An Effective Method of Head lamp and Tail Lamp Recognition for Night Time Vehicle Detection

Hyun-Koo Kim, Sagong Kuk, MinKwan Kim, and Ho-Youl Jung

Abstract—This paper presents an effective method for detecting vehicles in front of the camera-assisted car during nighttime driving. The proposed method detects vehicles based on detecting vehicle headlights and taillights using techniques of image segmentation and clustering. First, to effectively extract spotlight of interest, a segmentation process based on automatic multi-level threshold method is applied on the road-scene images. Second, to spatial clustering vehicle of detecting lamps, a grouping process based on light tracking and locating vehicle lighting patterns. For simulation, we are implemented through Da-vinci 7437 DSP board with near infrared mono-camera and tested it in the urban and rural roads. Through the test, classification performances are above 97% of true positive rate evaluated on real-time environment. Our method also has good performance in the case of clear, fog and rain weather.

Keywords—Assistance Driving System, Multi-level Threshold Method, Near Infrared Mono Camera, Nighttime Vehicle Detection.

I. INTRODUCTION

MODERN automotive vehicles include a variety of different lamps to provide illumination under different operating conditions. Headlamps are typically controlled to alternately generate low beams and high beams. Low beams provide less illumination and are used at night to illuminate the forward path when other vehicles are present. High beams provide significantly more light and are use to illuminate the vehicle's forward path when other vehicles are not present.

There are various countries with regulations to control the amount of glare experienced by drivers due to preceding vehicles (other vehicles traveling in the same direction) and incoming vehicles (vehicles traveling in the opposite direction). These laws obligate to the vehicle manufacturers to build vehicles that comply with these regulations. In order to prevent drivers of other vehicles from being subjected to excessive flare levels an automatic control of the vehicle headlamps can be

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done. For a preceding vehicle, the distance by which the controlled vehicle's headlamps must be dimmed, can be less that for an oncoming vehicle since glare form behind is usually less disruptive than oncoming glare. In the last few years many researchers have studied the effects of oncoming headlamps glare [1]. An automatic headlamp dimmer system must sense both the head lights of the oncoming vehicles as well as the tail lights of preceding vehicles. Then, it has to distinguish between trouble light sources, such as reflections of road signs or road reflectors, streetlights, etc, from light sources that require headlight control to avoid an undesirable performance. Under night time driving conditions the more confident visual information for detecting vehicles are their head lights and tail lights. Some researchers have been working on the development of systems for nighttime vehicle detection and they are based mainly in the detection of head lights and tail lights [2].

In this paper, we propose an effective nighttime vehicle detection method for identifying vehicles by locating and analyzing their head lights and tail lights. This proposed method comprises of the following processing stages. First, a fast bright object segmentation process based on automatic multi-level histogram thresholding is performed to extract pixel of bright objects from the grabbed nighttime road-scene images. The advantage of this automatic multi-level thresholding approach is its robustness and adaptability for dealing with various illuminated conditions at night. Then these bright components are then grouped by a projection-based spatial clustering process to obtain potential pairing head lights of oncoming vehicles, and tail lights of preceding vehicles. Accordingly, a set of identification rules are applied on each group of bright objects to determine whether it represents an actual vehicle. Finally, the distance between each of the detected vehicles and the camera assisted vehicle is estimated and reported. Experimental results demonstrate that the proposed method is effective on vehicle detection in night time road environments. We are implemented through Da-vinci 7437 DSP board with near infrared mono-camera and tested it in the urban and rural roads. Through the test, classification performances are above 97% of true positive rate evaluated on real-time environment. Our method also has good performance in the case of clear, fog and rain weather.

II. SPOTLIGHT EXTRACTION

A. Spotlight detection

In computer vision and image processing, Otsu's method is used to automatically perform histogram shape-based image thresholding [3], or, the reduction of a gray level image to a binary image. The algorithm assumes that the image to be thresholded contains two classes of pixels (e.g. foreground and background) then calculates the optimum threshold separating those two classes so that their combined spread (intra-class variance) is minimal [4]. The extension of the original method to multi-level thresholding is referred to as the Multi Otsu method [5]. In this paper, luminosity of grabbed images through NIR (Near Infrared Red) filter segmented minimum four level to maximum six level. At that time, we obtain Maximum segment level used by K-means method [6]. And we select the top two levels of segmented image pixel values. And then, we remove result image through median filter. And, a labeling process based on eight element connected labeling method is applied on extracted spot lights [7].
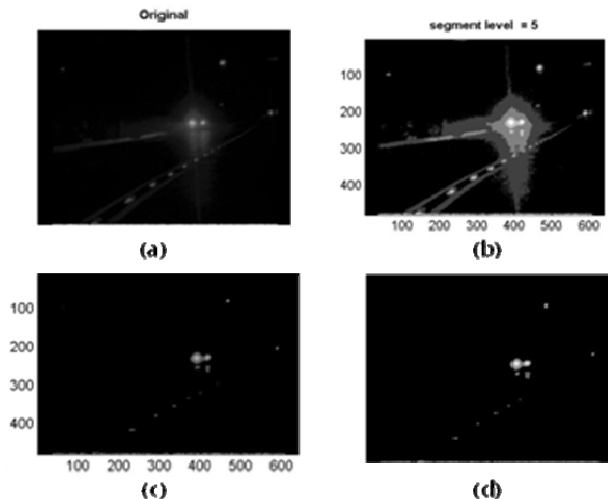

Fig. 1 Result of adaptive multi-level threshold method. (a) is original image, (b) is segment image of maximum five level, (c) is top two level image of (b) image, (d) removed noise image : result image
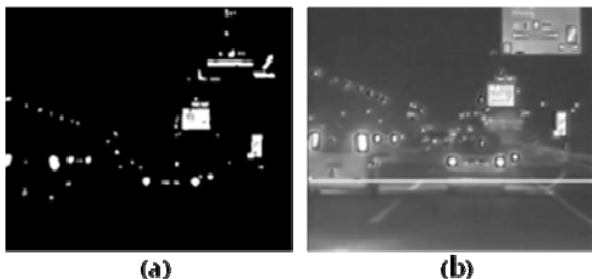

Fig. 2 Detect spot light. (a) is labeled binary image, (b) is result image of detected spot light.

B. Spotlight Tracking Method

Spot light tracking method has several functions. First, it has to temporal match spots over successive frames. This is necessary to adjust the confidence of a light. Once it has reached a sufficient level, the light is considered relevant. Secondly, tracking enables to analyze trajectory of moving spots. The trajectory enables to discriminate false detections and adjust the reaction time of the system. We use the well known Kalman Filter [8] to estimate the position (real coordinate of u, real coordinate of v) of spot at frame (t) time based on information collected on preceding frames. Then, a shortest path algorithm is used to match detections at (t) time with predicted ones at (t-1) time in finding the best global solution.

Fig. 3 Tracking spot light

III. SPATIAL CLUSTERING PROCESS

A. Spotlight Classifier Method

One of the most important problems of the system is to distinguish between vehicle's light and reflections of traffic signs and lane (main trouble light source). In this step, the detected bright objects are classified as signs or vehicles depending on some parameters using Support Vector Machines (SVM) [9]. Characteristic of traffic signs' reflectors have big distance motion vector and detected blob area is big. And, characteristic of lane's reflectors is same lane spot light are arranged and arranged vector value has big angle. Characteristic of general vehicle pair lights has small angle of between left lamp light and right lamp light and their angle has $-5°$ to $+5°$. And distance of vehicle pair lights between left light and right light is 0.9 m to 1.5 m.

An input vector was defined for the classifier. This vector is composed of different parameters which are computed per object and define the state vector fir the SVM. In this paper, using parameter vectors are follow:

- Area in spot light object
- Area of rectangle in spot light object
- Coordinate u of the object's centroid
- Coordinate v of the object's centroid
- Estimated Distance of the object's centroid
- Estimated Distance of each light object's centroid
- Angle value of each light object's centroid
- An input vector was defined for the classifier.

The output of SVM indicates whether the analyzed object corresponds to a vehicle or not and can be used as threshold for separating trouble light sources and vehicles. The classification between vehicles and reflector's lights it is more difficult at far distances. To solve this problem, in our paper, classifier method applied tracked light objects.

Fig. 4 Result of classified vehicle's pair lamp light. (a) one vehicle's lamp light classify, (b) many vehicles' lamp light classify.

B. Vehicle Position Estimation

The position of a vehicle is defined by its distance from the ego car and its vertical angle in the head lamp basis. The distance is necessary to adjust beam range and the vertical angle is necessary to adjust beam leveling. To calculate distance of pair light objects, we used to Inverse Perspective Mapping (IPM) transformation technique[10]. This method remove perspective effects and then remapping each pixel toward a different position and producing a new two-dimensional array of pixels.
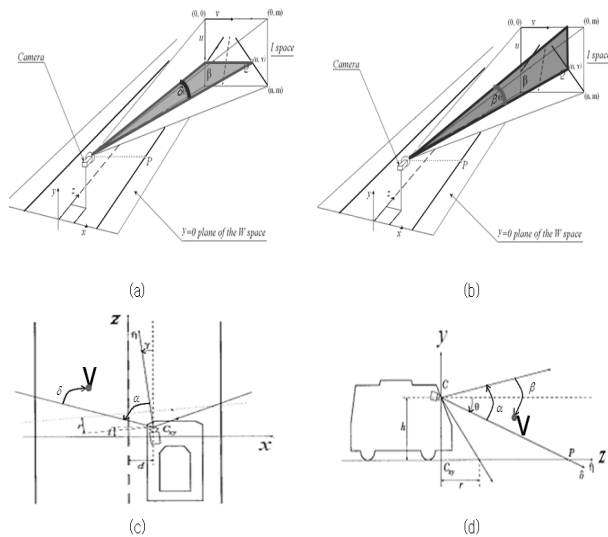

(a)   (b)

(c)   (d)

Fig. 5 Comparison of image space and world space.
(a) angle of v coordinates in the image space.
(b) angle of u coordinates in the image space.
(c) a horizontal fixed angle of camera sensor.
(d) a vertical fixed angle of camera sensor.

$$\frac{2\alpha}{m-1} = \frac{\delta}{v} \qquad \therefore \ \delta = \frac{2\alpha v}{m-1} \tag{1}$$

$$\frac{2\alpha}{n-1} = \frac{\beta}{u} \qquad \therefore \ \beta = \frac{2\alpha u}{n-1} \tag{2}$$

By using Eq (1) and (2), we obtain angle of u and v using a proportional expression. But when we calculate real angle (V_{rah}, V_{rav}) of object, we must consider camera aperture angle(α) and camera angular position (θ, γ). Angles of object (V) in the world space are given by Eq (3) and (4).

$$V_{rah} = \gamma + \alpha - \delta$$
$$= \gamma + \alpha - \frac{2\alpha v}{m-1} \tag{3}$$

$$V_{rav} = \theta - \alpha + \beta$$
$$= \theta - \alpha + \frac{2\alpha u}{n-1} \tag{4}$$

$$x = h \times \frac{\cos\left[(\gamma+\alpha) - v\frac{2\alpha}{m-1}\right]}{\tan\left[(\theta-\alpha) + u\frac{2\alpha}{n-1}\right]} + l,$$

$$z = h \times \frac{\sin\left[(\gamma+\alpha) - v\frac{2\alpha}{m-1}\right]}{\tan\left[(\theta-\alpha) + u\frac{2\alpha}{n-1}\right]} + d,$$

$$y = 0 \tag{5}$$

By using Eq (5), we obtain coordinates of world space angle. The results of this analysis can be seen in Fig. 6.
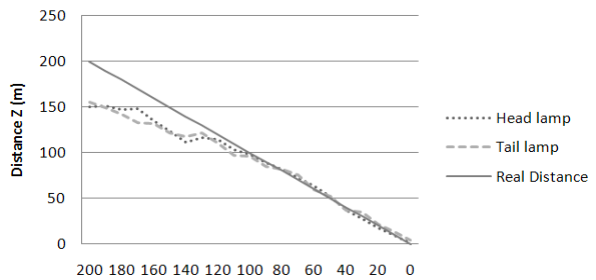

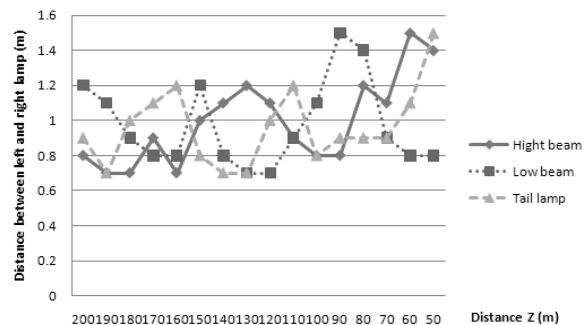Fig. 6 Distance estimation of vehicle pair lamps from 200 m to 0 m.

Fig. 7 Between Distance estimation of vehicle pair lamps.

IV. RESULTS

The proposed system is implemented on Da-vinci DSP 7437 board which is set up on our experimental camera-assisted vehicle. The frame rate of the vision system is 30 frames per second and the size of each frame of grabbed image sequences is 620 pixels by 480 pixels per frame. The proposed system gas been tested several videos of real nighttime rural and urban road-scenes under various conditions such as clear, fog and rain weather. Through the test, classification performances are above 97% of true positive rate evaluated on real-time environment.

V. CONCLUSIONS

This paper presents an effective method for detecting vehicles in front of the camera-assisted car during nighttime driving. The proposed method detects vehicles based on detecting vehicle headlights and taillights using techniques of image segmentation and clustering. To effectively extract spotlight of interest, a segmentation process based on automatic multi-level threshold method is applied on the road-scene images. To spatial clustering vehicle of detecting lamps, a grouping process based on light tracking and locating vehicle lighting patterns. For simulation, we are implemented through Da-vinci 7437 DSP board with near infrared mono-camera and tested it in the urban and rural roads. Our method also has good performance in the case of clear, fog and rain weather.

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