A COMPUTER VISION MODEL FOR VEHICLE DETECTION IN TRAFFIC SURVEILLANCE

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Abstract

Intelligent system for traffic surveillance and monitoring is increasingly a vital requirement for each and every urban city in the world. Existing automatic traffic surveillance systems are generally known to involve costly equipments with complicated operation procedures. Especially, the problem of video surveillance under nighttime condition is often neglected in those systems, which makes their performance vary largely between day and night time. In this current work we propose a robust nighttime traffic surveillance system which reuses the existing roadside cameras to capture traffic scenes, automatically analyse the traffic, and particularly focuses on the problem of nighttime traffic surveillance. The system consists of a preprocessing module, which is responsible for offline configuration for each specific traffic scene, and a traffic analyzing module, which deals with real-time detecting and tracking vehicles in that scene. The traffic information obtained from the system during the surveillance includes number of traffic lanes in the scenes, location of vehicles on the lanes and their traveling status. The developed system has been tested on many different nighttime traffic scenarios and proven to provide robust performance in both accuracy and processing speed.

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1. INTRODUCTION

Nighttime vehicle surveillance is always a complicated and uncertain area within any traffic surveillance system due to the weak illumination and headlights reflection on the ground. Moreover, the performance requirements are no longer left in prototype works at research labs but exposed to the real world problems. That demand makes the task of building such system high challenging, particularly in the requirements of speed and accuracy. There are some daytime traffic surveillance systems are built upon the motion detection methods to detect and track vehicles on high way. However, using the same approach to detect vehicles at night has never produced desirable results for research prototypes left alone meet the requirements for real world problems. These problems motivate us to approach nighttime Traffic Surveillance in a systematic methodology which integrates different advanced Computer Vision and Machine Learning techniques.

The first objective of this paper is to generate of set of useful traffic information for each particular location. The only input from the proposed system is the roadside camera normally installed at the traffic light. The expected traffic information includes the number of lanes in the traffic direction, the number of cars running on each lane, the status of each car (running at what speed or stopped for how long), and the travel route of the car (changing lane or not). The other main objective of this system is to guarantee the robust performance of the system, particularly the accuracy and the real-time processing speed.

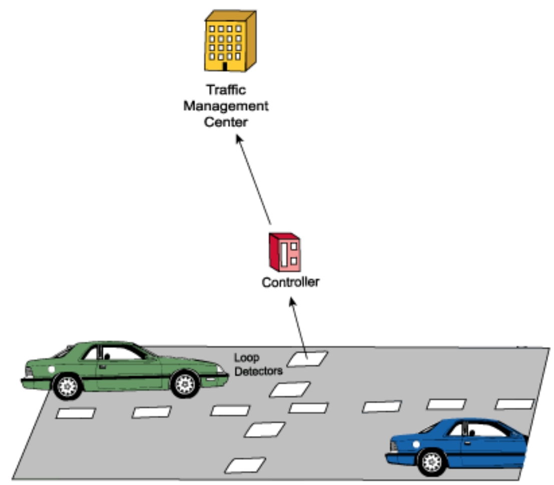
The rest of the paper is so organized that the Section II shares the existing work performed in this field, followed Section III explaining the usage of Computer Vision and image processing segmentation for vehicle head light detection and their by classifying the vehicle and Section IV discusses the simulation results of the experiments and finally the paper concludes.

2. LETERATURE SURVEY

The problem of detecting and tracking vehicle belongs to the field of traffic surveillance which is a subfield of Intelligent Transport System. Many systems and research proposals have been found and reviewed in order to derive the best solution for the initial objectives. The big picture is drawn starting from evaluating the aims and development stage of current Intelligent Transport System. Using a top down analysis, different methods of the Traffic Surveillance will first be reviewed and compared, then the specific approach of using computer vision in traffic surveillance as a non-intrusive methodology will be introduced. Lastly, different systems and literatures on two main streams of detecting and tracking vehicles at daytime and nighttime will be presented to reveal the possible approach for a robust nighttime traffic surveillance system.

Intelligent Transport System Known as one of the keys that help to create the future of the urban world ([1] [28]), Intelligent Transport System (ITS) really attracts many research groups in developing state-of-the-art theory and novel applications. The term Intelligent Transport System is used to define any system that applies Information and Communication Technology (ICT) into the development of transport infrastructure and vehicles ([28][26]).

Vehicle-based illustrates the characteristic of using some kind of devices installed in vehicles to locate its position using different methods of realizing and identifying. The three popular applications are Global Positioning System (GPS), Transponders, and Wireless Phones. Global Positioning Systems use earth-orbiting satellites to obtain the global map, and locate position of all vehicles with GPS box installed. The second approach using Transponders which are some kinds of vehicle tags that left inside the car and using synchronous data signal between the vehicles and the controllers on the transport infrastructure to recognize the occupation of the vehicle on the roads. The last method using Wireless Phones to send and receive traffic information from the Transportation Management Center (TMC) to notify the drivers about the neighboring traffic condition for efficient driving. All these methods are proven to produce high accuracy and fast data speed, but they all require vehicle owner to invest an initial capital to install one of those devices in their vehicles. That creates firstly a barrier for drivers with low budget, and second the privacy threats for those who do install one of those devices in their vehicles, since all the information is frequently and automatically sent to the database server [16].



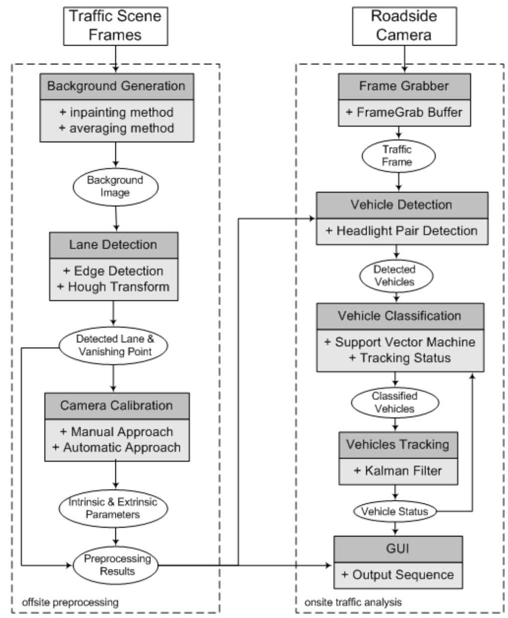
Among various emerging ICT fields, there exists a subfield called Computer Vision, which has existed for more than thirty years, but only recently that it is considered as a formal research area, thanks to the emergences of fast computer processors. The main objectives of Computer Vision are to learn ways of perceiving the world through graphical representation. Two main research areas of Computer Vision are in Robotics and Traffic Surveillance, where there normally exist some kinds of cameras that take the snapshot of the real world, and only by looking those images, there can be derived different information which is helpful to autonomously control an operation. Some famous applications of Computer Vision can be seen in face detection, image segmentation, 3D scene reconstruction, and general pattern recognition techniques. The employment of Computer Vision in traffic surveillance helps to reduce the implementation cost by reusing the roadside CCTV cameras installed on the road. In addition, by modeling the real traffic system, the information comprehensive to the machine includes all that are desirable for human purposes, for example, the position of the vehicles on the lanes, their speeding status, and their travel trajectory.

There have been around many systems developed by research groups in the world to tackle the problems of Vehicle Detection and Tracking. Some of the systems can be seen from the work of Wu et al. [41], Lin et al. [24], Song and Nevatia [35]. These systems make uses motion detection to recognize the vehicles as moving blobs and track those blobs for a number of subsequent frames. The applied methods normally include a hybrid approach of different algorithms like Linear Predictive Filter, Non-Parametric Model, Kalman Filter, or Mixture of Gaussians image B of the traffic scene, using either non-recursive or recursive generator [7], then for any frame image I, the decision to judge whether a pixel I(x, y) belongs to the foreground or not is based on its relationship to the corresponding pixel in the image. If the intensity of pixel I(x, y) is distinct enough from the background pixel B(x, y), it is said to be part of the moving foreground.

$$\frac{|I(x,y) - B(x,y) - \mu|}{\sigma} > T$$

3. PROPOSED SYSTEM

In order to fulfil the system initial objectives defined, the proposed system is divided into two main modules, offsite preprocessing and onsite analysis. The preprocessing module will be responsible for taking different images of a traffic scene to generate a set of information particularly useful and representative for that scene. The three interesting features of each traffic scene include the Background Image, the Lanes information, and the Camera parameters. Onsite traffic analysis module is organized into five main steps that take the input traffic video sequence, extract the image frame, and for each frame, detect the vehicles, classify them, track their status, and present results to a Graphical User Interface.



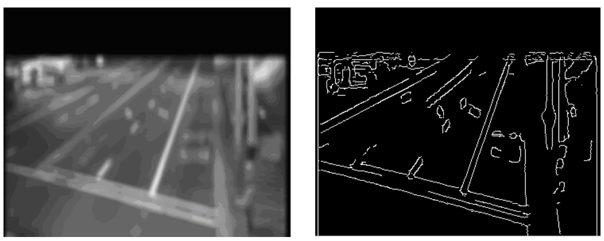
Preprocessing:

The approach of computer vision in traffic surveillance makes it simple and cost effective by only looking at two-dimensional images, there can be derived accurate analysis of the three-dimensional real world traffic scene. This approach, however, requires different mathematical computation to reveal the reveal the relationship between the 2D images with 3D world, this relationship is represented under the form of camera model intrinsic and extrinsic parameters, and are normally calculated during a process called Camera Calibration. The approach in calibrating camera directly on traffic road makes use of the available road lanes to calculate the vanishing point of the camera, as well as the stripe lane frequency to derive the ratio of the world and image distance on the traffic direction. The lane information is also useful for a traffic analysis system in judging the traffic flow and vehicle status on each lane. In order to carry out all these processes on the traffic scene, it is vital to carry out all the operations on an empty scene of the traffic location when there exists no vehicles in the image. This motivates to build up a separate module responsible for automatically generating a static background from a set of traffic scene images.

The nighttime framework from Pham and Vries [30] has implemented the Averagingmethod to get the background of the traffic scene, this method is the simplest and quickest way towards generating background image from a dynamic scenarios. The approach is to take the algorithmic mean of pixel intensity I(x, y) at the same location and put that into the background image B(x, y).

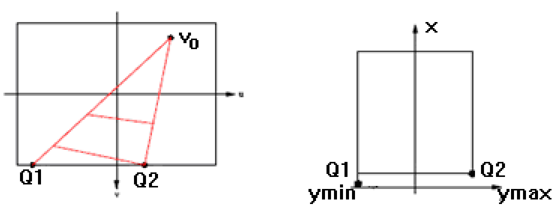
$$B(x,y) = \frac{1}{M}\sum_{i=1}^{M} I(x,y)$$

The importance of detecting lanes in traffic images has been mentioned in the beginning of this section, it is not only useful for displaying the vehicle status according to lane, but also important in the step of calibrating camera. The approach in detecting lane has been described in both Robert [33] as well as Pham and Vries [30], the system first tries to look for the lanes between the continuous lines, and then for each result lane, further operations will be applied to locate the stripe lines. The usefulness of these stripe lines are also mentioned in Camera Calibration section



$$u = f\frac{a_{12}x + a_{22}y + a32(z+h)}{a_{11}x + a_{21}y + a31(z+h)}$$

$$v = f\frac{a_{13}x + a_{23}y + a33(z+h)}{a_{11}x + a_{21}y + a31(z+h)}$$



By using three main values, namely the vanishing point, horizontal and vertical ratios, important camera parameters like focal length, pan, and tilt angles have been calculated and used to build a data structure for camera configuration. This data structure includes the lanes of interest11, the relative headlight radius and headlight distance lookup table (relationship between vertical coordinate of headlight pair distance).

Vehicle headlight detection

The main difference between vehicle headlights and other elements in the images of night traffic is that all headlights have greater intensity in grayscale level. That observation helps to make the decision of first converting the image into grayscale, and then using the brightness threshold to distinguish headlights with other background objects. The resulting blobs are then used to build the binary image in which only pixels with bright colour values exist. The result image still contains a lot of noise pixels, so two image processing operations of white top hat transformation and close have been applied to eliminate all those distracting pixels

Using the results obtained from the camera calibration steps to find the appropriate size of headlights, those white blobs that match the criteria will be considered as positions headlights on the vehicles, and the center weight of the blob will be recorded as the headlight position with a corresponding size. A structure of centre coordinates and radius of a headlight will be used as a representation for that headlight.

Vehicle headlight pair matching

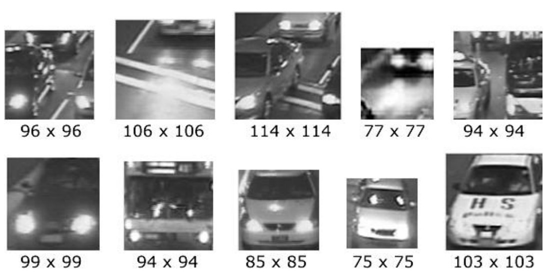
Once again, the result from camera calibration method has been used to find the appropriate headlight distance based on the vertical distance of a headlight from the top of the image.

A vehicle at night is defined by V = (P1, P2), where P1 and P2 are the two headlights with a certain distance | = f(Ph) away from each other, Ph is the vertical coordinate of each headlight in the 2-dimensional image coordination. This evaluation is carried on the left and right of every possible headlight to find its match. The returned headlight pairs are those vehicle candidates and there is a necessity for an addition classification step to verify the validity of those candidates.

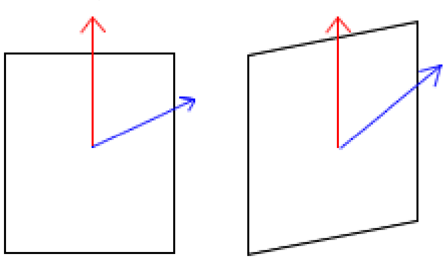
Vehicle Classification

The use of Principal Components Analysis (PCA) in reducing dimensions and extract featured parts of objects was first proposed by Kirby and Sirovich [21]. A concept called eigenpicture was defined to indicate the eigenfunctions of the covariance matrix of a set of face images. Following up this approach, Turk and Pentland [37] has developed an automated system using eigenfaces with the similar concept to classify images in four different categories, which help to recognize true/false positive of faces and build new set of image models.

Vehicle detection and classification have been done in different ways. Gupte et al. [13] used both object segmentation using background subtraction and tracking updates to identify vehicle positions in different scene. However, it was purely based on appearance based so the shadows are required to be removed before the actual classification, this makes it nearly impossible to be applied into night time traffic where shadow, reflection and illumination are always present. Nighttime vehicle detection was dealt with in Cucchiara work [11] on day and night vehicle detection. They use geometrical characteristic difference of headlight positions to distinguish between true and false positive of headlight positions. Though it is a good approach using feature extraction and treat night time scene differently from day time, there is no verification for those mere geometry difference.



Component Analysis



Eigenvector of a transformation

The covariance matrix of the input data is calculated starting from the algorithmic mean of all the vectors I1, I2, ... Im

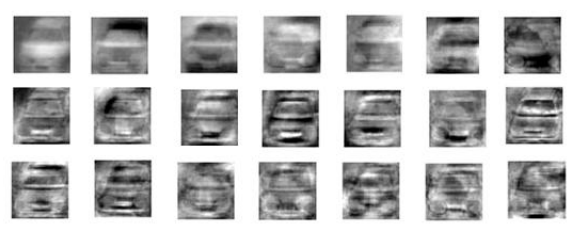
$$\Psi = \frac{1}{M}\sum_{i=1}^{M} I_i$$

$$\Phi_i = I_i - \Psi$$

$$C = \frac{1}{M}\sum_{i=1}^{M} \Phi_i \Phi_i^T$$

$$\lambda_k = \frac{1}{M}\sum_{i=1}^{M} (u_k^T \Phi_i^T)^2$$

The collection of M eigenvectors i can be seen as the reduced dimension representation of the original input data (with size N2) when M N2 This set of M eigenvectors will have a corresponding eigenvalue associated with it, with indicates the distribution of this eigenvector in representing the whole dataset. Many papers have shown that, only a small set of the eigenvectors with top eigenvalues is enough to build up the whole image characteristic. In our system, we keep P top eigenvectors, P represents the number of important features from the vehicle eigenspace, and form the vehicle eigenspace " (M rows, P columns).



Eigen Vehicless

4. SIMULATION RESULTS

In our experiment, numbers of vehicle and non-vehicle images are kept unchanged or changed very little, fold number for cross validation also kept constant since its change does not affect prediction rate much. Threshold ' for updating false positive also remains constant at values of 30 for our experiment, it is demonstrated from our experiment that the necessary number of updates for the same traffic monitoring scene is only about 10 for this threshold value, and after that very little update is required.

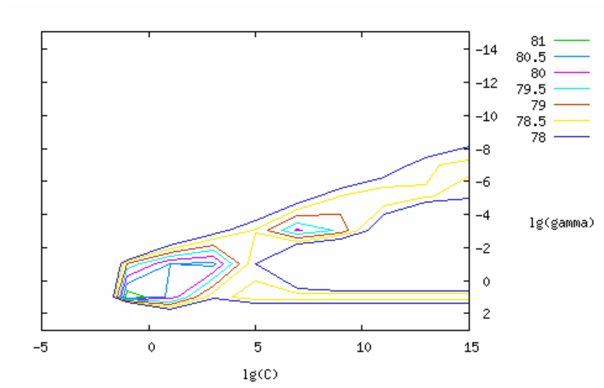


Table 5.3: Variable Analysis

Run	1	2	3	4	5	6	7	8
N	20	20	20	20	40	40	40	40
P	10	30	50	70	10	30	50	70
$t_{tr}(ms)$	1684	2305	2864	3225	4500	5132	5454	5763
$t_{pr}(\mu s)$	96	98	103	107	294	299	314	325
$t_c(s)$	5.639	5.762	6.037	6.614	17.321	17.798	18.378	19.22
$r_c(\%)$	2.35	2.401	2.515	2.756	7.217	7.416	7.658	8.008
U	23610	23560	23485	26521	23645	23562	23546	24012
U_f	3780	2457	2029	1419	2936	1649	871	864
V	35130	35234	35129	35294	35269	35964	34983	35127
V_f	3465	3175	3011	2951	1913	1935	1539	1539
$a_p(\%)$	83.99	89.571	91.36	94.65	87.583	93.001	96.301	96.402
$a_n(\%)$	90.137	90.989	91.429	91.639	94.576	94.62	95.601	95.619
$a(\%)$	87.666	90.421	91.401	92.931	91.769	93.979	95.882	95.937

Vehicle Detection From a Traffic Scene

5. CONCLUSION

A Computer Vision For nighttime traffic surveillance system has been developed which meets the initial objectives defined. The system is capable of producing the average accuracy of more than 90% with running speed of about 80% of hard realtime rate. Several problems in existing Traffic Surveillance systems described, like headlight reflections on the ground and occluded vehicles have been successfully solved in this system. Furthermore, the information obtained from this system is rich in variety and useful for any future monitoring system. Lastly, the approach of this system makes it simple and cost effective for the next deployment stage into the urban transportation infrastructure In addition to practical outcomes, there are many research ideas have been proposed, evaluated and implemented during the project. There is one conference paper has been submitted based on the outcome of this project in classifying vehicles using Eigenspaces and Support Vector Machine, and the proposed novel approach1 in calibrating camera using moving vehicle detection and Principle Component Analysis is also potential for another publication in the short term.

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