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Vehicle counting system using optimized virtual loop method based on Real Time video

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ABSTRACT
This paper describes a computer vision system to detect and count moving vehicles on roads. The system uses a real-time traffic video surveillance camera mounted over roads and computes the total number of vehicles which passed the road. Moving vehicle image is extracted using
'double difference image 'algorithm and counting is accomplished by tracking vehicle movements within a tracking zone, called virtual loop. The system was tested on a video surveillance record file of a road that has a medium-level traffic volume.

I. INTRODUCTION

With the rapid development of multimedia, wireless communication and cloud computing technology, video has become the main carrier of information in applications of management purposes. Video based real-time vehicle monitoring has become an important part of intelligent traffic systems, and counting is its basic function. Virtual loop method detect and count number of cars based on relative position of cars with virtual loop, which is simple and effective, and became a basic method to count vehicles in many related approaches[1]. Two aspects are needed for effective virtual loop detection: successful segmentation of moving vehicle(s) from background and an algorithm to avoid recounting of vehicles.

In this paper, we propose a system to count moving vehicles from surveillance videos, moving vehicle image is extracted using 'double difference image 'algorithm and
counting is accomplished by tracking vehicle movements within a virtual loop area with the help of detection lines.

The system works in 5 steps, as shown in Figure 1. All steps will be described in following sections.

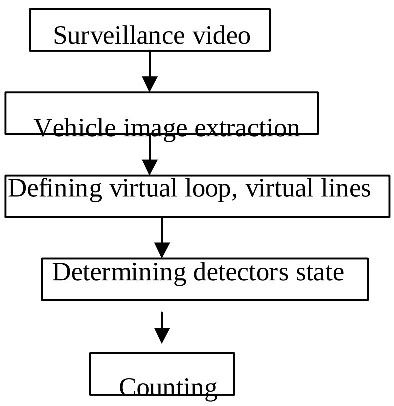


Figure 1. System overview

II. PREVIOUS WORK

As a main problem of motion detection, moving vehicles and moving region detection from video frames were accomplished by frame differencing method, background subtraction, or by computing the error between a background model and current frame.

Distinguish moving vehicles from the static background by modeling the background scene with Gaussian Mixture Model, and established tracking moving vehicles by Kalman filtering. In order to count passing vehicles, they defined a boundary for each outbound and inbound lane to form a region of interest. When position of a tracked vehicle gets out of this region in terms of pixel values, the counting algorithm increases the vehicle count by 1 for the corresponding lane. Accuracy of this approach relies on effectiveness of tracking procedure.

Kalman filter is used to track moving vehicles, while using virtual loop to detect vehicle presence on each lane. A drawback of traditional virtual loop method is wrong counting of non-moving objects, slower moving cars or closely following vehicles.

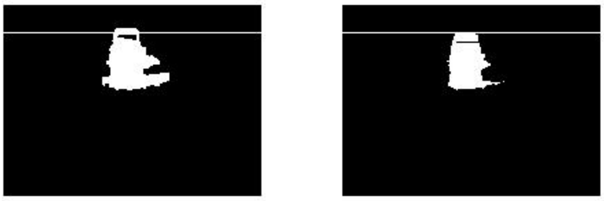
On the other side, traditional frame differencing algorithm acquires moving object contour by using image difference information between successive two frames and widely used in motion segmentation because of it's characteristics of easy to programming and less sensitive to changes of lighting conditions. But the approach also suffers drawbacks like foreground aperture and ghosting, especially sensitive to object speed and video camera frame rate [1].To solve these issues K.Yoshinari and M.Michihiko [5] proposed a variation of this method, called "the double difference" method which operates a thresholded difference between frames at time t ,t − 1 and t+1 and combine them with a logical AND. Davide A. Migliore and Matteo Matteucc[4] proposed a technique that uses both frame by frame difference and background subtraction. The difference between the actual frame and previous frame with the difference between actual frame and the actual model of background are combined to detect a moving object within the current frame. The first image of the sequence is used as initial background model and it is dynamically updated with the new frame according to motion segmentation. The approach is promising in robust motion detection as long as background model gives up-to-date information of the background.

III. VEHICLE IMAGE EXTRACTION USING DOUBLE DIFFERENE IMAGE

Correct position and correct shape of the vehicle is the key factor for accurate car counting when using virtual loop method, as it relies highly changes of pixels values. Contour on a normal difference image do not express the shape well of the object because it is a mixture of object shape on two different times. 'double difference image' approach uses information from previous frame and following frame to estimate shape and position of the vehicle on current frame, which gives more accurate position information.

To obtain 'double difference ' vehicle image, two difference images were generated from corresponding two successive images (frames at time 't-1','t' and 't+1) and then the difference images were binarized and logical 'AND' operation was executed on these two images . The car object in resulting image keeps original shape and position of car at time't'. At the same time, to eliminate isolated noise pixels, morphologically open, close, and dilate operation to binary images were executed.

Figure2. shows the normal difference image and double difference image of a detected vehicle on the lane. Moving position of the vehicle was correctly detected on double difference image, marked with white line, while normal difference image gives wrong information. Although the position difference on two images are quite small, but it has large effect when estimation relative position with virtual detectors.



(a) (b)

Figure 2. (a) normal difference image (b)double difference image

IV. SETTING OF VIRTUAL DETECTORS

3.1 Virtual loop setting

Extracted moving vehicle image obtained using procedures above include only the moving vehicle(s), we can select a rectangle region of M*N called virtual loop (compared to real induction loop vehicle detectors) or virtual detector on every lane and compute the area of objects in that region for each frame. M represents width of the region, and N is the length. Experiments show that M could have a value equal to 0.8-0.9 times of real line width to avoid interference from vehicles on other lane and road-side objects. Similarly, N could have a value of
0.4-0.8 times of real standard vehicle length..

The principles of traditional virtual loop method is that, if a vehicle is crossing the virtual loop region, area of objects in that region should be higher than certain threshold and the state of virtual loop is recorded as true(occupied by car(s)), otherwise, a false record will be stored(not occupied). We define presence of a vehicle for virtual loop by the equation (1).

When a vehicle is passing through the region, the state of virtual loops is changes from 0 to 1.

$$P=\begin{cases} 1 & \text{if area(virtual loop)> thr} \\ 0 & \text{otherwise} \end{cases} \qquad (1)$$

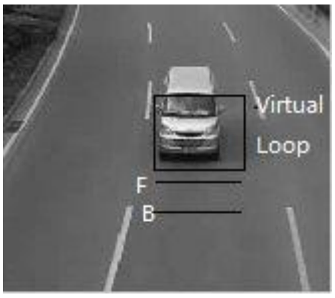


Figure 3. Setting of virtual detectors

3.2 Detection lines setting

Detection line is defined as a line on image plane, with certain width much smaller than virtual loop but with similar function. Detection lines play quite important role in our approach. It's statH is used in our algorithm as a reference signal to avoid recounting of vehicles when vehicle speed or frame rate is slow, and to avoid counting non-moving objects or non-vehicle objects moving on the road.

Our approach needs two detecting lines, placed parallel to virtual loop. First line, called line F needs to be close to virtual loop border at exit direction, while the second line, called line B keeps a distance equal to 3/5 or 3/4 of expected space headway from line F.

Presence of vehicle on detection lines is defined using equation (1) too, but with different threshold. Figure 3 shows the setting of virtual loop and detection lines.

V. VEHICLE COUNTING

When a vehicle passing through virtual loop area, counting procedure were accomplished by 3 steps:

Step 1: Vehicle approaching. As long as area of objects in virtual loop region reached the threshold value, counting process starts and following steps were marked as valid.

Step 2: Vehicle reaches line F and/or line B. If front of vehicle reached detection line F and not reached to detection line B on frame i, counting state is marked as true and fills 1 to corresponding line of a counting matrix. If the vehicle reached line F and line B at the same time on frame n , suppose, counting state is marked as false and all lines of counting matrix corresponding to frame i to frame n are filled with 1 and line corresponding to frame n is filled with 0.

Step 3: Vehicle leaving line B. Calculate number of vehicles during the period using value of counting matrix. If the value corresponding to frame i is 1 and the value corresponding to frame i-1 is 0, add 1 to total number of vehicles.

VI. EXPERIMENTAL RESULTS AND DISCUSSION

In order to test effectiveness of the propose method, system was implemented on Maltab and tested on a freeway surveillance video file, with resolution 320*280, captured at sampling frequency of 30 frames per second and test result was compared with result of traditional virtual loop method. Test result was given on Table1.

Test results show that, the system could count cars with high accuracy under various day time conditions.

Table1. Experimental results

Virtual loop Algorithm	Counted number of cars	Actual number of cars
Double difference +detection line	120	121
Single difference without detection line	116	

Compared to counting error of 5 vehicles while using traditional virtual loop method, our approach gives good counting accuracy, and we believe that error rate of traditional virtual loop method increases when sampling frequency or average vehicles speed changes unexpectedly.

We observe that this system will depend on, to certain extent the visual angle and the choice of the position of video camera. In most real applications surveillance camera position is fixed over the road at construction period. Besides that, sampling frequency of video camera should not be lower than 16 frames per second. These conditions could be easily satisfied in real applications, and our method could give good results compared to other approaches.

Same method could be used to extract other traffic data like occupation, average speed etc. with slight changes to the algorithm.

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