

Nighttime Vehicle Detection System Using Bio-Inspired Image Enhancement

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Abstract: In recent years detecting and recognizing vehicles at a nighttime has played an important role for surveillance applications, traffic control and autonomous driving. Detection of vehicles at nighttime is also a challenging research area in Intelligent Transportation System (ITS). Visibility is a major issue for safe driving at nighttime. As nighttime scenes have low contrast and luminosity, it is very challenging task to recognize vehicles. According to road accident survey majority of accidents are occurs due to rear end collision because taillights or brake lights of the vehicles are often very salient. At a nighttime the contrast between object and background in fact overall brightness is very low. Low brightness also causes poor feature description (size, shape, edges, and colors). Only salient features are visible in nighttime scenes such as headlight, taillights and beams, street lamps and traffic scenes with reflectors. Thus in nighttime vehicle detection the target object is the taillights of the vehicles. Nighttime vehicle detection has a great importance to solve the problems like variability in vehicle shapes, various illumination conditions and driving behaviour. This paper presents effective nighttime vehicle detection system using Bio-inspired image enhancement approach which is based on concept of retinal image processing that involves rod and cone photoreceptor cells. Rod cells are function in less intense light however cone cells are responsible for color vision. To extract the features of nighttime images the convolutional neural network (CNN), histogram of oriented gradient (HOG) and local binary pattern (LBP) is used. Accurate Region of Interest (ROI) is generated using taillights region of vehicles with object proposal methods. Accuracy of this system is based on the quality of input image.

Keywords: Bio-inspired images enhancement, Intelligent Transportation system (ITS), feature extraction, Region of interest (ROI), Vehicle-detection, Retinal Image Processing, Photoreceptor.

I. Introduction

Nowadays, accidents at a nighttime are increase in tremendous rate because of low visibility on roads at nighttime. The road transportation system plays crucial role not only for the society but also for the peoples by providing movements of goods and individuals and various social and economic services are easily accessible by these systems. Due to expansion of road network and motorization the challenges of facing adverse factors such as road accidents is increased. Nighttime vehicle identification is an important research area in advanced driver

assistance (ADAS) and automated driving system (ADS). About 30% of vehicular accidents are caused by rear end collision [1]. Therefore for implementation of safety features in vehicles, detection of the vehicle in night traffic scenes holds a great importance. This paper focus on detecting the vehicles in night traffic scenes, which are in front of driver to avoid rear end collision. Various state-of-art methods are available for detecting vehicles in daytime which can be knowledge based, motion based or appearance based. Different techniques for detection of vehicles are reviewed in [2]. However in nighttime traffic scenes contrast between the target object and entire background in fact overall brightness is low, so the features of the object such as edge, color, shape become unclear. For accurate detection of vehicle, before feature extraction the enhancement of the contrast, brightness and images is necessary. The retinal information processing mechanism of biological visual system is used to enhance night time images, which is effective approach for night time image enhancement. At the nighttime the moving vehicle often turn on the taillights which are the most salient. Taillights have some properties which are identified as:

- Amongst the brightest object in the image.
- Taillights are comes with pairs so close to each other.
- Taillights have same size, shape and also are symmetrical.
- Taillights are must be red in color.

The existing vehicle detection techniques in view of single features [3], [4] have been proved to be effective. However in any case, when managing more complex scenes, these kinds of detection strategies may prompt misclassifications. So there is the need of more effective approach which will improve the vehicle detection rate. To reduce road accidents at a nighttime and to improve luminosity, identification of vehicles in front of vehicle as well as approaching vehicles (travelling in the other direction than a host vehicle) is necessary. This paper focus on detection of vehicle, consisting of taillight segmentation, taillight pairing and tracking. The general methodology of proposed nighttime vehicle detection system is as shown in Fig. 1.

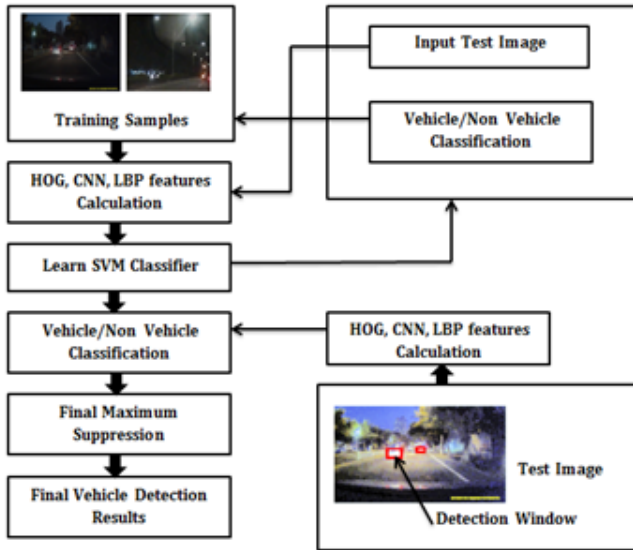


Figure 1. General Methodology

II. Related Work

A. Vehicle Detection

Nowadays nighttime vehicle detection is a vast area in research. It is valuable research in Advance Driver Assistance System (ADAS) as well as traffic surveillance system. Numerous research analysts have worked in this research area. In recent decades, automatic vehicle detection technique is a broad study area. Over the past decades, for road safety the technique of detecting vehicles based on vision have gained an increasing amount of attention. Mukhtar et al. [5] studied various comprehensive systematic methods of on-road vehicle detection based on vision and system of tracking for collision avoidance system (CASs). Their work is based on process of vehicle detection starting from selection of sensor in order to detect and track vehicle. Chen et al. proposed an effective system of traffic surveillance for moving vehicle detection and tracking in nighttime traffic scenes is proposed in [6]. The proposed method in [6], recognizes vehicles by detecting and locating headlights and taillights of the vehicles using pattern analysis and techniques of image segmentation. The vehicle detection and tracking system is introduced in [15].

B. Feature Extraction

Some of the vehicle detection methods uses feature extraction strategy that can represent attributes of the entire vehicles. An object detection system is discussed in [7] which is based on mixture of multiscale deformable part models. The feature extracted by the deformable part models (DPM) was considered as a variation of HOG for detection of objects. P. F. Felzenszwalb et al. [7] describes a system for object detection; using mixture of multiscale deformable part models, it represents highly variable objects. Razavian et al. [8] proposed a simple framework in which extracted CNN features were used to learn a detector using support vector machine (SVM) classifier and it is extremely viable and effective. Recently, each step of DPM was mapped to an equivalent CNN layer (deep pyramid DPM) [9]. Tehrani et al. [10] proposes a technique that optimizes the object structure in deformable part models using the idea of latent filters. Author [10] used IR camera to evaluate proposed method for detecting cars in urban areas at nighttime. Xueyun Chen et al.

in [11] proposed a method hybrid deep neural network (HDNN) to extract multi-scale features and as compared to traditional DNN for detection of vehicle, the proposed method [11] HDNN was more effective.

C. Image Enhancement in Nighttime Scenes

At a nighttime due to low contrast, luminosity and low brightness, detecting vehicle is a challenging task. K. Robert in [12] proposed a new framework for vehicle detection that is mainly depends on feature detection hierarchy and its fusion. Among these the features of the images are extracted in first layer of hierarchy; next layer is responsible to fuse features of the image to detect features of the vehicles such as headlights and the last layer fuses features of the vehicles. Wei Zhang et al. [13] proposed a novel approach for traffic surveillance at nighttime that involves detection, tracking and pairing of headlights. Author introduced two features for detecting headlights of the vehicle (1) reflection intensity map and (2) reflection suppressed map. For that they used Markov random field model for differentiating light pixels from reflection pixels. In [14] Hemanth Kumar B. K. et al. introduced a nighttime vehicle recognition using the taillights by image processing. Various vehicle detection techniques reviewed in [16].

III. Bio-Inspired Image Enhancement

The human eye and brain are biological systems that have capability to adapt, change, act like a sensor and they are very reliable processors that can be able to enhance, segment, register and recognize the vision or images that images are called as biologically inspired images and enhancement of those images is called as Bio-Inspired image enhancement. The bio-inspired image enhancement uses Retinal Image Processing which deals with the rod and cone photoreceptor cells of human eye [1]. Hulin Kuang et al. [1] proposed a novel bioinspired nighttime image enhancement approach. Fig.2. shows bio-inspired nighttime image enhancement.

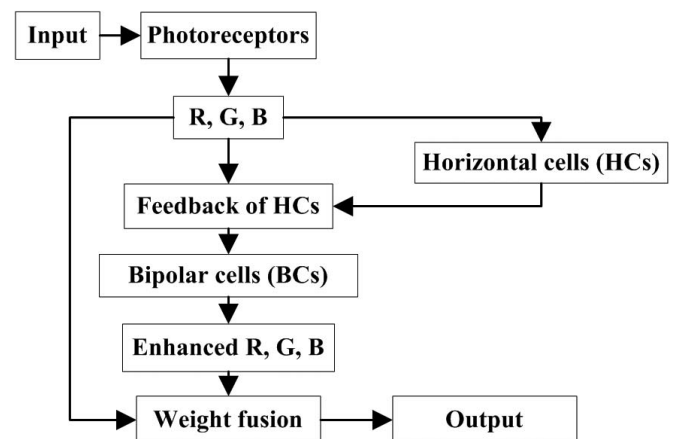


Figure 2. Bio-inspired nighttime image enhancement

IV. Mathematical Model

Let us assume,

$I = \{I_1, I_2, I_3 \dots I_m\}$ as the image dataset and

$N = \{v_1, v_2, v_3 \dots v_n\}$ Number of vehicles

- Input Test Image (I) = $\{I\}$

- **Image Enhancement Process** $(E) = \{I, P, C\}$
Where,
I = Input Image $\{I_1, I_2, I_3 \dots I_m\}$
P = Three types of cone photoreceptor Cells $\{p_1, p_2, p_3\}$
C = Contrast enhancement image $C = \{c_i\}$
- **Feature Extraction** $(F) = \{H_{value}, C_{value}, L_{value}\}$
Where,
Hvalue = Histogram value
Cvalue = CNN value
Lvalue = LBP value
- **Detection Process** $(D) =$
 $\{C, \{R_1, R_2 \dots R_n\}, f, \{(t_1, t_2), (t_3, t_4) \dots\}\}$
Where,
C = contrast image from image enhancement process
 $\{R_1, R_2 \dots R_n\}$ = set of ROIs
f = Filtered Image
 $\{(t_1, t_2), (t_3, t_4) \dots\}$ = detected taillights
- **Postprocessing** (P)
- **Output** $N' = \{v_1', v_2', v_3', \dots, v_n'\}$

Our System $S = \{I, E, F, D, P, N'\}$

V. System Architecture

There are two approaches for nighttime vehicle detection such as image based approach and sensor based approach. The most common approach is by using a camera to capture images in nighttime. This image sequence is then processed in order to detect presence of vehicle. Another approach to deal with this problem of temporary blindness is by using light intensity sensor and estimation of presence of vehicle based on intensity of light. Fig. 3. shows system architecture.

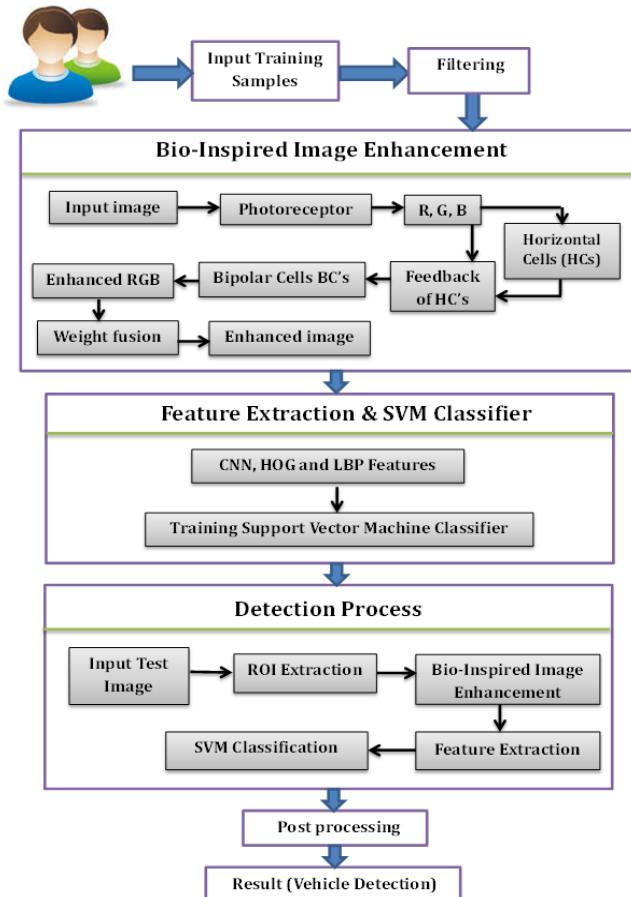


Figure 3. System Architecture

In this system, there are three main modules.

- 1) Bio-Inspired Image Enhancement
- 2) Feature Extraction and SVM Classification
- 3) Detection Process

Steps to be considered: The system consists of following steps.

1) Input Image: User inputs training samples from dataset.

2) Filtering: Filtering is a technique used to modify and enhancement of an image. Filtering is widely use to change the image appearance and some image parts by altering the shades and colors of pixels. It is used to increase contrast and brightness.

3) Bio-Inspired Image Enhancement: In Bio-Inspired nighttime image enhancement input frame is sampled into three types of cone photoreceptor cells. Given an input image $I(x; y)$, it is first sampled by three types of cone photoreceptors, that is, converted to R, G, and B channel images (i.e, $I_c(x, y)$, c_2 R,G,B) components of input image and are processed by long, medium and short wavelength cone photoreceptors [1]. Horizontal cells collect the three cone signals from the photoreceptor cells. Bipolar cells transmit signals from horizontal cell or photoreceptor cells to the ganglion cells and we get enhanced image.

4) Feature Extraction: The methods such as convolutional neural network (CNN), histogram of oriented gradient (HOG) and local binary pattern features (LBP) are included in feature extraction. Different attributes of vehicles are represented by these features and these features also demonstrate different accuracy for recognition of vehicle.

5) ROI Extraction and Speeded up ROI: Contrast enhancement of test image is performed for extraction Region of Interest (ROI). For this purpose, RGB image is converted into color intensity image as:

$$C_i = \frac{MAX(R,G,B)}{255}$$

For Speeding up ROI detection training overhead is minimize we propose to classify training ROI samples and using the centroid of each class as a training sample.

6) Classification: In the classification stage objects are classified between vehicles and non vehicles. For classification Support Vector Machines are used. By using feature vectors of positive and negative samples support vector machines are trained. To improve recognition accuracy, combination of scores of each feature along with their weights is performed. On the weight of each classifier, classification contribution is dependent.

VI. Algorithm

Nighttime Vehicle Detection Algorithm

Input: Input training samples from dataset $\{I_1, I_2 \dots I_n\}$

Output: Vehicle Identification $\{O\}$

Method:

- Analyze the form of training samples for valid inputs.
- Image enhancement process**
 - Select the one image from the dataset as a test image $\{I_1\}$
 - Three types of cone photoreceptors (Image) $\{C_1, C_2, C_3\}$
 - Bio-Inspired image enhancement step: It consists of contrast enhancement of image
- Feature Extraction process**
 - Extract Histogram (HOG) values as a set of $\{H_{v1}, H_{v2}, \dots, H_{vn}\}$
 - Extract Convolutional Neural Network (CNN) values as a set of $\{C_{v1}, C_{v2}, \dots, C_{vn}\}$
 - Extract Local Binary Pattern (LBP) values as a set of $\{L_{v1}, L_{v2}, \dots, L_{vn}\}$
- Detection process**
 - Extract the ROIs, as $\{R_1, R_2, \dots, R_n\}$ = set of ROIs
 - Filtered image $\{f\}$
 - Segmentation of taillights one by one as a set of $\{t_1, t_2, \dots, t_n\}$
- Apply Support Vector Machine (SVM) Classifier to classify the taillights
- Postprocessing
Vehicle Identification

VII. Experimental Setup

The experiments is conducted on a Laptop with Intel(R) Core (TM) i3 CPU M380 @2.53GHz 3GB RAM with Windows 7 operating system and MATLAB R2017a Tool. The total Elapsed time is 28.244608 seconds.

VIII. Results and Discussions

User input test image then it is converted into photoreceptor image and contrast enhancement of image is done using Bio-inspired image enhancement method. Fig. 4. shows test image, photoreceptor and image enhancement process.

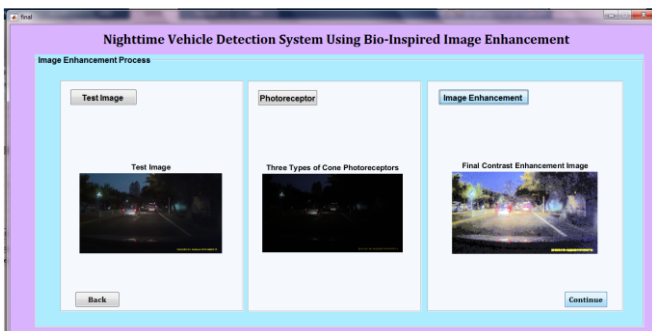


Figure 4. Test image, Photoreceptor, Image Enhancement

After image enhancement features are extracted using convolutional neural network (CNN), histogram oriented gradient (HOG) and local binary pattern (LBP) and SVM classifier is applied for the classification of vehicles and non vehicles. Fig.5. shows ROIs, Feature Extraction, SVM classification and final detection results.



Figure 5. ROI, Feature Extraction, SVM classification, Detection Results

A. Performance Evaluation:

Total number of samples = 40

$$DetectionRate = \frac{Correct\ Detections}{Ground\ Truths} \times 100 \quad (1)$$

$$FPPI = \frac{Total\ false\ detections}{Number\ of\ images} \quad (2)$$

$$MissRate = \frac{Total\ number\ of\ missed\ detections}{Number\ of\ image\ samples} \quad (3)$$

The experiment is conducted on 40 nighttime image samples for identification of vehicle and its taillights. It is seen that this method is able to detect presence of vehicle in most cases. However, false positives are observed based on complexity of night scenes. The correct detection of vehicle and false positives are shown in the figure below. Experimental analysis is shown in table 1. Detection rate for which is 95%, false positive per image is 0.2 and miss rate is 0.175

Total Samples(40)			
Ground Truths	Correct Detections	False Positives	Missed Detection
40	38	8	7

Table I. Test Results Table

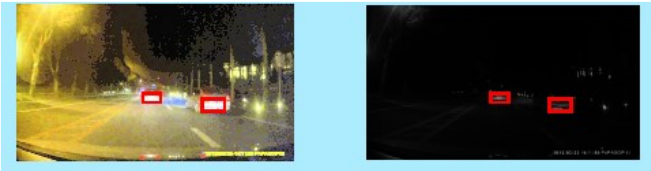


Figure 6. Correct Detection



Figure 7. False positives

A. Performance Graph:

Figure shows performance graph of the system which shows detected vehicles and number of vehicles

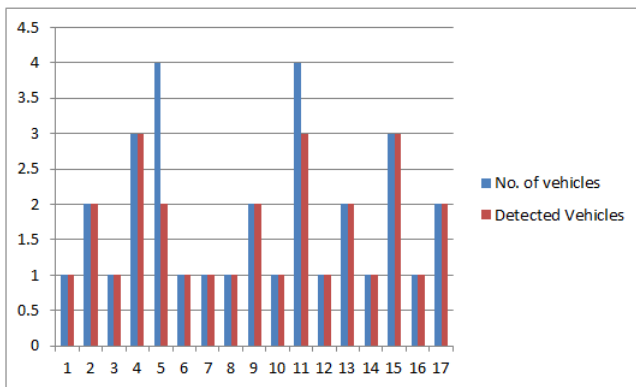


Figure 8. Number of vehicles and detected vehicles

IX. Conclusion

In this paper, nighttime vehicle detection system using bioinspired image enhancement is introduced. In this image is taken as a input from dataset, image preprocessing improves quality of the image by some image enhancement techniques nighttime image enhancement is done, then feature extraction strategies such as histogram of oriented gradient (HOG), convolutional neural network (CNN) and local binary pattern (LBP) are used to extract features. This technique proposes a nighttime vehicle detection method using bio-inspired image enhancement. This technique enhances the contrast and brightness preserving and improving object details. This novel approach hence contributing to better vehicle detection.

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