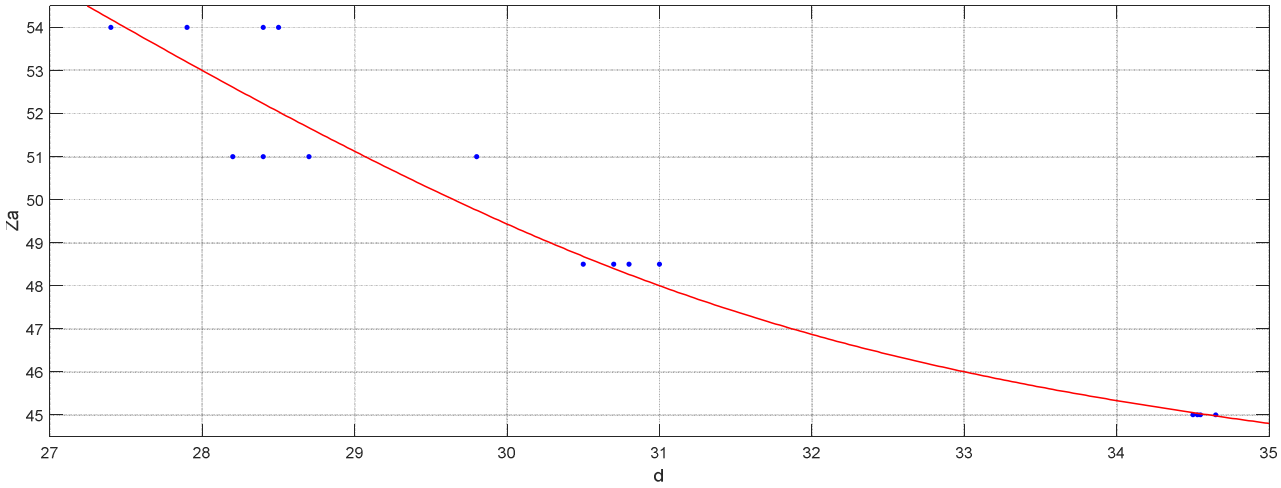

Figure 2. *Distance vs. Disparity.*

4. Accuracy and Result

Table 1 shows the results and estimated ranges and correspondence errors at the height 0.207 while in the same condition triangulation resulted in the overall all error of around 1.534 (Table 2) which illustrates that the curve fitting is more reliable than triangulation method to estimate the coordinates in unclean water.

Table 1. *Location of the stereo cameras with respect to the coordinate system (Eng Swee, Abu Hassan et al.).*

POINT	X_a	Y_a	Z_a	X_{cm}	Y_{cm}	Z_{cm}	$X_{cm}-X_a$	$Y_{cm}-Y_a$	$Z_{cm}-Z_a$
A	25.5	15.2	52.21168	25.3905	15.9679	52.65442	0.1095	0.7679	0.442743
B	25.5	10.2	51.97172	25.505	10.3011	52.26716	-0.005	0.1011	0.295438
C	25.5	5.2	52.21168	25.5668	4.7284	52.62503	-0.0668	-0.4716	0.413351
D	20.5	15.2	51.43987	19.7323	15.6933	51.60911	0.7677	0.4933	0.169236
E	20.5	10.2	51.19629	19.8188	10.12	51.29653	0.6812	-0.08	0.100238
F	20.5	5.2	51.43987	19.9485	4.5658	51.63763	0.5515	-0.6342	0.197765
G	15.5	15.2	51.14743	14.8737	15.5359	51.36049	0.6263	0.3359	0.213056
H	15.5	10.2	50.90246	14.9679	9.9074	51.06623	0.5321	-0.2926	0.163769
I	15.5	5.2	51.14743	14.8711	4.383	51.40979	0.6289	-0.817	0.262362
J	10.5	15.2	51.34257	9.959	15.3388	51.80681	0.541	0.1388	0.464245
K	10.5	10.2	51.09853	9.6925	9.7623	51.47327	0.8075	-0.4377	0.37474
L	10.5	5.2	51.34257	9.9342	4.2563	51.79858	0.5658	-0.9437	0.456012
				Average Absolute Error			0.478308	-0.15332	0.29608
				Overall Absolute Error			0.207023		

Table 2. *Comparison between Triangulation and Curve fitting result.*

POINT	X_a	Y_a	Z_a	X_{cm}	Y_{cm}	Z_{cm}	$X_{cm}-X_a$	$Y_{cm}-Y_a$	$Z_{cm}-Z_a$
A	25.5	15.2	52.21168	26.33262	17.61261	46.53489	0.832619	2.41261	5.676788
B	25.5	10.2	51.97172	26.77853	11.49915	47.03898	1.27853	1.29915	4.93274
C	25.5	5.2	52.21168	27.35783	5.390316	47.8433	1.857832	0.190316	4.368376
D	20.5	15.2	51.43987	20.2515	17.43249	46.86324	-0.2485	2.23249	4.576628
E	20.5	10.2	51.19629	20.55318	11.35478	47.27646	0.053182	1.15478	3.91983
F	20.5	5.2	51.43987	21.13769	5.239964	48.15208	0.637686	0.039964	3.287795
G	15.5	15.2	51.14743	14.04363	17.34062	47.08737	-1.45637	2.14062	4.060064
H	15.5	10.2	50.90246	14.38453	11.15211	47.42574	-1.11547	0.95211	3.47672
I	15.5	5.2	51.14743	14.77199	5.000583	47.85367	-0.72801	-0.19942	3.293765
J	10.5	15.2	51.34257	7.645883	16.74413	46.05063	-2.85412	1.54413	5.291942
K	10.5	10.2	51.09853	8.15319	11.02806	47.59281	-2.34681	0.82806	3.505716
L	10.5	5.2	51.34257	8.772129	4.977117	49.03488	-1.72787	-0.22288	2.307691
				Average Absolute Error			-0.48478	1.030994	4.058171
				Overall Absolute Error			1.534795		

Comparison of the estimated ranges and actual distances carried out in this research. The X, Y coordinates of the object are estimated by centroid coordinates obtained by left camera and Z direction is estimated through the disparity values obtained by stereo pair.

5. Conclusion

In this research, two Microsoft USB cameras were used as stereo pair. Image segmentation performed in the background. The noise occurred during edge detection removed by applying basic morphology method. The distance estimated using the extracted information from stereo pair. the average errors of the coordinates in triangulation method and the curve-fitting tool method were calculated. Final overall error shows that using curve fitting tool has around 0.207 cm error while the overall error of triangulation is around 1.534795 cm in unclean water which is too much in range estimation. Therefor curve-fitting tool was presented as the better method than triangulation method for Underwater Object using stereo vision.

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