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Comparison Between Triangulation and Curve Fitting Tool Methods for Underwater Ranging Using Stereo Vision

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Abstract

There is a growing interest in underwater applications. 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. Finally, It will be shown that curve fitting is better than triangulation method to estimate the coordinates with the overall error of around 0.5 cm with water condition where the overall error of using triangulation method is around 2.2 cm which is too much in range estimation.

Keywords

Stereo Vision, Triangulation Method, Curve Fitting Tool Method, Camera Calibration

1. Introduction

The main purpose of computer vision is to enable the computer to realize its environment from visual formation [1, 2]. So stereo vision system (SVS) is designed to achieve this goal [3, 4]. Stereo vision is an attractive technique to extract information of depth from image. This technique is inspired form human vision. SVS is a technique to get the 3D information from 2D images[5].

Nowadays, stereo vision system is applied in many tasks, like in medicine used to remote surgery. This system improve surgical accuracy and enhance patient safety [6]. Also it is used in car industries to distance measurement and in lane departure warning [7, 8]. SVS is also used in automation tasks such as picking up, volume measurement and 3D location [9].

Recently, there is growing interested in stereo vision system in the underwater application[10]. This research focuses on these tasks [11, 12].In the next section, the, proposed methodology of this research consist of Implementation of Stereo Vision System using in the underwater area will be explained.

2. Methodology

2.1. Implementation Procedure

Camera calibration should be performed before the main steps of procedure, because lack of the calibration negatively affects the result. Intrinsic and extrinsic parameters are calculated via camera calibration process. These parameters are used in rectification section of the process. Image segmentation based on proposed technique is an important step that takes place after alignment of the images in which mathematical morphology process is divided into three parts which dilate the captured images, filling the interior gaps and smoothing the object using image eroding. Disparity calculation is the next step and it is not applicable unless the centroid of the image is calculated. In addition, Estimation of three dimensions is performed after disparity calculation. Figure 1 shows the implementation and the graphical representation of the proposed methodology of this research.

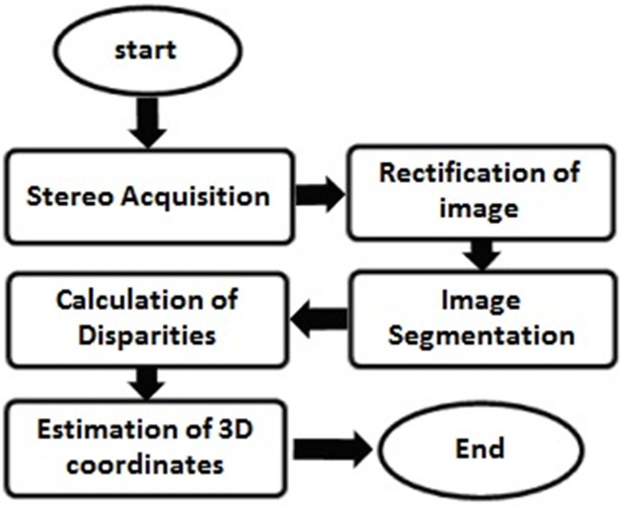

Fig. 1. *Implementation of Stereo Vision System.*

2.2. Range Estimation

Define abbreviations and acronyms the first time they are used in the text, even after they have been defined in the abstract Camera calibration should be performed before the main steps of procedure, because lack of the calibration negatively affects the result. Intrinsic and extrinsic parameters are calculated via camera calibration process. 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 gray scale. Alignment of the object in images in horizontal direction is performed after image acquisition. Image segmentation based on proposed technique is an important step that takes place after alignment of the images. Disparity calculation is the next step and it is not applicable unless the centroid of the image is calculated. Estimation of three dimensions is performed after disparity calculation.

2.3. Image Segmentation

Image segmentation in this research consists of three methods; Edge base segmentation, selection of the largest area, and mathematical morphology are put to gather to perform the image segmentation. Image segmentation starts after rectification process. The mathematical Centroid of the Centroid of the images will be calculated after the segmentation process. The following Equations (Equation 1 – Equation 2) calculate the centroid of the images.

$$\bar{x} = \frac{1}{A_t}\int_{Area} x dA \quad (1)$$

$$\bar{y} = \frac{1}{A_t}\int_{Area} y dA \quad (2)$$

Where

$\bar{x}$ and $\bar{y}$ are the centroids of the coordinates and A_t is the total area in the region

2.4. Disparity

Two corresponding points are different. These differences can be estimated easily with Equation 3 in the following section in order to set the primary condition for curve fitting tool.

$$d = \sqrt{(\bar{x}_l - \bar{x}_r)^2 - (\bar{y}_l - \bar{y}_r)^2} \quad (3)$$

where $\bar{x}_r$ and $\bar{y}_r$ are the location of the centroid coordinates of x and y in the right images $\bar{x}_l$ and $\bar{y}_l$ are the location of the centroid coordinates of x and y in the left images

3. Curve Fitting Tool Method

x and y locations of the object are given by the centroid coordinate which is obtained 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, estimate the value of input and output as x and y coordinate. The next step uses 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.

4. Accuracy and Result

The results of testing and experimenting the stereo camera estimation were performed in with and without water conditions in order to extract the functionality of the stereo vision system. As it is shown in Table 1 and 2, Triangulation method and Curve fitting tools were used to estimate the three dimensions of the object by conversion of the pixels to centimeters, comparing the results, calculation of the errors, and curve fitting tool method was chosen as an estimation method. Further, the overall error of using curve fitting tool is around 0.5 cm for with water condition where the overall error of using triangulation is around 2.2 cm in water condition, which is too much in range estimation. As a result, the overall result of CF TOOL method is as better method than triangulation method to range estimate of underwater object. All results were compared to the actual distance in order to compare the accuracy of the system.

5. Conclusion

In this research, two cameras (left and right) were used as stereo vision systems. The X and Y coordinates of objects were estimated from the centroid of the left image of the object, and Z coordinate was estimated based on disparity values of the images for the stereo vision system. Displacement of the image of the object is removed by image rectification process. Image segmentation was done successfully to remove noise such as reflection of light source in the image. The error of disparity was minimized after segmentation process. The average errors of the coordinates in triangulation method and the curve-fitting tool method were computed. Estimation of the coordinates was done in the clear water in constant light source. Different directions of the light source and transparency of the water or any liquid medium has a serious effect on the range estimation process in under water estimation. The better resolution of camera leads to better estimation. More accurate system is needed for range estimation in under water medium. The overall error of using curve fitting tool is around 0.5 cm for with water condition and the overall error of using triangulation is around 2.2 cm in water condition, which is too much in range estimation. Therefore curve fitting tool was found as a better method than triangulation.

Table 1. *All actual value is compared with estimated value based on curve fitting tool method and overall error.*

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	25.8498	15.8814	52.67242	0.3498	0.6814	0.460737
B	25.5	10.2	51.97172	25.9288	10.2162	52.32914	0.4288	0.0162	0.357417
C	25.5	5.2	52.21168	25.9563	4.6044	52.64927	0.4563	-0.5956	0.437594
D	20.5	15.2	51.43987	20.0094	15.7291	51.63429	-0.4906	0.5291	0.19442
E	20.5	10.2	51.19629	20.0262	10.1432	51.31566	-0.4738	-0.0568	0.11937
F	20.5	5.2	51.43987	20.1186	4.6799	51.62988	-0.3814	-0.5201	0.190007
G	15.5	15.2	51.14743	14.3149	15.652	51.3689	-1.1851	0.452	0.221472
H	15.5	10.2	50.90246	14.4172	10.0301	51.06366	-1.0828	-0.1699	0.161196
I	15.5	5.2	51.14743	14.5209	4.4921	51.38407	-0.9791	-0.7079	0.236644
J	10.5	15.2	51.34257	8.7255	15.5086	51.77032	-1.7745	0.3086	0.427752
K	10.5	10.2	51.09853	8.8451	9.8964	51.44146	-1.6549	-0.3036	0.34293
L	10.5	5.2	51.34257	9.0091	4.431	51.76183	-1.4909	-0.769	0.419264
				Average Absolute Error			0.89566667	0.42585	0.2974003
				Overall Absolute Error			0.539639		

Table 2. *All actual value is compared with estimated value based on triangulation method and overall error.*

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	49.09124	30.96504	17.54334	55.27075	5.465044	2.343342	3.120442
B	25.5	10.2	49.05853	31.04976	11.30957	54.86376	5.549759	1.109573	2.913193
C	25.5	5.2	48.53576	31.49011	5.193966	54.16003	5.990108	-0.00603	3.675922
D	20.5	15.2	48.8501	23.5425	17.49252	53.76199	3.042503	2.292515	2.589768
E	20.5	10.2	48.61474	23.71825	11.36891	52.9818	3.218253	1.168915	2.58155
F	20.5	5.2	48.23124	24.06879	5.324087	52.53922	3.568791	0.124087	3.208628
G	15.5	15.2	48.84299	16.36084	17.41036	53.4827	0.860836	2.210361	2.304437
H	15.5	10.2	48.32581	16.57077	11.33449	52.16016	1.070771	1.134491	2.576654
I	15.5	5.2	47.98111	16.92447	5.148887	51.79658	1.424471	-0.05111	3.166325
J	10.5	15.2	49.21604	9.201756	17.07302	54.61137	-1.29824	1.87302	2.126527
K	10.5	10.2	48.34413	9.450686	11.17816	52.57419	-1.04931	0.978165	2.754401
L	10.5	5.2	48.35048	9.704003	5.026008	52.90711	-0.796	-0.17399	2.992092
				Average Absolute Error			2.777841	1.122133	2.834162
				Overall Absolute Error			2.244712		

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