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Toward Exposure Control for Robot Vision in Rapidly Changing Environment

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ABSTRACT

Simultaneous Localization and Mapping (SLAM) of the robot means to estimate the position of the robot using the sensors and generate the map. Laser, ultrasonic, and camera sensors are the typical sensor choice mainly used in SLAM application. When the wheel odometry is not available, robots heavily rely on visual odometry. However, the cameras are vulnerable to a light condition such as sunlight or illumination changes. Therefore, these disadvantages should be avoided via camera exposure adjustments. This paper introduces a simple and practical method for determining exposure time through image entropy information and demonstrates through experiments.

1. INTRODUCTION

Cameras are one of the most commonly used sensors when performing robot navigation or SLAM. The cameras are cheaper than radar and LiDAR sensors and are light enough to be easily applied to any robot platform. However, cameras are vulnerable to lighting and illumination changes. Thus exposure control is required to overcome these issues.

Camera exposure control has been researched for a long time in the field of computer vision. The built-in automatic exposure control function allows the camera to find the right exposure time. However, this function is limited in a sudden change environment or backlight. Because it finds the optimal exposure time through the average of the brightness, there is an over-saturated or an under-saturated region when the brightness difference in one image frame is severe. To solve this problem, [1] uses the exposure time using the weight function. In a typical camera, it is assumed that the main object is located in the center of the image. That is, after dividing the main object regions and the background regions, the exposure time is determined by setting the weight of the area differently.

In the field of robot vision, optimizing the camera exposure time was introduced [2] by

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examining the gradient domain for maximum features. A gradient-based image quality metric and show that it is robust in HDR environments by an extensive evaluation in different scenarios [3]. Moreover, they exploit the photometric response function of the camera to design their exposure control scheme.

The image histogram is widely accepted to capture the overall distribution of an image. A histogram of a specific image can be used to determine the overall intensity of an image distribution. An image gradient [4] is a directional change in the intensity or color in an image. Image gradients can be used to extract information from images. Entropy is a measure of the uncertainty of the condition or its average information content. In order words, entropy [5] (more specifically, Shannon entropy) is the expected value (mean) of the information contained in the image.

In this paper, we introduce a method of determining the exposure time with a lot of information in the image through image entropy.

2. Exposure control for robot vision

The relationship between the brightness level and the exposure time is shown in the following equation. EV is exposure value that controlled by exposure time, and Bl is brightness level of the image.

$$\mathrm{EV}_{\mathrm{n+1}} = \mathrm{EV}_{\mathrm{n}} + log_2 \, Bl_n - log_2 Bl_{n+1}$$

2.1 Image entropy

$$\mathrm{H(X)} = -\sum_{0}^{255} P(X_i)\log(P(X_i))$$

The continuous entropy equation indicates an image information. $f(x,y,t)$ represents the normalized brightness level of the pixel at position x,y after t times fine to course transformation.

$$H(f) = -\int_0^y \int_0^x f(x,y,t)\ln\big(f(x,y,t)\big)dxdy$$

2.2 Exposure control using image entropy

Bl_{n+1} is optimal brightness level of the image and we can find the exposure time with the maximum entropy value according to the image brightness level.

$$\Delta EV = ln\frac{Bl_n}{Bl_{n+1}}$$

3. Experiment

This experiment was performed in an indoor office environment with an illuminance of 735 [lux]. Our camera configuration is shown in Figure 1. One camera is auto exposure control mode and the other camera is exposure control by image entropy information.

Fig1. Camera configuration for exposure control

The results of the exposure control are shown in Fig 2. The exposure time computed by the automatic exposure control is 2800 [us], which shows that it contains the saturated region. On the other hands, the exposure time computed by the entropy is 2000 [us] to minimize the saturation region.

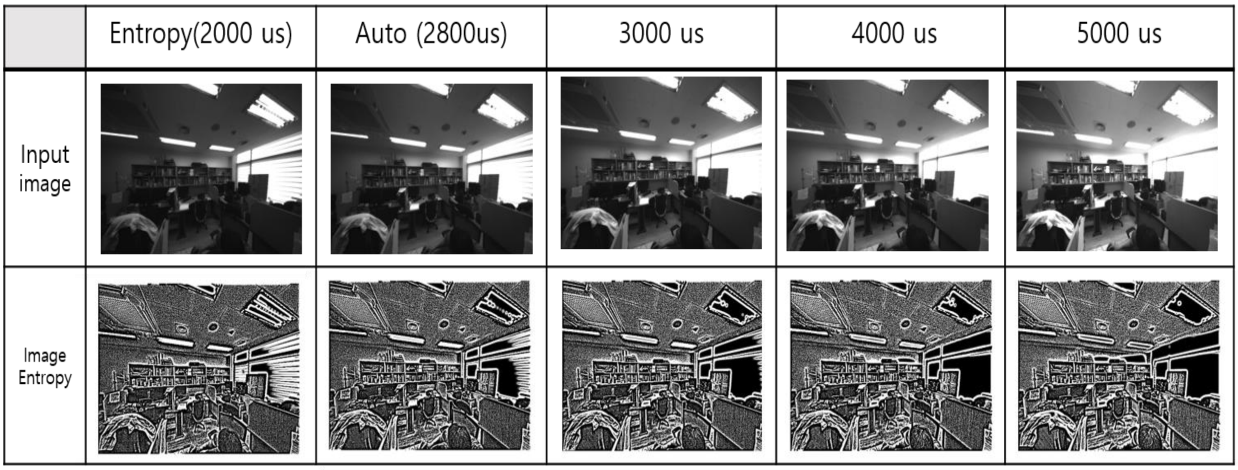

Fig2. Result of exposure control

4. CONCLUSIONS

In this paper, a method for determining optimal exposure time using entropy information is described. Experimental results show that the camera's automatic exposure control function is not suitable for robot vision. In other words, the image with the highest information in the robot vision is the best image. However, tracking the entropy information while changing the brightness value is inefficient. Therefore, it is necessary to determine the fastest exposure time through the correlation between the brightness level and the image information.

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