Auto-Exposure Control Method for a Stereo Camera Robust to Brightness Variation

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Abstract

This paper proposes an AE (Auto-Exposure) control method for stereo cameras. Image processing has a problem that it shows different performance depending on brightness values even with the same image processing algorithm. Auto-exposure control solves this problem by maintaining the brightness value of the acquired image. If preprocessing maintains the brightness value of the acquired image in a stereo camera, the performance of the image-processing algorithm becomes more stable. Traditional Auto-exposure control methods change the average brightness value of the image to attain the desired brightness value. However, this method is a disadvantageous in that it responds sensitively to exterior lighting sources and incurs low resource efficiency. The proposed method uses Gaussian sampling, with more sampling in the center region such that the sensitivity to light from exterior areas decreases and the resource efficiency improves. In experiments we confirmed that the performance of the proposed method is improved compared to that of existing methods.

Keywords: Auto-Exposure; Stereo Camera; Gaussian Sampling; AE; AEC

1. Introduction

Recently, various studies using Kinect sensors, a product of Microsoft, have been conducted. Many people are becoming interested in research and companies related to stereo cameras.

The Kinect sensor is a device that uses infrared patterns. However, one disadvantage is that it works only indoors. A stereo camera can utilize the disparity of observation spaces and the 3D shapes of objects through its imaging capabilities. For this reason, stereo cameras are used in vehicles and robots, particularly because they are feasible in outdoor environments [1].

Cameras are sensitive to light, and image-processing algorithms are highly influenced by the brightness of the acquired image.

Traditional methods respond sensitively to the light of exterior regions by means of brightness values of pixels for entire image regions. However, these methods are associated with unstable brightness information [2].

This paper proposes an auto-exposure control method for a stereo camera.

The proposed method a weight value using Gaussian sampling, which considers the stereo camera structure with an overlap region between different cameras.

The paper is organized as follows. Section 2 introduces the traditional auto-exposure method. Section 3 introduces the proposed method using Gaussian sampling considering the stereo camera structure. Section 4 compares the proposed method with the traditional method in experiments. Finally, Section 5 concludes the paper.

2. AE (Auto-Exposure) Control

Figure 1. Brightness of images according to the exposure time

The brightness of images according to the exposure time is shown in Figure 1. Even when images are obtained in the same environment, the brightness of the images depends on the exposure time. The brightness of an image increases with a longer exposure time and decreases with a shorter exposure time.

The performance of an image-processing algorithm such as one that processes detection and recognition steps is influenced by the brightness of the obtained images. Therefore, auto-exposure control technology that maintains the brightness value of an acquired image is desirable [3].

Figure 2. Auto-exposure control flow chart

As shown in Figure 2, auto-exposure control computes the brightness of captured images and compares the brightness value with a reference value. It then controls the next exposure time. By decreasing the exposure time when the brightness value is higher than the reference value or by increasing the exposure time when the brightness value is lower than the reference value, the brightness of the acquired image is held constant [4-5].

Figure 3. Pixel sampling method in another paper [6]

Figure 3 shows pixel sampling method in another paper. Usually average brightness of input image is computed by using the whole pixels of image. But in reference paper, average brightness is computed by using one pixel per 16 pixels for efficiency of little resource. As shown left in Figure 3, it uses one pixel of the 4 pixels in row and one pixel of the 4 pixels in column to compute average brightness.

Table in Figure 3 shows the computation results comparing to the one using whole pixels of image. As shown in the table, there are no big difference between using the whole pixels of image and using 1/16 sampling pixels [6].

3. Proposed Method

The traditional auto-exposure control methods have problems when applied to a stereo camera.

Figure 4. Stereo camera structure

A stereo camera matching algorithm finds a disparity value in the overlapping region of the obtained left and right images. However, as shown in Figure 4, a stereo camera has non-overlapping regions depending on the distance between the two cameras. When applying the auto-exposure control method to the entire region in the images obtained by a stereo camera, instability arises due to the brightness values of non-overlapping regions [7].

To mitigate the problems that arise when using the entire image region, this paper proposes a Gaussian sampling method [8]. Generally, main objects or regions of interest are positioned in the center of an image.

As shown in Figure 5, with more sampling of the center region and less sampling of exterior regions, the method becomes less sensitive to the brightness of the exterior regions.

Additionally, considering the structure of a stereo camera moving the center point of the Gaussian pattern can be expressed by equation (1), which represents the shifting of the center point with the non-overlapping region of images on the left and the right.

Figure 5. Gaussian sampling pattern

$$\begin{aligned} Center_{left} &= \frac{Width_{image} + Pixel_{baseline}}{2} \\ Center_{right} &= \frac{Width_{image} - Pixel_{baseline}}{2} \end{aligned} \quad (1)$$

Figure 6 shows the result after shifting the center of the Gaussian pattern considering the overlapping region.

The traditional auto-exposure control methods have problems that they compute improper average brightness values for they are sensitive to the brightness of the exterior areas of images. In additions, they compute improper average brightness values using the brightness value of non-overlapping regions of the stereo camera.

Figure 6. Result of Gaussian pattern shifting

4. Experimental Results

The paper compares the proposed method with existing methods to confirm the performance of the proposed method.

An experiment was done in an indoor condition that excluded light changes in order to compare the operating time and computed average brightness values of images.

Table 1 shows the compared results of the computed average brightness values. Comparing the proposed method with existing methods, the computed average brightness values are similar for the experiments done indoors, but the proposed method uses less pixel information.

Table 1. Average brightness comparison

VGA(640*480) sized images (obtained by a stereo camera)		
Methods	Total pixels	Average brightness
Whole pixels	614,400	90
1/16 sampling pixels	38,400	90
Proposed method	2,308	92

Figure 7. Brightness variation due to exterior light

Figure 7 shows the input images used in the experiment to compare the brightness stability. The images have various brightness levels due to the light from the exterior area. In the figure, (a) and (b) are images obtained in a dark outdoor environment; (c) and (d) are images obtained in a bright outdoor environment, and (b) and (d) are images captured with illuminating light in the exterior regions.

Figure 8 shows that the proposed Gaussian sampling method responds less sensitively than the whole pixels method according to a change in the exterior region. For (c) and (d), the brightness of the center region is high; therefore, the proposed method, which gives a higher weight to the center region, has a higher average brightness value than the whole pixels method. However, the difference in the computed brightness values for images (c) and (d) is less when using the proposed method, indicating that it is less sensitive to changes in exterior regions than the whole pixels method.

Figure 8. Influence of an exterior light source

Figure 9. Stereo camera attached to a vehicle

A performance test was done using a stereo camera attached to a vehicle, as shown in figure 9. Stereo camera is connected to the PC with Camlink cable, and proposed method was applied with real-time processing. We obtained images using the proposed AE and obtained images without using proposed AE, then compared the results of stereo matching algorithm using them.

Figure 10. Performance comparison with the stereo-matching algorithms

Figure 10 shows the results when applying the proposed AE method in an outdoor environment and using DP(Dynamic Programming) and NCC(Normalized Cross Correlation) in stereo matching algorithm. The figure shows that the results of stereo matching have fewer holes when using the images with the proposed AE applied than using the images without the proposed AE method applied.

5. Conclusions

In this paper, a method to improve the performance of a traditional AE method using Gaussian sampling is proposed. Comparing to the existing methods, the proposed method computes the brightness of images using fewer pixel images. Moreover, it is less sensitive to the brightness of exterior regions. It can also improve stereo matching algorithms in an outdoor environment. In this paper, the AE method is applied by connecting a PC and stereo camera with a Camlink cable. For further work, the algorithm will be implemented in an ASIC(Application Specific Integrated Circuit) in a hardware design or will be implemented in an ISP(Image Sensor Processor) of a CIS(CMOS Image Sensor).

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