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A Traffic Monitoring System for a Mixed Traffic Flow Via Road Estimation and Analysis

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Abstract—**A Traffic Monitoring System (TMS) is the most important element in the Intelligent Transportation Systems (ITS), especially in a developing country like Vietnam with a mixed traffic flow of vehicles including motocycles and cars. A traffic flow varies in different daytime, therefore the adoption of the TMS for an adaptive control of the traffic light timing is very essential. The proposed TMS system uses one CCD camera mounted to view from the rear of moving vehicles appearing in a distance from a viewed span of the camera to the stopline of the cross-roads, which is denoted by *L* and statistically determined. The timing of the traffic light can be adaptively adjusted according to the estimated traffic flow which is based on the video sequence captured by the camera in its span on the road, where the gaps between the vehicles are used to determine the density of vehicles appearing in the camera span. This method enables to implement a simple but efficient traffic flow control especially in crossroad context compared to other convenient methods.**

Keywords—traffic monitoring; traffic light control; roadways

I. INTRODUCTION

So far, the estimation of transport flow solely based on the determination of the number of vehicles passing through a road section at a time and set up the corresponding timing of the traffic signals. In developing countries like Vietnam with a mixed flow of vehicles including motorcycles, the estimation of the traffic flow becomes a more complicated problem, since motorcycles can move in a jumble with cars as long as there is enough spaces or gaps simulated as in [1] but in Vietnam it is a more complicated task. Therefore, the traffic analysis based on counting the number of vehicles seems to be neutralized. In addition, classification of vehicles is also a challenge task [2]. This method however simulates and estimates the mixed traffic flow in the context of a university campus and therefore is not the case of the road context.

The method presented in [3] utilizes the approach of a synchronous control system as depicted where a green light system operates in the adjacent intersections like green waves with the aim to control and monitor the speed of vehicles on the roads for reduction of a jam and potential accidents, especially in the rush hours. However, this method estimates the control time for the traffic light systems at intersections, which are synchronous only, without taking into account of an adaptive adjustment of the traffic signals for a thorough traffic.

Another method in [4] uses Vehicular Ad Hoc Networks (VANETs) to estimate the vehicle stop time for each traffic light pair for timing.. This method is not reliable because the data from the simulation scenarios can not respond immediately to the traffic flow which is quickly increased in a short time. This method also has not addressed to the case when the vehicles accelerate or decelerate at the moment the signal lights change.

An automatic traffic flow control and monitoring has been focused so far by researchers, where traffic flow is estimated by using cameras mounted on roads to capture the vehicle traffic and analyse the flow instead of the conventional methods which typically utilize sensor devices for vehicle counting as in [5]. These methods however do not include the delay time for the vehicles waiting at a further distance to start moving at the moment to switch from red to green light signal can. The delay time in this case actually is small but it is significant compared to the switching time of the traffic light signals.

This paper proposes a new method based on the traffic video analysis including determination of length of all vehicles waiting to estimate the vehicle flow and uses the results as the input for automatic timing of the traffic lights accordingly. The system uses a camera viewed from the tail of the vehicles appearing in a distance from the viewed span of the camera to the stop line of the cross-roads, which is denoted by L for the case of one-way street. Based on the roadway area found in the captured traffic video which is occupied by the vehicles, the traffic flow will be estimated and then the traffic light timing update will be available accordingly. In the context of Vietnam transport behaviour, the vehicles typically consist of a mixed flow of motorbikes with other transport means.

While the vehicles waiting before the stop line, the traffic light signal turns in green, the vehicles start moving in first in first out manner with various speeds till the last vehicle in the line. Therefore, the length of the vehicles in queue should be taken into account for more accurate determination of traffic flow, which is fully automatic. The experimental results performed by utilization of the proposed approach is shown to be promising to resolve the problem of automatic control and monitor traffic flow.

This paper consists of 3 main parts, where the first one introduces briefly about the proposed automatic determination of the traffic flow. Part 2 follows to illustrate the implementation of the proposed system in details. Next, the experimental results,

performance evaluation and discussion are presented in the last part 3 and followed by the future work.

II. PROPOSED SYSTEM IMPLEMENTATION

A. System model

The proposed system is designed to monitor the traffic flow of vehicles moving in road lanes which is based on the determination of free area left by occupation of the vehicles in the viewed span of the mounted camera. The distance L corresponding to the viewed span of the camera as depicted in Fig. 1 is set appropriately for the height and view angle of each camera mounted in a crossroad.
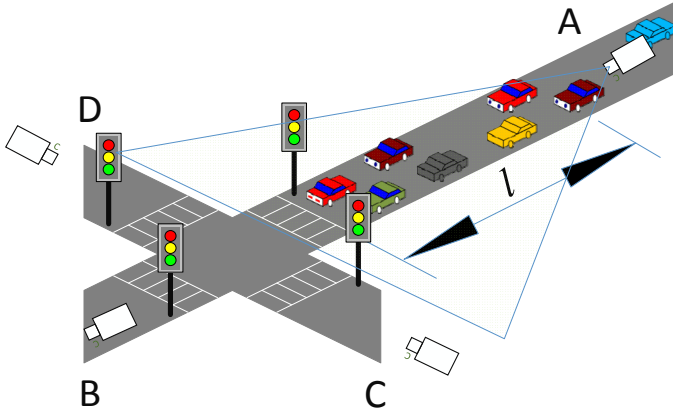

Fig. 1. System model

B. Determination of the roadway area

In the camera based traffic management, vehicles were detected by adoption of adaptive background subtraction for real-time segmentation of moving regions in image sequences [6]. This method proposed to model each pixel as a mixture of Gaussians and using an on-line approximation to update the model, and then classify the pixel based on whether the Gaussian distribution which represents it most effectively is considered part of the background model. The pixels corresponding to the vehicle which have passed though the camera view are detected, traced and then synthesized in a given time period to eliminate the shadow from the sunlight or streetlight.
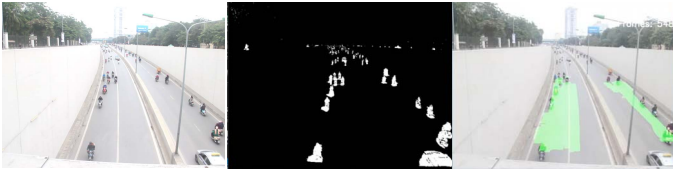

Fig. 2. A video frame of a vehicle flow captured by the camera: a) Original frame; b) Its binarization; c) The road found in the frame marked by green area.

Fig. 2 shows the roadway found from the vehicle flow which passes through and is marked by the green area. A given frame is first binarized by Otsu as in [7] and then the roadway area is determined by the binary blocks which typically correspond to

the motorcycles appearing in the frame. The detection accuracy may be affected by the shadow of vehicles in the roadway because of the shadow probably coming from sunlight or night lighting.

Since the roadway is found by this simple method, the elapsing time is therefore reduced in comparison with that in the conventional methods where utilize vehicle counting. Next, the proposed system detects the cars passing through the green region and occupy the detected background area. Based on the consideration of the area left after the occupation, the traffic flow detection becomes a simple task, rather than vehicle counting. In this system, the height and the view angle of the camera will be statistically calibrated to fix the view span.

C. Estimation of traffic flow and control

This paper refer the method described in [8] for traffic flow, however with few modifications to work with multiple road lanes with a mixed flow of vehicles, which is typical transport context in Vietnam. Usually motorcycles move close enough as well as stop by the stop line at a crossroad at very near distance each to other. Therefore, the lanes on the road way which has been detected will be helpful in the estimation of the traffic flow. The peak hour factor (PHF) is first evaluated by:

$$PHF = \frac{Hourly\ volume}{Peak\ flow\ rate\ (within\ the\ hour)} = \frac{V}{6\,x\,V_{10}}, (1)$$

where

V is hourly volume (*vehicle/h*), and
V_{10} is volume during the peak 10 min of the peak hour (*vehicle/10 min*)

The average travel speed of the vehicles in a distance L (*km*) is then determined by

$$S = \frac{nL}{\sum_{i=1}^{n} t_i}$$

$$= \frac{L}{\frac{1}{n}\sum_{i=1}^{n} t_i}$$

$$= \frac{L}{t_a} \quad (2)$$

where

S is average travel speed *(km/h)*,
L is length of the highway segment *(km)*,
t_i is travel time of the ith vehicle to traverse the section *(h)*,
n is number of travel times observed, and

t_a $= \frac{1}{n}\sum_{i=1}^{n} t_i$ = average travel time over L *(h)*.

One should note that L (*km*) is the distance from the viewed span of the camera to the stop line at a cross-road as shown in Fig. 1. The traffic density is then given as

$$D = \frac{V}{S} , \qquad (3)$$

where

    D is density *(vehicle/km)*,
    V is hourly volume – flow rate *(vehicle/h)*, and
    S is average travel speed *(km/h)*

The density of traffic vehicles can be calculated with a smaller unit kilo-meters. In this case, the camera can be clearly observed length of about 50 ~ 100 meters.

$$Density(vehicle / km) = \frac{1000}{spacing(m / vehicle)} . \qquad (4)$$

The headway is defined as the time between successive vehicles as they pass a point on a lane or roadway, also measured from the same point on each vehicle. The headway can be easily measured with stopwatch observations as vehicles pass a point on the roadway, and expressed by:

$$Headway(s / vehicle) = \frac{spacing(m / vehicle)}{speed(m / s)} . \qquad (5)$$

The flow rate is related to the average headway of the traffic stream, and expressed as:

$$Flowrate(vehicle / h) = \frac{3600}{headway(s / vehicle)} . \qquad (6)$$

Information of the determined traffic density, length distance corresponding to the vehicle queue, and monitoring road sections will be used for automatic timing update on the traffic light system for a given cross-road rather than the use of traffic information only. In the real situation on the cross-road, the camera will be activated periodically for each cycle of time *t* to find the roadway and then start estimation of vehicle queue.

III. EXPERIMENTAL RESULTS AND DISCUSSION

As shown in Fig. 4, the simulation scenario is performed at a 4-way cross-road using 4 surveillance cameras which are mounted in each road A, B, C, and D at the distance *L* as depicted in the system model in Fig. 1. The lane width for road A, B, C, and D is 12m, 12m, 10m, and 10m respectively.

Fig. 5. An example of 3 frames extracted from an input video sequence

Fig. 5 demonstrates some the monitoring frames extracted from the input video sequence, which is captured by the surveillance in a real transport scene of Vietnam.
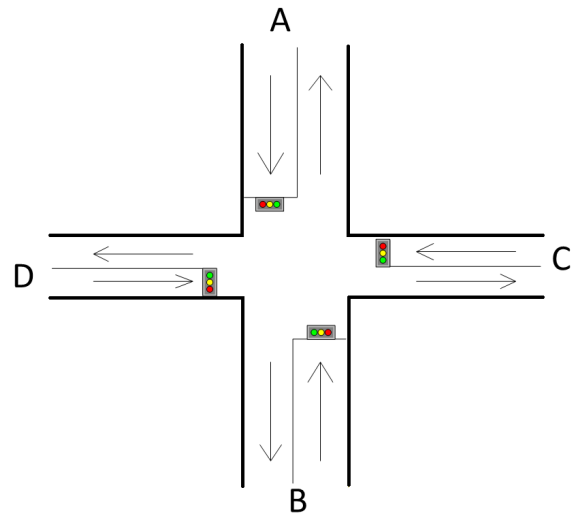

Fig. 4. Simulation scenario

Typical vehicles have to follow the predefined lanes, and therefore surveillance cameras which are installed in each cross-road at the distance *L = 50m* from the stop line will monitor driving behaviour. In this simulation, the distance *L* is appropriately calibrated for setting the corresponding span view of the cameras on the existing lanes. As the red light signal has been turned on, the system algorithm will start to analyse the vehicle occupation before the stop line, meanwhile the waiting queue length of the vehicles is also estimated.

TABLE I. UPDATED TRAFFIC LIGHT TIMING ACCORDING TO DENSITY ESTIMATION

Phase	Density	V	S	Current Green light timing (s)	Updated green light timing (s)	Current Red light timing (s)	Updated red light timing (s)
A to B	130	4568	35	30	20	20	15
B to A	112	4147	36				
C to D	98	3015	32	20	15	30	20
D to C	84	2929	35				

According to the simulation scenario given in Fig. 4, the system has estimated on the input video sequence to update the green light and red light timing for two-way phase AB and phase CD, respectively. As shown in Tab. I, the green light and red light timing are directly estimated using Equation (3) which counts the number of vehicles passing through in a time unit for different phases.

Tab. II shows the estimated update of traffic light timing which is based on evaluation of the road occupation of vehicles and the vehicle queue length including the gap between vehicles. The queue length on the phase A to B while the red light on is determined 16m corresponding to the length of three successive automobiles, since the ratios of motorcycles/automobiles for the phase A to B and phase C to D in the input video sequence are 6/1 and 10/1, respectively Other phases operate in the similar manner of the phase A to B. The updated traffic light timing based on the proposed method is shown appropriate compared to that based on the density estimation in Tab. I and the effect from the update of traffic light timing where the queue length has been eliminated.

TABLE II. UPDATED TRAFFIC LIGHT ACCORDING TO ESTIMATION OF QUEUE LENTH, ROAD OCCUPITON, AND VEHICLE GAPS

Phase	Queue length (m)	Area road occupied (%)	Gap between vehicles (%)	# of vehicles	Updated red light timing (s)
A to B	16	80	20	20	15
B to A	16	80	20	18	
C to D	11	80	20	17	20
D to C	11	80	20	17	

IV. CONCLUSIONS

This paper has proposed a new method to estimate the accurate the traffic flow based on the road analysis and detection of vehicle queue using the surveillance camera mounted in a cross-road, and then it is utilized in automatic timing control of traffic light signals. This method does not take into account the traffic density of vehicles; therefore, the verified performance is promising to apply in real transport context in Vietnam or developing countries.

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