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Review of Traffic Density Analysis Techniques

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Abstract: Congestion in traffic is a serious problem nowadays. From city roads to highways, a lot of traffic problems occur everywhere in today's world. Bad traffic management leads to wastage of lot of man hours. These frequent traffic problems like traffic jams have lead to the rise of the need for an efficient traffic management method. Current traffic control techniques involving magnetic loop detectors buried inside the road, infra-red and radar sensors [2] on the side provide limited traffic information and require separate systems for traffic counting and for traffic surveillance. In contrast, video based systems offer many advantages compared t existing technologies [1][2][3]. There can be many reasons for bursty traffic like insufficient capacity, unrestrained demands, large red light delays etc. This paper summarizes a review on various methods for developing an intelligent traffic detection algorithm based on different research papers referred. It also shows a review on different methods under image processing for developing an intelligent traffic system. Various methods on this topic have been explored on this topic like, intelligent traffic controller using real time image processing[1]-[13], using DSP and NIOS II [20], using embedded system[16] [19]and using wireless sensor network [14][15]. Various authors use different techniques like detecting the subsequent numbers of vehicles detected from the video captured using the cameras installed at the lanes or using live feed from cameras at traffic junction for real time traffic density calculation using image and video processing or making use of wireless sensors to sense presence of traffic on roads. Comparison and survey of all these methods is shown in this paper which concluded that use of image processing makes analysis of traffic comparatively efficient. Reasons proving the same are discussed in paper below.

Keywords: Traffic density analysis, image and video processing, reduced traffic congestion, traffic management, digital image processing.

I. INTRODUCTION

Traffic congestion has become a significant problem in recent years. The main reason behind it is the increase in the population in large cities and respective increase in number of vehicles. The traffic jams not only affect the human routine lives but also lead to a rise in the cost of transportation. Therefore an automated traffic system is required to manage the traffic congestion problem smoothly. This paper reviews different techniques of traffic density calculation and development of intelligent traffic systems. Some of the algorithms discuss about calculation of traffic density on roads in real time environment using image processing techniques. Few other techniques also discuss methods other than image processing for the same purpose like use of sensors, embedded systems, microcontrollers etc All the techniques based on image processing make use of cameras installed at the traffic junctions to capture live videos of the road conditions. Frames are captured form those videos and further processed to acquire the traffic density count on a particular lane at a particular instance of time. All the five methods can be summed up into four general modules – Image acquisition, Preprocessing, Density calculation and Traffic control.

Image acquisition is same in all methods. The density calculation algorithms differ. One of the methods makes use of morphological operations like erosion and dilation and motion detection [1]. Another method makes use of background subtraction, canny edge detection and Moore neighborhood algorithm for vehicle count [2]. One of the authors proposes an algorithm for density calculation rather than counting number of vehicles [3]. Another method [4] makes use of two techniques combined together: gradient magnitude and direct subtraction for density calculation. And the last method [5] makes use of canny edge detection and gradient based detection for detecting edges of vehicles and then gets the count of vehicles by comparing reference and real images.

The rest of the paper is organized as follows. Section II discusses the review of the existing technologies for vehicle density calculation. The III section gives the comparative study of all the image processing based algorithms and their implementation. Section IV describes the merits and demerits of those algorithms. Lastly, Section V provides the results of the comparison.

II. RELATED WORK

Current traffic control techniques involve the use of techniques like magnetic loop detectors buried under road or infra red radar sensors. Inductive loop detectors provide a cost effective method but they have a high failure rate and they obstruct traffic during repair. On the other hand, infrared sensors are affected to a large extent by fog as compared to cameras. One of the methods reviewed in the paper suggests implementation of traffic light and congestion control system for day light sequences using image processing and sends information of congestion to the road side unit using Zigbee protocol

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[4]. Image Processing Based Intelligent Traffic Controller System proposes a design to favor advancement in traffic control technologies along with the emergency vehicles detection system using the most effective canny edge detection algorithm and Radio frequency identification (RFID)[2].

Some methods [12] also propose to make use of a wireless sensor network for intelligent traffic routing. This concept is based on using sensors and a transmitter.

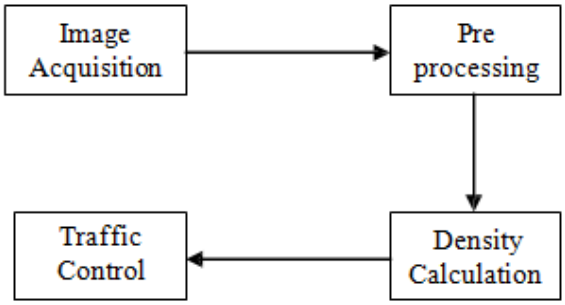

FIGURE I. BASIC ARCHITECTURE OF SYSTEM FOR TRAFFIC DENSITY CALCULATION

Another method proposes the development of VANETs (Vehicular Ad Hoc Networks), which are the quintessential of the new types of networks emerging in the wireless technologies [6]. The salient features of VANETs are to provide communication between vehicles themselves and between vehicles and road side units. But this method suffers from a limitation that to implement VANET the appropriate hardware has to be installed on every vehicle which can be comparatively difficult to install in a two-wheeler. Similarly, another method presented a new model for intelligent traffic systems which will encapsulate the features of surveillance via the cameras present on the junction and with the help of data delivery systems let the users access that data. Image Analysis and foreground/background modeling schemes would be the important elements of Surveillance [7].

Other than this, another author provides a design of an integrated intelligent system for management and controlling traffic lights with the help of Photoelectric Sensors [8]. Real time traffic control system makes use of morphological operations to calculate traffic density at the roads and then uses fuzzy logic controller for the traffic flow [9]. A lot of authors [11] [3] [4] [5] [12] propose to use the density calculated for controlling Traffic lights switching automatically. These systems propose that if the traffic density is high the time duration for traffic lights to be kept on is also high and vice versa. Some methods also propose different vehicle detection techniques for day and night time conditions [13].

Review of all the existing methods show that use of image processing overcomes many of the disadvantages of other existing algorithms.

The next section now provides a comparative study of few of these algorithms with a brief about implementation.

III. COMPARITIVE STUDY OF THE IMAGE PROCESSING ALGORITHMS

Image processing is any form of signal processing for which the input is an image, such as a photograph or video frame; the output of image processing may be either an image or a set of characteristics or parameters related to the image. Most image-processing techniques involve treating the image as a two-dimensional signal and applying standard signal- processing techniques to it. The picture of a road can be represented as digital data i.e. binary data but it needs to be processed before using so as to extract relevant information from it. This is to be done because when the image is captured from natural environment, the image is raw and unformatted. Therefore operations like image enhancement, edge enhancement, brightening etc are used.

A common architecture of the system for traffic density calculation can be as follows-

- Image acquisition
- Preprocessing
- Density calculation
- Traffic control

All the techniques reviewed in this paper follow the same common architecture. So a comparison of all the techniques can be made based on these four modules.

1. Image acquisition

All the methods discussed in this paper make use of cameras for image acquisition. A camera is installed at any of the tall structures like polls at the traffic junctions so that it can capture the overlook of the traffic scene on the road. Frames of images are then extracted from the video captured by the camera. These frames are then analyzed and preprocessed to detect and count the vehicles present or the vehicle density.

2. Preprocessing

Preprocessing is done to get a clear image. Since the images are extracted from real time video frames the images can be distorted or blurred or dark etc. like images can be blurred when the weather is foggy or rainy. Similarly, images can be darker when captured at night time conditions or can be too bright when it's very sunny (like in afternoon).Therefore different preprocessing methods are applied on the images to improve the quality of the image, according to the objective of the user. In static background subtraction method the images captured are first converted into grayscale. Later the grayscale is converted into binary. After that erosion and dilation are applied according to requirement for a clearer image [1]. On the other hand, in Canny edge detection method first the image is converted to grayscale and then every frame is applied with background subtraction for object detection [2].

In a self proposed algorithm in [3] first the image is converted to grayscale and then further processed for density calculation. Another method involving dual technique combination proposes to use grayscale

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conversion along with background subtraction to detect foreground objects on a fixed background [4]. In the gradient based image enhancement method [5] [11] the author makes use of gamma correction for image enhancement.

Preprocessing plays an important role as the images are captured from the live videos so they can be affected by the surrounding conditions of the road. The images can be blurred, distorted, very bright or very dark etc. So preprocessing helps to improve the quality of the image that further helps in better analysis of the image and traffic density calculation also. Following figures show some preprocessing outputs:

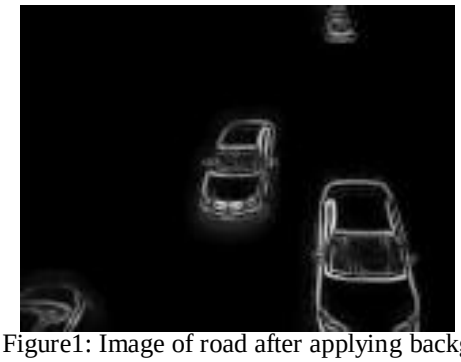

Figure1: Image of road after applying background subtraction and wiener filter [4]

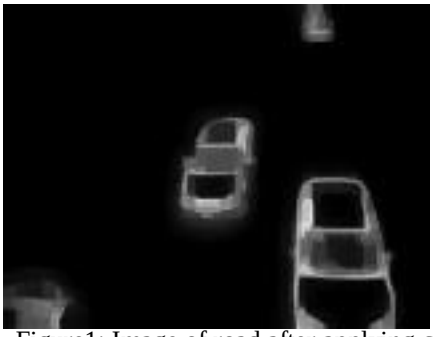

Figure1: Image of road after applying closing operation [4]

3. Density calculation/Vehicle count

In the background subtraction technique [1] a combination of motion detection and vehicle detection is used. For motion detection, analysis of two consecutive frames is taken into account, in which the histogram of key region parts of the frames is analyzed. The histogram is then compared with the determined threshold. A constraint stated with this method is that the key region should be at least 3-pixel wide profile of the image along the road.

The difference between these profiles then shows the displacement or motion of the object. For vehicle detection,the image of the road is divided into subparts. Then background subtraction technique is used.

In the Canny edge detection method [2] an adaptive background subtraction is used. After that, canny edge detection method is applied for edge detection of the vehicle which will detect all the edges of the vehicles present in the image. Canny edge detector may prove to be effective as it considers all neighborhood pixels while detecting edges. For object detection, Moore neighborhood algorithm is used along with the Jacob's criterion.

This method is supposed to give better results as compared to static background subtraction. In another self proposed method [3] the author has proposed to calculate the density of vehicle traffic rather than calculation the number of vehicles. This means, for instance, the vehicle density of a truck could be equivalent to two medium sized cars. This method proposes to be better than counting number of vehicles.

The reason is that, counting number of vehicles may be a problem when image has different types of vehicles, like car, bicycle etc.

TABLE I. COMPARISON OF ALL THE METHODS

Methods	Image Acquisit	Preprocessi	Density Calculation
Background Subtraction technique	Uses cameras	Grayscale conversion, Binary conversion, Erosion, Dilation	Motion detection using Consecutive frame comparison based on histogram key region and Vehicle detection using background
Canny Edge Detection Technique	Uses cameras	Grayscale conversion, Background subtraction	Canny edge detection for vehicle edge detection, Moore neighborhood algorithm for object count
Self proposed algorithm by author	Uses cameras	Grayscale conversion	Self proposed algorithm and formula for vehicle density calculation (mentioned in the paper [3])
Dual method technique	Uses cameras	Grayscale conversion	using a combination of gradient magnitude and direct subtraction techniques to detect vehicles
Gradient Method	Uses cameras	Grayscale conversion, gamma correctio	using canny edge detector and gradient based edge detection

But calculating density of each vehicle will consider all types of vehicles in traffic.

The author also proposed a formula for the same [3] –

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C = h*no. of rows in subtracted image*no. of columns in subtracted image*no. of frames per second

Where,h =height of camera from road

In the Dual method technique [4] the author uses a combination of gradient magnitude and direct subtraction techniques to detect vehicles present on the lanes. The reason for using these two techniques simultaneously is that each of them overcomes the disadvantage of the other. In direct subtraction method color of vehicle can be problematic in finding density.
This problem is resolved using gradient magnitude. While in gradient magnitude method, there can be situations where detected edges may not form closed contour. This problem is resolved using direct subtraction. In the Gradient method technique [5] the author proposes to use edge detection for making vehicle count. Edge detection in this method is done using canny edge detector and gradient based edge detection.

According to the review done, the self proposed method [3] gives the most explanatory and proving results as compared to all other methods discussed in this paper.

4. Traffic control
The calculation of vehicle count/density is utilized for further traffic control for different purposes in different methods. In the first method, the vehicle count is used to develop an android app that will give the user details about the traffic jam conditions at any particular location. In the second method, the density calculation helped in automatic traffic lights switching for better traffic management. It contributed to a special feature, i.e. detection of presence of emergency vehicle on the lane. When this happens, then that lane is given preference over others and the traffic lights are switched accordingly.

Similarly, in the third, fourth and fifth method the traffic density/traffic count calculation helps in automatic switching of traffic signals, based on the number of vehicles present at any particular lane at any instance of time.

The comparison of these algorithms shows that vehicle density calculation can be achieved with the help of various algorithms. Table I briefs the whole comparison of the five methods discussed.

IV. ADVANTAGES & DISADVANTAGES

All the algorithms reviewed in this paper are based on the use of image processing techniques for calculating the traffic density present at a particular road, at any instance of time.
As it can be seen from the discussion in previous section, all the methods have some similarities and some dissimilarity also. Each method poses some advantage and some disadvantage at the same time.
These advantages and disadvantages are briefed up as follows in the Table II below-

TABLE II. ADVANTAGES AND DISADVANTAGES OF ALL IMAGE PROCESSING BASED METHODS

Method	Advantage	Disadvantage
Background Subtraction technique	Cost effective, Scalability	No solution for robustness to occlusion, Not practically implemented, No hard results of performance
Canny Edge Detection technique	Cost effective, Scalability, Improved vehicle detection efficiency	No solution for robustness to occlusion, Time consuming, Not consistent with changing environment
Self proposed algorithm by author	Less installation cost, Less maintenance cost, Improved efficiency in traffic control and vehicle detection	Results get affected during low light conditions like after sunset
Dual Method Technique	Less installation cost, system considers situations of occlusion	The proposed method seems to be complex, Does not work well in low light conditions
Gradient method	Cost effective, method proposed seems simple, makes use of canny edge detector which is quiet efficient	Proposed system does not apply for night time, image matching for vehicle count does not seem to be very efficient

V. CONCLUSION

Automatic traffic density estimation and traffic control through image processing plays an important role for traffic management in mega cities. Traffic congestion is becoming a serious issue. There are many reasons for traffic congestion situations like inefficient transport management, incomplete information regarding traffic etc. Traditional traffic density estimation methods such as radars, loop sensors, ultrasonic waves etc. have some limitations like high cost, sensitivity to external environmental conditions, lighting conditions etc. The algorithms discussed in this paper show some advantages as well disadvantages at the same time. The advantages that all the five image processing based methods show are low hardware cost, scalability, dynamic background subtraction etc. On the other hand they also show some disadvantages like ineffective results during Night time conditions, no solution posed for occlusion problem etc. The review on the above discussed algorithms for

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estimating traffic density at a particular time on a particular lane shows that accuracy of vehicle detection using image processing techniques can be increased to further extent by introducing changes in the algorithms discussed. Like in background subtraction method [1] dynamic background subtraction can be introduced for better results. Similarly in Canny edge detection method [2] solutions for occlusion problem can be introduced for more accurate results. In the self proposed algorithm [3] and Dual method technique [4] solutions for performing the density calculation in night time conditions also. Another change that can be done is making use of thermal cameras in place of simple cameras for image acquisition purpose. Since thermal cameras work on change in temperature so it will help to exclude the parked vehicles on the road to be counted in road traffic density. Another problem that exists is night time traffic analysis. This can be solved by using infrared cameras for night time view. The main problems faced in preprocessing are removal of noise and unwanted background. For this adaptive dynamic background subtraction and edge detection can be useful. In some cases morphological operations can also help to get the complete information of the vehicle shapes. For object counting, Canny edge detector has proved to be the most efficient according to the literature survey done as it is not susceptible to noise interference and it also detects true weak edges [17] [18].Introducing such changes can help getting better results and thus making image processing better method for traffic density calculation than any other method.

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