Object Segmentation under Varying Illumination Effects

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Abstract. Image segmentation is one of the medium levels of image processing. In this paper, illumination is the issue of segmenting various objects. This work proposed and evaluated two methods for image segmentation. First, we proposed region growing based method to find region that represented object of interest. Second, we proposed edge suppressing based method by the use of analyzing tensor. The experiment demonstrated that region growing method has limitation in image segmentation for object color variation. The system shows effectiveness of the method by implementing edge suppressing method in three different objects as foreground object, and four different objects as background object. Using edge suppressing, this system performed successfully under different illumination intensities.

Keywords: Segmentation, illumination, color, region growing, edge suppressing.

1 Introduction

Image processing plays an important role for industrial and service robot. In the areas of robot navigation, image processing has a main role in recognizing environments [6], [11]. Robust visual tracking are important in robotic application such as mobile robots [16]. A lot of works related to image processing was done in visual servoing for object tracking [5], [10]. However, object recognition and detection require a strong image segmentation [18]. Therefore, image segmentation plays an important role in image processing for object recognition and detection. [8] introduced color image segmentation using seed-fill algorithm based on YUV color space to recognize robot soccer. This method can quickly complete image recognition under condition of ensuring the accuracy. Image segmentation is a step of image processing to separate object of interest from the background. Many methods for image segmentation were proposed, such as threshold [4], [9], and edge detection [1], [13], [14]. Robot vision needs an excellent sensor to provide the information of the environment. However, variation in light illumination in environment can influence the image [17]. Therefore, the problem of image segmentation is the issue of illumination. Uneven illumination has impact on the image segmentation result. Top Hat transformation and watershed algorithm combine with homomorphic filtering can solve image segmentation with uneven illumination particle image problem. This filter works in frequency domain and Top-hat transformation can removes a large

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area of background. This method gives a satisfactory result and has some limit effects to the severe adhesion particle of image [19]. [12] proposed a segmentation method with two criteria: single point light source and general illumination condition for image segmentation undernear light source. [15] introduced Illumination Segmentation Model (ISM) to detect edge for non-zero autoregressive coefficient and perform segmentation. An image segmentation technique by analyzing shades and reflection of scene's object are able to separate novel object in complex environment under illumination at different wavelengths [3].

2 Design Method

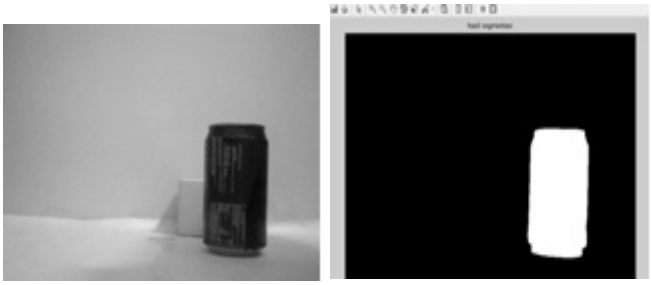
This paper focused on segmentation to separate object of interest from the background under different illumination intensities. We present two algorithms for image segmentation: region growing and edge suppressing. The proposed model started with image formation model. An imagecharacterized by two components, that are the amount of illumination incident $i(x, y)$ and$r(x, y)$ illumination reflectance [7], that is :

$$f(x, y) = i(x, y)r(x, y) \tag{1}$$

From (1), the condition of illumination reflectance affects pixel intensities of an image captured by a camera. Therefore, illumination plays an important role and this paper examined the effect of illumination with respect to the result of segmentation. Besides, the color of an object is the factor the image formed. Therefore, various objects were used for this experiment. This system consists of two main parts, image segmentation and image enhancement. The amount of illumination reflectance by an object was captured by a camera in image acquisition process and the computer received it as an input image. The computer process an input image with segmentation method to separate object of interest from the background. Region growing is one of the region based segmentation method, it starts from seed point $S(x, y)$ and expands itself into a region with the same characteristics until it finds a boundary to the adjacent region with different characteristics region. Region growing can give the information on a region that represents a point of an object H(*x,y*), based on homogeneity test, that is :

$$\mathrm{H}(x, y) = \mathrm{TRUE}, \text{if } |f(x, y) - S(x, y)| \leq T \tag{2}$$

Where H(*x,y*) can be obtained if the pixel intensities $f(x, y)$ is reduced by a seed value of less than or equal T as a threshold value. Image segmentation was implemented using region growing approach in two different objects with a contrast color as shown in Fig. 1. A blue can was used as a foreground object, and the other object as a background object. Using region growing, we can separate object of interest from the background as shown in Fig. 1. Further, the region growing method was tested on images with respect to object color variation.



(a) (b)

Fig. 1. (a) Original image contained a can as an object of interest and a yellow box as an object background (b) A can was separated from the background after segmentation process using region growing approach

(a) (b)

Fig. 2. (a) Original image before segmentation (b) Image segmentation result using region growing

Fig.2 shows respectively an original image and the corresponding experimental image segmentation result using region growing method for various colors of objects. Region growing method gave bad result of image segmentation against varying color object. Therefore, we proposed another method for image segmentation with edge suppressing. Edge suppressing proposed cross projection tensor derived from local edge structure in an image to suppress edge [2]. This method consists of two different images, those are image A and image B. Image A was captured as a foreground image consisted of an object of interest, and image B was captured as background image. Gradient of image convoluted with Gaussian kernel to produce smooth structure tensor G_σ is defined as:

$$G_\sigma = (\nabla \mathrm{I} \nabla I^T) * K_\sigma \tag{3}$$

Where $\nabla \mathrm{I} \nabla I^T$ denotes gradient of image at each pixel, gradient image transposed and K_σ denotes Gaussian kernel of variance sigma, that is:

$$K_\sigma = \frac{1}{2\pi\sigma^2} e^{-\frac{x^2+y^2}{2\sigma^2}} \tag{4}$$

Where x, y denotes pixel component in horizontal and vertical coordinate. Smooth structure tensor can be decomposed as:

$$G_\sigma = [\mathrm{v}_1 \quad \mathrm{v}_2]\begin{bmatrix}\lambda_1 & 0\\ 0 & \lambda_2\end{bmatrix}\begin{bmatrix}\mathrm{v}_1^T\\ \mathrm{v}_2^T\end{bmatrix} \tag{5}$$

Where λ and v are eigen value and eigen vector, respectively. The cross projection tensor $D^B$is obtained by the rules: if there is an edge in B ($\lambda_1^B > 0$), remove that edge by setting μ_1=0 μ_2= 1. By selecting eigen vector v and eigen value $\mu_1$and μ_2, then the projection tensor can be stated as :

$$D^{self} = [\mathrm{v}_1 \quad \mathrm{v}_2]\begin{bmatrix}0 & 0\\ 0 & 1\end{bmatrix}\begin{bmatrix}\mathrm{v}_1^T\\ \mathrm{v}_2^T\end{bmatrix} \tag{6}$$

$$u_1 = \mathrm{v}_1^B, \mathrm{u}_2 = \mathrm{v}_2^B \tag{7}$$

We removed edges by using affine transformation for gradient of image A with cross projection tensor D^B, that is :

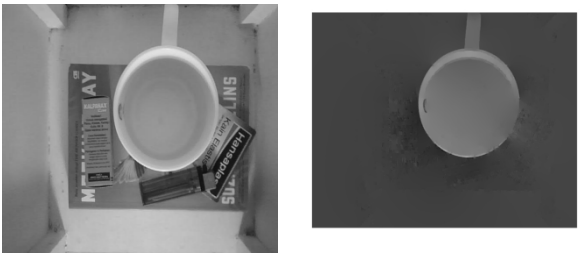
$$\nabla A' = D^B \cdot \nabla A \tag{8}$$

Reconstruction from $\nabla A'$ gives image A'as a result of this process. It contains an object of interest with free from the background.

3 Experimental Result

Having analyzed the study result mentioned previously, we implemented the system to several different illumination conditions and different objects. In the experiments, various images consisted of background object and object of interest were taken by using a web camera. We tested edge suppressing method under 12 illumination conditions with 10 lux until 1100 lux. The illumination was built using a light source (a lamp) located 27 cm from the scene. Background objects are represented by a book, an orange box, a lighter. In order to test the performance of the method, we executed the simulation programs with the use of MATLAB. Using edge suppressing, a mug as foreground object can be separated from background object shown in Fig. 3. Fig. 3 shows the corresponding segmentation result of the image a book as an object background is removed. Experiments are performed in complex condition as shown in Fig. 3 and give the successful percentage result in Fig. 8. The edge suppressing method is compared with canny edge detection method for image segmentation. Fig.6 shows that canny edge detection method failed to separate foreground object from background object. For the same illumination condition we used a mobile key (a security bank transaction device) for foreground object in Fig.4. Segmentation result in Fig. 4 shows error in boundary of mobile key as foreground object, because of color similarities between foreground object and background object.

The edge suppressing method was also evaluated on a long but thin object (a pen). Similar result of error was obtained in the boundary due to the color similarities between a pen and the corresponding background object in certain area as shown in Fig. 5.



(a) (b)

Fig. 3. (a) Original image before segmentation (b) Image segmentation result using edge suppressing

(a) (b)

Fig. 4. (a) Original image before segmentation (b) Image segmentation result edge suppressing

(a) (b)

Fig. 5. (a) Original image before segmentation (b) Image segmentation result edge suppressing

(a) (b)

Fig. 6. (a) Original image before segmentation (b) Image segmentation result canny edge

The segmentation successful rate is defined as follows,

$$\text{Successful rate} = (\text{sum of segmented pixels / total pixels that represent a perfect object image}) \times 100\ \% \quad (9)$$

We evaluated edge suppressing method in two different background objects condition. First condition used one object as background, while second condition used four different objects as background. Fig. 7 and Fig. 8 show the successful rate percentage of segmentation in different illumination intensities for various objects with different types of shapes. The segmentation was performed with a successful rate of higher than 90% in low to high illumination intensity (501 lux to 1100 lux) with a mug object as shown in Fig.7. This method gives an effective and consistent result under 801 lux to 1100 lux of intensity with a pen as foreground object as shown in Fig. 7. From the result of Fig.7, we consider the variation of color in mobile key under low light intensity effect segmentation. Edge suppressing method perform better in larger object as shown in Fig. 7 a mug has the highest successful rate. Foreground object which has similarity color with background object is treated as part of background and gives the mobile key successful result lower than mug.

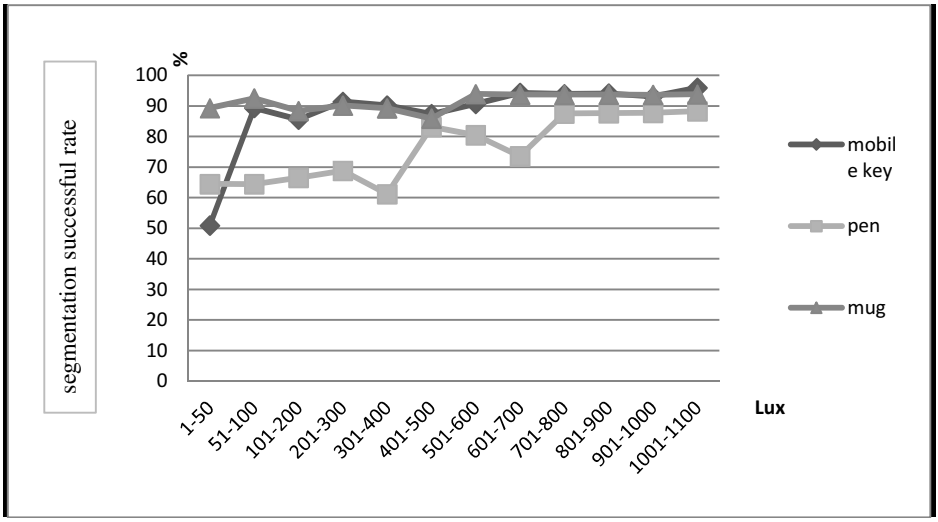


Fig. 7. Segmentation successful rate result using edge suppressing method in first condition

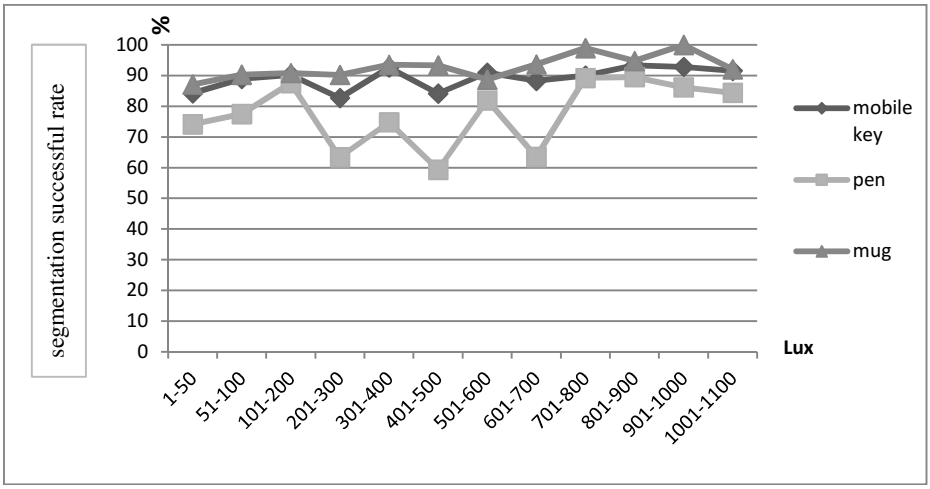


Fig. 8. Segmentation successful rate result using edge suppressing method in second condition

4 Conclusion

This paper presented image segmentation with problem issue in illumination effects. We introduce image segmentation method using region growing and edge suppressing techniques. Region growing and edge suppressing method were implemented in the

system under varying illumination condition for various color objects. The result shows that edge suppressing method reached a satisfactory result for three different object of interest with high illumination intensity (501 lux to 1100 lux) using edge suppressing method. In low illumination intensity (10 lux to 500 lux), segmentation gives the best result for an image as a mug as an object. With a pen object, segmentation was performed with a successful rate of higher than 60% in low illumination intensity (10 lux – 500 lux). The experiment using region growing method shows limitless for image segmentation in various color objects. For various objects condition, region growing method failed for object segmentation, while edge suppressing method give better result for segmentation. Based on the experiment result, edge suppressing technique can be applied for image segmentation in real condition under varying illumination. Edge suppressing method gives consistent result in high intensities (801 lux to 110 lux) for three various foreground objects. Potential application for object segmentation using edge suppressing method can be used for pick and place application for various types of parts to be selected.

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