

# HSV Color Space Based Lighting Detection for Brake Lamps of Daytime Vehicle Images

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**Abstract:** We propose a method for detecting the lit portion of brake lamps from rear images of vehicles. Its effectiveness was confirmed for 526 rear images. We used 526 Caltech Cars 2001 (Rear) images published by the California Institute of Technology as input images. These images were photographed in the daytime by the in-vehicle camera. The rear image of the car in front was captured. When the brake lamps were lit, the color was red, and the brightness was high. By determining this color from the image, the lighting of the brake lamps could be detected.

**Key words:** Brake lamp detection, autonomous vehicle, driving assistance, computer vision, image processing.

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## 1. Introduction

The number of traffic accidents occurring in Japan was 573,842 in 2014. Looking at traffic accidents by accident type, rear-end accidents account for about 40% of the total [1]. In order to prevent such accidents and reduce damage, automobiles capable of performing automatic braking and automatic driving are being developed [2]-[4]. It is important to detect the state of the vehicle in front to implement a mechanism that performs automatic braking and automatic driving.

The purpose of this research is to confirm the effectiveness of the method of detecting the lighting of the brake lamps of an automobile experimentally. By detecting the lighting of the brake lamps, it is possible to improve the precision of warning to the driver. When approaching the stopping vehicle ahead, automatic braking will help prevent rear-end accidents.

In this paper, we make the following contributions. First, we present a brake lamp lighting detection scheme for rear-facing traffic vehicle based on HSV color space and location conditions of brake lamp. Second, we show in experiments that the specified ranges in HSV color space are useful to extract lamp candidate portions for the rear car images dataset. Third, we show in experiment that the accuracy of brake lamp detection evaluated with the car rear image dataset is sufficient for the future driving assistant system.

## 2. Related Works

As color is a major characteristic of brake lamp lighting, it is used extensively in most brake lamp detection. The variety in color spaces is large. RGB color space is primary color space in which input images are represented [5]. The RGB information of images is usually translated to another color space for processing such as YCbCr color space [6],  $L^*a^*b^*$  [7] and HSV color space [8], [9]. HSV (hue, saturation,

value) is one alternative representation of the RGB color model, designed to more closely align with the way human vision perceives color-making attributes. There is no clear tendency toward the use of one particular color space, but color spaces such as HSV color space where color and intensity information is separate are clearly preferred.

Detection approaches can be categorized as either learning-based [10] or model-based. The model-based approach relies on heuristically determined models using geometrical shape and location. BLOB (i. e. connected component) analysis is applied in various degrees for calculating BLOB properties such as width, height, center coordinate, area, aspect ratio, etc. [7], [9], [11].

### 3. Lighting Detection Method

#### 3.1. Color Information

When the brake lamps light, the color is red, and the brightness is high. By determining this color from the image, the lighting of the brake lamps can be detected. To find a color from within an image, you need to specify the color as a number. As a method of expressing colors, there is a method of specifying H, S, V. H means hue, S means saturation, and V means brightness, which is closer to human senses and easier to set when expressing colors numerically. For this reason, in this research, the input image (RGB) is converted to an HSV image, and the lit portion of the brake lamps is detected [12], [13]. The color of the brake lamps is set as the hue H greater than 168 or less than 8, the saturation S greater than 100, and the brightness V 220 to 255.

The regions are segmented by color information. From a rear color image, pixels are extracted in the range of H, S, and V that correspond to the brake lamps lit. A binary image is constructed where white pixels correspond to the pixels of the color image within the ranges. From the binary image, connected components are extracted as candidate regions.

#### 3.2. Location of Brake Lamp

Brake lamps are commonly located on the left and right of the rear part of the car. The other central brake lamp is located at the center of the rear and at the high position. The central brake lamp is not the target of our method. For the outer two brake lamps, the height from the ground is almost equal. Utilizing this commonality, red signals and red signboards are not detected as brake lamps. Each pair of candidate regions is checked by the several assumptions about the geometry of brake lamps.

### 4. Experiment of Lighting Detection

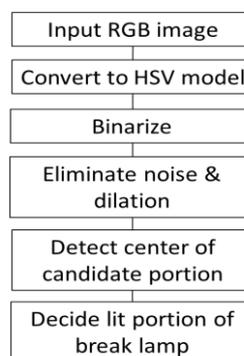


Fig. 1. Flow of lighting detection for brake lamp.

We use 526 Caltech Cars 2001 (Rear) images published by the California Institute of Technology as input images [14]. These images are daytime images photographed by the in-vehicle camera, and the rear part of

the car in front is captured. An experiment will be made to see whether detection of the lit portion of the brake lamps is possible from these images. Fig. 1 is a flowchart of the detection of the lit portion of the brake lamps. OpenCV 2.4.1 was used for image processing.

The input image shown in Fig. 2 is converted into the HSV image shown in Fig. 3. Binarization is performed as shown in Fig. 4 according to the above-described color of the lit portion of the brake lamps. Thereafter, noise elimination and dilation shown in Fig. 5 are performed. Then, the center coordinates of the white portions are detected, and it is judged whether they coincide with the arrangement feature at the time of lighting the brake lamps. When the difference is equal to or less than the threshold value (15 pixels), it is regarded as the lit portion of the brake lamps.



Fig. 2. Input image.



Fig. 3. HSV image.

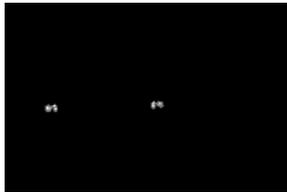


Fig. 4. Binary image.

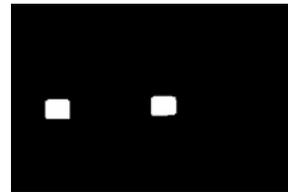


Fig. 5. Noise elimination and dilation.

## 5. Experimental Results of Lighting Detection for Brake Lamps

The number of successful detections for the lit portion of the brake lamps was 289 for 526 sample images on the rear of the car (357 for the number of times the brake lamps were lit and 169 for the images not lit). For the images in which the brake lamps were lit, 68 images were missed. In addition, 18 images were incorrectly detected when the brake lamps were not lit.

### 5.1. Success and Failure of Lighting Detection for Brake Lamps



(a) Success



(b) Success



(c) Success



(d) Failure (false negative)



(e) Failure (false negative)



(f) Failure (false positive)

Fig. 6. Example of detection result of brake lamps.

An example of successful detection (a) – (c) and failure (d) – (f) is shown in Fig. 6. The detected portions are indicated by double circles. Two detected brake lamps of outside rear body are shown by double circles. One brake lamp or traffic light sign is shown by single circle. Generally in binary classification, a false positive is an error in detecting in which a test result improperly indicates presence of brake lighting (the result is positive), when in reality it is not present. On the other hand, a false negative is an error in which a test result improperly indicates no presence of brake lighting (the result is negative), when in reality it is present. The examples of result (d) and (e) show the failure because of detection of single brake lamp. The example of failure (f) shows that a test result improperly indicated presence of brake lighting, when in reality the brake lamps were not lit.

## 5.2. Cause Analysis on Misdetection and False Detection

Dark brake lamps are the cause of misdetection when they are out of the range of the threshold value for brake lamp lighting detection as specified by the detection program.

As a cause of error detection, sunlight striking the brake lamps should be considered. This is because when the vehicle is hit by sunlight, the brake lamp portion becomes bright red, exceeding the threshold value for brake lamp lighting detection, resulting in false positive detection.

## 5.3. Precision and Recall Ratio

The relevance ratio is an index on accuracy. Precision rate = the number of correct answers of detection results / the number of detection results. In addition, recall rate is an index on coverage, Recall ratio = number of correct answers of detection result / number of correct answers.

Table 1 shows the number of experimental image samples. Table 2 shows the precision ratio and the recall rate of the experimental result of the brake lamp lighting detection.

Table 1. Number of Experimental Image Samples

|              |          | Predicted |          |        |
|--------------|----------|-----------|----------|--------|
|              |          | Positive  | Negative | Amount |
| Ground truth | Positive | 289       | 68       | 357    |
|              | Negative | 18        | 151      | 169    |
| Amount       |          | 307       | 219      | 526    |

Table 2. Precision and Recall

| Precision       | Recall          |
|-----------------|-----------------|
| 94.1% (289/307) | 81.0% (289/357) |

## 6. Conclusion

The effectiveness of our proposed method for detecting the lit portion of brake lamps from rear images of vehicles was confirmed for 526 rear images. Our proposed method is based on HSV color space and geometric location of brake lamps. The precision rate 94.1% and the recall rate 81.0% was obtained for Caltech dataset, Cars 2001 (Rear). As a cause of error detection, sunlight striking the brake lamps should be considered.

Future work will be done to improve the accuracy of detection. A driving lane detector would be useful, and it is necessary to cope with external factors such as sunlight. We would investigate how our algorithm would work under different illumination conditions such as day, night, cloudy day, and so no.

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