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Research Article

Feature-based Stereo Correspondence Algorithm for the Robotic Arm Applications

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Abstract

The three dimensional information about the workspace is indispensable for robot movement and object inspection in robotics and automation applications. Many of these applications rely on stereo correspondence algorithms to acquire the depth information of a scenery. Feature based algorithms gives faster results which involves the extraction of edges and corners. This work proposes a fast stereo matching algorithm that involves image segmentation, centroid computation and disparity mapping. Estimation of an object's range in this work is done using curve fit.

Keywords: *Stereo vision, disparity, feature based algorithm, centroid, curve fit.*

1. Introduction

There are a lot of industrial applications that requires the use of robot arm to assist in assembly operation as well as pick and place operation. Blind industrial robot can handle only the objects that are placed in fixed or predefined location and it just suitable for repetitive tasks. The visual information about the workspace can be used for guidance and planning of robot motion [Radhakrishnamurthy, *et al*, 2007]. Stereo vision tries to imitate the ability of the human brain to infer depth from a scene and consequently uses the same principle. Fig.1 shows the overview of stereo vision system.

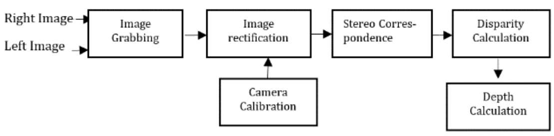

Fig.1 Overview of stereo vision system for depth perception

The system for calculating depth starts with grabbing the images. Stereo vision cameras capture left and right view of the scene under study. In other words two web cameras on top of the robot view the scene. Due to lens distortion and camera displacements the next step is to rectify the images in order to make use of the epipolar constraint. Therefore both cameras need to be calibrated first to get the camera parameters [Tsai, R. Y. 1986]. The knowledge of the camera parameters is used to rectify both images.
Rectification determines a transformation of each image plane such that pairs of conjugate epipolar lines become collinear and parallel to one of the image axes, usually the horizontal one [Fusiello, *et al*, 2000].To simplify the search process for corresponding points of a pair of stereo images, the image planes must be aligned exactly. Since in reality, it is hard to align two cameras with exactly aligned image planes, an image rectification process is required, which transfers the image planes of the two cameras to the same common plane. In simple only the one dimensional search is required instead of two dimensional search since there is no shift in the y direction for the case of rectified images.

Stereo correspondence aims to find the best matching pixels of two input images.Based on accuracy and efficiency, the matching algorithms can be grouped two main categories-local methods and global methods [Scharstein, D., *et al*, 2002]. Global methods are accurate but time and computational cost is higher due to their iterative nature.

Accuracy becomes main concern in applications such as precise 3D surface modelling, especially when dealing with object surfaces with complex reflectance behaviour and poor texture. Efficiency is important when the stereo system is employed in real-time applications such as robot navigation, video surveillance, and civil protection. Performance of stereo algorithms depends on the cost function used for the similarity measure.

Feature based algorithms gives faster results which involves the extraction of edges and corners. These algorithms find the correspondence between some feature

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points of the stereo image pair, and usually give sparse disparity maps.

The application of vision technology leads the robot navigation and the operation of robotic arms. J. Sanchez Antonio and M. Martinez Josk (2000] presented the programming robot-arm system for carrying out flexible pick and place behavior using visual perception. The system used an ultrasonic sensor to detect the distance, however, the accuracy of finding the distance by using an ultrasonic sensor is less compare to the stereo vision. Radhakrishnamurthy *et al*. (2007) had adopted the stereo vision for the bin picking application. The proposed bin picking process consists of object segmentation module and object localization module .In this work, the segmentation module not performed well as partial noise of the image is not removed. Bad segmented image will influence the accuracy of the image localization.

Eng Swee Kheng *et al*, [2011] describe the stereo vision system for robot arm guidance. The system utilizes the feature base stereo matching algorithms to solve the stereo correspondence problem. The curve-fitting tool is used to estimate the distances of the object

2. Stereo correspondence using image segmentation and curve fit

The stereo matching algorithm that involves image segmentation, centroid computation and disparity mapping have been discuss in this section. Image segmentation is done by using canny edge detection, disparity is obtained by finding the centroid coordinates of two images. The curve fit is used to obtain range estimation. The depth of the objects obtained can be used for the robot arm applications.

2.1 Image segmentation

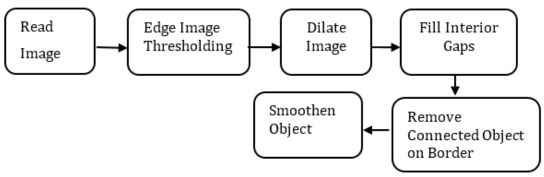


Fig.2 Image Segmentation

Main goal of image segmentation is to divide image into parts that have a strong correlation with objects or areas of the real world contained in the image. An object can be easily detected in an image if the object has sufficient contrast from the background. Canny edge detection and basic morphological operations-dilation, smoothening and erase has been applied to detect the object.Fig.2 shows the system over view.

2.2 Centroid Computation of the objects

After the segmentation of objects in the input stereo pair the 'x' and 'y' coordinates of centroid of the objects is to be computed. The centroid of objects are calculated using the following equations.

$$A_T\overline{x} = \int_{Area} x dA \qquad (1)$$

$$\overline{x} = \frac{1}{A_T}\int_{Area} x\, dA \qquad (2)$$

$$A_T\overline{y} = \int_{Area} y dA \qquad (3)$$

$$\overline{y} = \frac{1}{A_T}\int_{Area} y\, dA \qquad (4)$$

A_T is the total area of the segmented object and $\overline{x}$ and $\overline{y}$ are the centroid of the object.

2.3 Disparity

Disparity is the displacement of matching points from left image to right image. The difference between locations of the same object (identified by correlating left and right views) on the two images is called disparity. The disparity can be mathematically expressed as

$$d = \sqrt{(\overline{xl} - \overline{xr}\,)^2 + (\overline{yl} - \overline{yr}\,)^2} \qquad (5)$$

Where $\overline{xl}$ and $\overline{yl}$ are centroid coordinates for the x and y locations of the left image and $\overline{xr}$ and $\overline{yr}$ are centroid coordinates for the x and y location of the right image. The depth of objects can be obtained from this disparity.

2.4 Curve Fit

Estimation of an object's range in this work is done using fitting the curve in Matlab. The X axis represents the disparity value and in Y axis represents the depth value.

3. Experimental set up

For acquiring stereo images Nikon COOLPIX S3 100 cameras are used. Base line distance is kept 65 mm. Measure the actual distance from the camera to the object .A range of 15cm to 105cm is used for this set up. Artificial illumination is provided so that two views are taken at same illumination condition. Fig.3 shows left and right views of some sample input images taken.

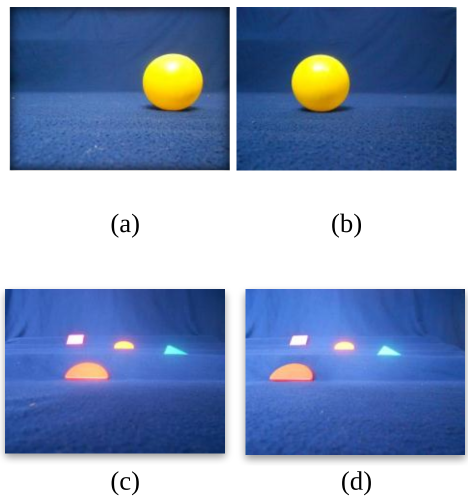


Fig.3 Input images used for Range estimation (a) & (c) Left views (b) & (d) Right views.

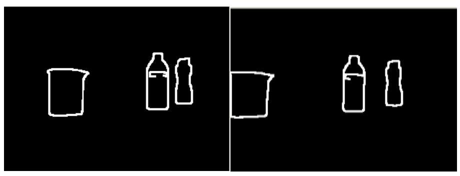
4. Steps for Depth calculation using image segmentation and curve fit

1. Read input images.
2. Edge detect using canny edge detection
3. Dilate 3 pixels to get clear edges.
4. Fill the gaps for any discontinuity to get closed boundary.
5. Clean and smooth the image using Gaussian filter.
6. Correlate the objects in left and right image, compute centroid.
7. Take difference between centroid to obtain disparity.
8. Plot estimated disparity vs. Actual depth measured using curve fit.
9. From this distance, objects placed within this curve range can be obtained.

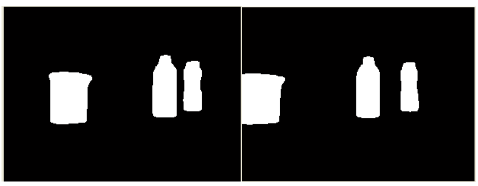
5. Results and Analysis

The colour images that are captured from the stereo cameras are converted to the grayscale. The Canny edge detector is used to obtain Segmented Object. Fig. 4 (a) & (b)shows input images, (c)&(d)edge images (e) &(f) segmented objects and (g) appearance of user interface.

(a) (b)



(c) (d)



(f) (g)

(g)

Fig.4 Input images used (a) Left image (b) Right image.(c) &(d) Edge images (e) & (f) Segmented objects.(g) User interface for range estimation using centroid computation.

Fig.5 shows the curve obtained using curve fit. From this, the depth of an object can be obtained.

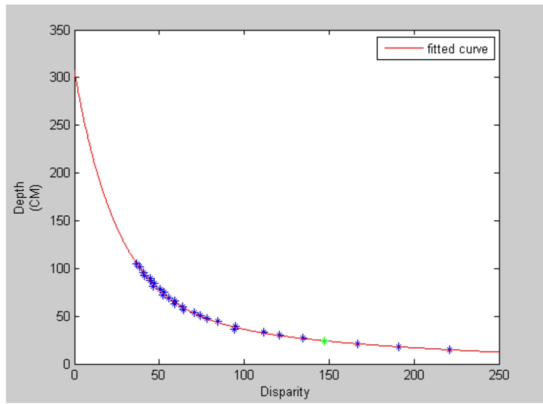


Fig. 5 Disparity vs Depth

5.1 Error analysis

Error between the computed depth d_C (x, y) and the actual depth d_T(x, y), is calculated as

$$E = |d_C(x,y) - d_T(x,y)|$$

Table.1 shows the error in the depth calculated.

Table 1.Error in depth calculated

Trial	Actual distance (cm)	Computed distance (cm)	Error (cm)	%Error
1	15	14.895	0.105	0.7
2	18	18.0462	0.0462	0.25
3	21	21.1926	0.1926	0.91
4	24	24.2345	0.2345	0.98
5	27	26.7236	0.2764	1.02
6	30	29.9086	0.0914	0.30
7	33	32.3288	0.6712	2.03
8	39	38.362	0.638	1.64
9	48	47.6672	0.3328	0.69
10	51	50.357	0.643	1.26
11	54	53.2635	0.7365	1.36
12	60	58.8671	1.1329	1.89
13	66	65.007	0.993	1.50
14	72	69.535	2.465	3.42
15	75	74.0869	0.9131	1.21
16	78	77.1436	0.8564	1.09
17	81	82.6183	1.6183	1.99
18	84	83.5691	0.4309	0.51
19	87	86.7254	0.2746	0.32
20	90	87.449	2.551	2.83
21	93	94.397	1.397	1.50
22	96	95.4485	0.5515	0.57
23	102	101.1414	0.8586	0.84
24	105	105.9703	0.9703	0.92

A maximum error of 3.42% is observed for distances within the range 15cm-105 cm. The main advantage of this algorithm is it requires little computational cost - it gives fast result. Estimated time requirement is around 1.45 seconds.

Conclusion and Future work

Stereo vision play an importance role in robotic pick and place application. The image segmentation process is done and the background and the correlated object in the image were separated. Further, the noise that occurs after edge image thresholding process has been removed by applying the basic morphological operation. The distances of objects from the camera were estimated by using curve fit method. Future work will include algorithm suitable for non-ideal lighting conditions and incorporating neural network for occlusion handling.

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