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Algorithm Research of Moving Vehicle Detection and Vehicle Flow Statistical Based on Machine Vision

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Abstract. In recent years, Intelligent Transportation System (ITS) has become a research focus in transportation field. Vehicle detection is an important part of Intelligent Transportation System. In this paper, detection of moving vehicles based on machine vision is studied, and the algorithms of moving vehicle detection and vehicle flow statistics are proposed. The algorithms of moving vehicle detection include: Background difference method and frame difference method; the algorithms of vehicle flow statistics include: the method of virtual coil and the method of vehicle counting based on pixel. Through extensive experiments, the methods proposed in this paper can accurately detect moving vehicles and counting, and have reliability and real-time, satisfy the real-time demand.

Keywords: Intelligent Transportation System; Machine vision; Moving vehicle detection; vehicle flow statistical

1. Introduction

With the development of economies, the requirement of transportation is also on the increase. The traffic is so heavy that the accident is always happen. To resolve the problem, the traditional way is to build or enlarge the road. But the space is very limited; what's more, the speed to build the road is much slower than the growing speed of transportation demand. In the situation, Intelligent Transport System arises spontaneously. We have to work out many problems for the system, one of the important points is vehicle detection.

The traditional vehicle detection methods include: ultrasonic testing; induction coil testing and so on. The advantage of ultrasonic testing is installation without damage the road, and can not be influenced by road construction. The disadvantage is easy to be influenced by the blocking of vehicles and pedestrian. The advantage of induction coil detection is high precision. The disadvantage is the surface of the road will be damaged and not easy to install, because it has to set inside the road. In order to absorb the advantages of these two methods and solve the shortcomings, then using machine vision to solve the vehicle detection has become one of the hot spots in the world.

Vehicle detection include: moving vehicle detection and queue length detection. Moving vehicles detection is using appropriate technology to process the information of moving vehicles image and distinguish the moving target from the image sequence and counting. It is not only one of the most important problem of information extraction based on machine vision, but also a basis of higher level of video analysis (such as object-based video coding, target tracking and motion analysis).

Currently, there are three moving vehicle detection methods: background difference method; frame difference method and optical flow method. Through extensive experiments, the advantage of the

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background difference method is can obtain complete moving targets, and the disadvantage is it depends on the quality of background model and easy to be influenced by the change of natural environment(Such as weather, light, sun position etc). The advantage of frame difference method include: easily implemented and low complexity; real-time monitoring; not sensitive to light changes and adaptable for highly dynamic environment, and not easy be influenced by the target's shadow. The disadvantage of frame difference method include: easy to produce fault and voids in the image of vehicle; can not get complete information of vehicle; the virtual shadow will be produced easily when the speed of moving vehicle is too fast, and this means that the detected moving vehicles are larger than the actual vehicle, even appear the situation that one target into two goals. The computation of optical flow method is too complicated, and easy to be influenced by noise. If there have no specific hardware, it generally difficult to detect moving vehicles for real-time. After comparing these methods, to combine the advantages of background difference method that can get complete information on moving targets and the advantages of frame difference method that the less sensitivity to the light changes of the scene and the strong adaptability to the dynamic environment. So, this paper will combine the background difference method and the frame difference method to detect moving vehicles.

2. Design of moving vehicle detection based on machine vision

Design of moving vehicle detection based on machine vision includes: getting image sequences of moving vehicles; detection and segmentation of moving vehicles; vehicle flow statistical. We can use a fixed camera to shot video of moving vehicles on the city roads to get image sequences of moving vehicles. Detection and segmentation of moving vehicles is preprocessing the image sequence of moving vehicle, then using a series of methods to extract information of moving vehicle from image sequences, and binary the image, remove the shadow, using mathematical morphology to process image, then it can get complete information of moving vehicles. Vehicle flow statistical is set virtual coil on the image and set appropriate threshold, then using the change of pixels when vehicle through the detection area to determine whether the vehicle is through the detection area and counting.

The flow chart of moving vehicle detection based on machine vision as shown in Figure 1.

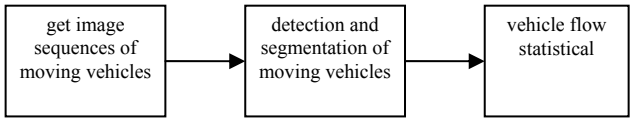

Figure 1. The flow chart of moving vehicle detection based on machine vision.

3. The algorithm of moving vehicle detection based on machine vision

3.1. Preprocessing algorithm of moving vehicle image

It is inevitable that image change caused by external factors when get image sequences of moving vehicles, such as optical noise and sampling errors, etc. so, the image pre-processing operations before moving vehicle detection is very important, and the quality of pre-processing operations will directly influence the result of detect.

3.1.1 Image filtering

Any original images have some degree of noise interference. This noise usually caused by camera equipment and the external environment. Noise make image quality change bad, blur an image, and even submerge the characteristics that need to detected, make the difficulty for the image analysis. So, in the image preprocessing stage, how to filter out the noise becomes more important. The purpose of image filtering is to eliminate all interference noise, and try to maintain the characteristic of image in the same time. Filtering methods include: the field average method; gauss filtering method; linear filtering method; median filter method and mean filter method.

3.1.2 Image enhancement

Filtering the image to remove noise will cause image quality decline, and make differences with original one. It is necessary to process the image which have degraded, and make the processed image more

advantageous to get the important information. This treatment called image enhancement. Methods of image enhancement including: grey level transform; image smoothing; image sharpening and histogram modification.

3.2. Mixture gaussian background model

Because mixture Gaussian background model have good robustness and stability, it be widely used in image sequence processing. In the process of build the background model, every brightness of pixel that changes through time is not be seen as one Gaussian distribution in mixture Gaussian background model, but the sum of multiple Gaussian distribution. Match each of the observed pixels according to the current eigenvector, and then pixels will be classified as background or foreground according to the matching results and use current eigenvector to update the current model.

In this modeling process, brightness value of each pixel be seen as a stochastic process that changes with time in successive image sequence. This brightness value be seen as a scalar for the gray image but be seen as a vector for the color image. For the sequence of brightness value in (x_0, y_0):

$$\{X_1, X_2, \cdots, X_t\} = \{I(x_0, y_0, i) : 1 \le i \le t\} \quad (1)$$

Where $I(x_0, y_0, i)$ represent video image sequence, and X_i represent the brightness value of (x_0, y_0) at time i .For the gray image, X_i is a scalar, but for the color image, X_i is a vector.

For the change process of each brightness value $\{X_1, X_2, \cdots, X_t\}$, its probability distribution described by a Gaussian mixture model, the formula is:

$$P(X_t) = \sum_{i=1}^{K} \omega_{i,t} * \eta(X_t, \mu_{i,t}, \Sigma_{i,t}) \quad (2)$$

Where represent the number of Gaussian distribution in Gaussian mixture model. Generally, choice the value between 3 to 5 is good. X_t is the pixels value at time t. $\omega_{i,t} (\sum \omega_{i,t} = 1)$ is the weight of each Gaussian distribution, $\mu_{i,t}$ and $\sum_{i,t}$ is mean and covariance of Gaussian distribution of No. i at time t . $\eta(X_t, \mu_{i,t}, \Sigma_{i,t})$ is the probability density function of Gaussian distribution of No. i at time t. Compare the pixel value that collected in the new moment with the current Gaussian distribution to get the best match, and update the parameters of Gaussian mixture model. Finally, the pixel which the value that belong to the background distribution be seen as background, and other pixel be seen as foreground.

Through repeated and numerous experiments, mixture Gaussian background model can estimate the background better then other methods. In particular, mixture Gaussian background model can works well with multi-peak gray distribution of pixels that caused by the movement of background(such as the swaying of the leaves; fluctuations watermark; flashing lights, etc). The result of Gaussian mixture background model as shown in Figure 2.

Figure 2. The result of Gaussian mixture background mode

3.3. The algorithm of moving vehicle detection

The methods of moving vehicles detection include: background difference method; frame difference method and optical flow method. Because background difference method depends on the background model's quality, and easy be influenced by external changes in the natural environment. Frame difference method is easy to produce fault and voids in the image of vehicle and can not get complete information of vehicle, this paper use background difference method combine frame difference method to detect moving

vehicle. This way not only can take full advantages of two methods, but also can inhibit the shortcomings of their own and improve the stability of moving vehicle detection.

3.3.1 Background difference method

The basic principle of background difference method is using one image in the sequence to subtract the background image. The advantage of this method is accuracy and real-time. $B(i,j)$ represent the background image, $I(i,j)$ represent the current image, the expression of difference image $D(i,j)$ is of the form:

$$D(i,j) = I(i,j) - B(i,j) \tag{3}$$

3.3.2 Frame difference method

The basic principle of Frame difference method is compare the different of gray values of two adjacent image, then extract the movement region of image sequence through threshold. Suppose the difference between consecutive frames can be expressed by binary difference image $D(i,j)$:

$$D(x,y) = \begin{cases} 1 & \left|I_{k+1}(i,j) - I_k(i,j)\right| > T \\ 0 & otherwise \end{cases} \tag{4}$$

3.4. Image segmentation of moving vehicle

For the difference image under different light condition, using fixed threshold to binary the image can not get good result obviously. The threshold not only can separate the target from the background, but also can intelligently select according to different images. Due to the vehicle traffic image is not too complicated, and grayscale distribution are relatively concentrated, this paper using Otus threshold techniques to extract moving vehicles. This method is simple and self-adaptive, and has been widely used in some real-time image processing system. The result of background difference and frame difference after threshold as shown in Figure 3.

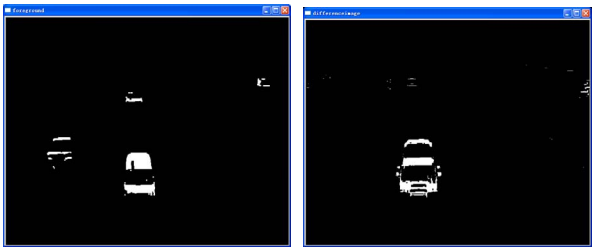

Figure 3. The result of background difference and frame difference after threshold

3.5. Shadow detection and removal of moving vehicles

Through the analysis of traffic video sequences, we may see both the shadow and the moving vehicle have the following two features:

（1）There are significant differences on the pixel grayscale between the shadow of moving vehicles and reference background.

（2）There are same attributes between the shadow and moving vehicles (Such as speed, direction, etc).

In view of the above characteristics, there exist shadow effect in most cases when using background difference method to detect and extract moving vehicles, and the area of moving vehicles which be extracted will large than the actual one, and it can lead to two serious flaws. The one is the shape of the vehicle be influenced by its shadow, that mean the shape of the same vehicle with the changes in different light. This will affect the subsequent vehicle classification and confirm the position of moving vehicles; another is that the shadow may make the shapes of the vehicles large; lead to two or more vehicles stuck together and be treated as a whole. This will affect subsequent processing (such as vehicle flow statistical, etc). Therefore in transportation examination system, moving vehicle shadow detection is essential for subsequent processing.

In the YUV color space, compared with the non-shaded background, Y component of shaded background which represent brightness information have a big change, but the U, V component which represent color information change little, so we can focus on the shadow in the Y component. In this paper, we only use the Y component to detect the shadow. Through numerous experiments, brightness of the

shadow is always less than brightness of the non-shadow area. In other words, ratio of the current shadow pixel and the corresponding background pixel $\frac{I_Y(x,y)}{B_Y(x,y)}$ is always less than 1. $I_Y(x,y)$ represents the current shadow pixel, $B_Y(x,y)$ represents the corresponding background pixel. Taking into the brightness of dark foreground objects often even lower than the shadow, it is necessary to give a suitable minimum. Therefore, using the following equation for shadow detection.

$$P(x,y)=\begin{cases}1 & \alpha\le\frac{I_Y(x,y)}{B_Y(x,y)}\le\beta \\ 0 & \text{otherwise}\end{cases} \quad (5)$$

Threshold α which is mainly used to remove the dark prospect of vehicle interference，β is used to identify light-colored vehicle. α take of 0.4, β take of 0.99.The result of Shadow detection shown as Figure 4.

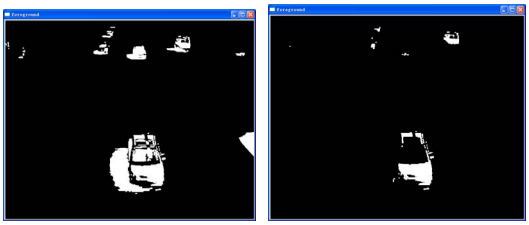

Figure 4. The result of Shadow detection

The results show that using only the brightness component can detect most of the shadow region, and can solve the phenomenon that moving vehicles connected to each other caused by shadow; However, many foreground area be misjudged to shadow, especially when the brightness of vehicle is not very different with shadow area. More accurate shadow detection method under the YUV color space also waits for the further research.

4. vehicle flow statistical

4.1. Set the virtual detection coil

Vast majority of vehicles on city roads drive by lane. According to this characteristic, set a virtual coil on each lane separately and numbered individually. The height of coil is half the length of small vehicles, to reduce the impact of on the count caused by adhesions around the vehicle.

4.2. Vehicle counting algorithm based on pixel

When a vehicle through a virtual coil, the pixel in the coil will change. According to the number of pixels which are changed to determine whether a vehicle through the coil. In the beginning, set one coil in each lane, and set the appropriate threshold to background difference method and frame difference method. In this paper, I set the threshold for both of methods were 800 and 200，and mark the initial state of each virtual coil for 0, this mean no vehicle through the coil. Read into the video sequence circularly. when the number of pixels of foreground greater than the threshold of the two vehicles detection method, mark the state of the coil for 1,this mean have a car through the coil, and set the counter to 1 at this moment until the number of foreground pixels of consecutive frames below the threshold, and we think that the vehicle has left the coil in this moment. Accumulate the counter of all the coils, and get the number of vehicles. Finally, set the counter to zero and continue reading the next frame.

5. Simulation results

The video which be used in this paper is shooting during the day. The video is 30 frames per second. The size of each frame is 640*480. Before using the algorithm which be discussed in this paper to process images,

pretreatment the video images as follows: On the premise of does not affect the calculation results, taking into the requirements of real-time, we extract the image in every two frame, this mean the video is 15 frames per second. Draw the virtual coil ahead of time according to the relationship between the position of the camera and the lane.

Using OPENCV1.0 to achieve the algorithm in this paper, the simulation results shown in Table 1.

Table 1. Simulation results

	Detection time（/s）	Detected traffic flow	actual traffic flow	Accuracy rate（/%）
Road A	100	23	24	95.8
Road B	150	30	32	93.7
Road C	300	70	74	94.5

Experiments show that in the author's computer which is CORE 2 and CPU Clock Speed is 1.66GHZ, without any optimization and hardware acceleration, Meet the requirements of real-time fully.

6. Conclusion

This paper studies a core technology of Intelligent Transportation System that is moving vehicle detection algorithm. First of all, proposed method of detecting moving vehicles that combine the background difference method and the frame difference method. Using Gaussian mixture background model to estimate background, and this method has good self-adaptability, and can effectively extract the background and real-time updates it. Then using the current frame image minus background image and subtract two adjacent frames image, through the threshold segmentation algorithm to get moving vehicles, and using shadow detection algorithm under YUV color space to detect and eliminate the shadow of moving vehicles. Finally, through the change of the number of pixels in the virtual coil to determine whether a vehicle through the coil and counted.

Through the experiment, using the moving vehicle detection algorithm which be proposed in this paper can get accurately moving vehicles. When using the algorithms which involved in this paper for experiment, it can get ideal result.

7. References

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