Moving Vehicle Detection and Tracking Algorithm in Traffic Video

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Abstract
Aiming at the defects and shortages of traditional moving vehicles detection algorithms, by the analysis and comparison of the existing detection algorithms, we propose an algorithm that combined with frames with symmetric difference and background difference to detect moving vehicle in this paper. First, two different difference images by using frames with symmetric difference and background difference are gained respectively and two binary images can be gained by the appropriate threshold, then the contour of moving vehicles can be extracted by applying OR operation in the two binary images. Finally, the precise moving vehicles will be gained by mathematic morphological methods. In this paper we use Harris operator, Feature Points such as edges and corners are extracted, followed by block-matching to track the Feature Points in successive video frames. Many vehicles can be tracked at the same time automatically since the information is obtained from video sequences.

Keywords: moving vehicle detection, tracking, symmetric difference, background difference

1. Introduction

In traffic video contains plenty of important information, such as vehicle speed, vehicle type, running directions, traffic flow. To gain these data, the first thing to do is to detect moving vehicles, then analyze these trajectories by the tracking. It's the important reflect of video monitoring system intelligent.

Commonly used target detection algorithms are optical flow method, frame difference method, the background difference method [1]. The optical flow method is use of optical flow field to achieve motion detection. Its advantages are the optical flow carries a wealth of information about the moving vehicles information and the scene of the three-dimensional structure information. It can detect moving vehicles in the case of do not know the anything of the scene. However, the method is computing time and weak in practical and real-time. The frame difference method is from the results of two successive images difference operation to detect moving vehicles. Its advantages are easy to implement and not sensitive to the change of illumination. However, It may not extract the vehicle boundary when the moving vehicle is traveling slowly, the extraction of the vehicle will stretch when the moving vehicle is traveling too fast [2]. The background difference method is from the results of the current frame and background different to extract the moving vehicle. Its advantages are easy to obtain the vehicle description, but It's susceptible to illumination change, background motion, such as the swing of the trees in the wind, background changed caused by moving vehicle [2, 3]. So timely update background and establish a suitable background model, we usually used algorithms are Single Gaussian Model, Gaussian Mixture Model, based on statistical method [4].

The vehicle tracking is a subject of concern in the field of computer vision. The moving vehicle tracking means to detect, extract, recognition and tracking the moving vehicles in the image sequence. So we can obtain motion parameters of moving vehicles, such as position, speed, acceleration and trajectories. To futher processing and analysis, realize the behavior understanding, in order to complete higher level tasks. Moving vehicles tracking technique is usually achieved through vehicle detection [5]. Commonly used target tracking algorithms are based on model, based on region, based on contour, based on feature [6, 7]. We use the method of base on feature in the paper, this method has significant advantages: the movement of symbolic mode is simple, smooth and independent movement. Motion analysis can not

distinguish the moving objects are rigid and non-rigid, not vehiclees geometry, because symbolic features are easy to catch, and can be matched to the features of each symbol.

Using background difference method and frame difference method are combined to detect the moving vehicle in the reference [8]. It will not only overcome the shortcomings of the two methods, and also obtain more comprehensive information about moving vehicles. But this method is not a good solution for the impact of dynamic scene changes, and no background update. So we propose an algorithm that combined with frames with symmetric difference [9] and background difference to detect vehicles basis on the reference [8]. Experimental results show the algorithm has a better detection effect.

2. Research Method
2.1. Thought of Moving Vehicle Detection Algorithm

The two different difference images by using frames with symmetric difference and background difference are gained respectively, next binarizing the difference images, then applying logic OR operation between the two binary images, finally, using morphological methods to remove noise. Algorithm's thought flow chart as shown in Figure 1.
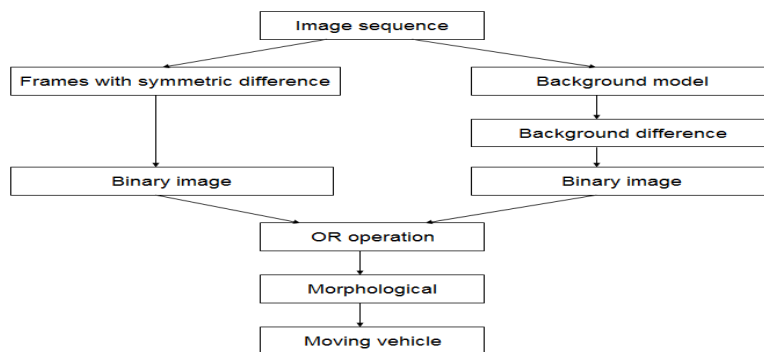
Figure 1. Algorithm's Thought Flow Chart

The specific implementation steps of the detection algorithm as follows:

(1) Frames with Symmetric Difference Algorithm

Frame difference obtain motion region by two adjacent frames, but the extracted moving vehicle is the relative change in part of before and after frames, It's cannot detect the overlapped portion, resulting in the detected vehicle will produce the phenomenon of "empty". However, the frames with symmetric difference algorithm is improved on the basis of frame difference method, and to better extract the contour of moving vehicle in the middle frame, thereby obtaining a better background image. Assuming that F_t represents the current frame, F_{t-1}, F_t, F_{t+1} are three successive frames in the image sequence [10], the difference algorithm steps as follows:

1) Calculate the F_t frame and the F_{t-1}, the F_{t+1} frame image difference

$$\begin{cases} D_{t-1,t} = |F_t - F_{t-1}| \\ D_{t,t+1} = |F_t - F_{t+1}| \end{cases} \tag{1}$$

2) Gain two binary images of the result of step 1) by using the appropriate threshold.

$$D_{t-1,t} = \begin{cases} 1 & |F_t - F_{t-1}| \geq Th_{t-1,t} \\ 0 & |F_t - F_{t-1}| \leq Th_{t-1,t} \end{cases} \tag{2}$$

$$D_{t,t+1} = \begin{cases} 1 & |F_t - F_{t+1}| \geq Th_{t,t+1} \\ 0 & |F_t - F_{t+1}| \leq Th_{t,t+1} \end{cases} \tag{3}$$

3) Calculate the binary image of current frame:

$$D_t = \begin{cases} 1 & D_{t-1,t} \cap D_{t,t+1} = 1 \\ 0 & other \end{cases} \tag{4}$$

(2) Background Difference Algorithm

Commonly used background difference algorithms are Multi-frame average method, Single Gaussian Model, Gaussian Mixture Model. The core of the background difference is the maintain and updating the background model, while Gaussian Mixture Model is the best detecting effect currently, therefore, we adopt the algorithm to detect moving vehicles.

Gaussian Mixture model [11, 12] establish K Gaussian models for every pixel, as long as the pixel conform to the one of K Gaussian models in the detecting process, It is considered that the pixel is a background pixel, otherwise it is considered the pixel of vehicle. Experience value of K is a small number from 3 to 5. The PDF (probability density function) of the kth Gaussian distribution at t moment is shown in Equation 5:

$$P(X_t) = \sum_{k=1}^{K} W_{k,t} * \eta(X_t, \mu_{k,t}, \sum_{k,t}) \tag{5}$$

X_t represents the value of pixel at t moment, $W_{k,t}$ is the weight of the kth Gaussian distribution at t moment, conform $0 \le W_{k,t} \le 1$ and $\sum_{k=1}^{K} W_{k,t} = 1$; $\eta(X_t, \mu_{k,t}, \sum_{k,t})$ is the probability density of the kth Gaussian component at t moment, defined as Equation 6:

$$\eta(X_t, \mu_{k,t}, \sum_{k,t}) = \frac{1}{(2\pi)^{\frac{n}{2}} |\sum_{k,t}|^{\frac{1}{2}}} \bullet e^{-\frac{1}{2}(X_t - \mu_{k,t})^T \Sigma_{k,t}^{-1} (X_t - \mu_{k,t})} \tag{6}$$

$\mu_{k,t}$ represents the Mean Matrix of the kth Gaussian component at t moment, $\sum_{k,t}$ represents the Covariance matrix of the kth Gaussian component at t moment.

1) Model match, update

For new observed value X_t, it will be match with the k Gaussian distributions sorted by priority ω / σ from high to low, matching condition as Equation 7:

$$|X_t - \mu_{k,t-1}| < D\sigma_{k,t-1} \tag{7}$$

$\mu_{k,t-1}$, $\sigma_{k,t-1}$ represent respectively Mean and standard deviation of the kth Gaussian distribution at t-1 moment, D is custom constants, it be set to 2.5 in the paper.

According to the matching result to update the parameters of the model:

$$\omega_{k,t} = (1-\alpha)\omega_{k,t-1} + \alpha M_{k,t} \tag{8}$$

α represents learning rate, for the distribution of the match, $M_{k,t} = 1$, other $M_{k,t} = 0$; the parameters of distribution of the match (meet Equation 7) update mean and variance according to Equation 9:

$$\mu_{k,t} = (1-\rho)\mu_{k,t-1} + \rho X_t, \quad \sigma_{k,t}^2 = (1-\rho)\sigma_{k,t-1}^2 + \rho(X_t - \mu_{k,t})^T(X_t - \mu_{k,t}) \tag{9}$$

ρ represents parameter learning rate, $\rho = \alpha\eta(X_t | \mu_k, \sigma_k)$.

If there is no Gaussian distribution match with pixel X_t, the minimum weight of the Gaussian distribution will be updated X_t as mean and σ_0 as standard deviation, σ_0 is usually for a large constant, it be set to 15 in the paper. Weight will be updated to $\omega_{k,t} = (1-\alpha)\omega_{k,t-1} + \alpha$; the weight of other Gaussian distributions will be updated according to $\omega_{k,t} = (1-\alpha)\omega_{k,t-1}$, mean and variance not change.

2) Generate background distribution

After the parameters of Gaussian Mixture model updated, K Gaussian distributions arranged in a descending order in accordance with $\omega_{k,t}/\sigma_{k,t}$. It may be describe a stable background when the sort is in the front, so we select before B Gaussian distributions as background pixel model:

$$\mathrm{B} = \arg{}_b \min(\sum_1^b \omega_{k,t} > T)$$

(10)

T is the predetermined threshold ($0.5 \leq T \leq 1$), if T too small, background is usually described with one Gaussian distribution; and if T too big, background will be described with several distributions. So take T=0.85 in the paper.

(3) Moving Vehicle Segmentation

Check matching relation between the value of pixel X_t and before B Gaussian distributions at t moment, if the value of pixel X_t and one of Gaussian distributions matching, and the point as the background, otherwise the point is along to moving vehicle.

(4) Binarizing Difference Image

After obtain background image B_t, the current frame F_t and background image subtraction, the difference image d adopt adaptive threshold to get binary image D_B. Formula is shown Equation 11:

$$d = \left| F_t - B_t \right|, \; D_B = \begin{cases} 1 & d \geq Th_t \\ 0 & d < Th_t \end{cases}$$

(11)

(5) Binary Image OR Operation

Combine two binary images derived from the algorithm, It's mean each pixel of the two binary images applying OR operation, formula is shown Equation 12:

$$D = \begin{cases} 1 & D_t \bigcup D_B = 1 \\ 0 & D_t \bigcup D_B = 0 \end{cases}$$

(12)

Thus, frames with symmetric difference can be detect the motion region which background difference failed to detect, while background difference can be detect overlapped area which frames with symmetric difference failed to detect. The algorithm make use of the advantages of the two methods complementary, and the shortcomings minimized. so as to obtain a more entire motion region.

(6) Morphology Image Processing

Due to camera internal factors and the impact of external factors, the image of binarizing process would contain some isolated points and small gaps, mathematic morphology is a method that in order to solve these effects. Morphology processing method mainly contain Dilation, Erosion, Open operation and Closing operation. Using these operations can eliminate a number of isolated points, noise and so on, so can obtain an accurate shape.

2.2. Feature Point Extraction and Tracking

The basic principle of moving vehicle tracking is based on some of the characteristics of the target vehicle in the image sequence to match, then associated with the same target in the different frames of the image sequence, finally obtain the process of target motion vehicle trajectory [13, 14]. Usually select the position, speed, color, sharp and texture as the target

vehicle matching features. The essence of the vehcile tracking is the continuous cycle process of moving vehicles matching–moving vehicles matching template updating and correction–moving vehicles estimation and prediction.

(1) Feature Point Extraction

Extraction of the Feature Point is described in many papers, such as [15]. The Feature Point is extracted using the Harris operator in this paper. The Harris operator is a technique for deriving the Feature Point based on the correlation of image signals, where the correlation output value grows for the Feature Point existing in the edges and corners. The Harris operator is defined by Equation 13 and Equation 14:

$$A = \sum_{(x, y) \in N_0} \nabla I(x, y)^T \nabla I(x, y) \tag{13}$$

$$= \sum_{(x, y) \in N_0} \begin{bmatrix} \dfrac{\partial I(x, y)}{\partial x} \\ \dfrac{\partial I(x, y)}{\partial y} \end{bmatrix} \begin{bmatrix} \dfrac{\partial I(x, y)}{\partial x} & \dfrac{\partial I(x, y)}{\partial y} \end{bmatrix},$$

$$Harris = \det A - \kappa(trA)^2 = \lambda_1 \lambda_2 - \kappa(\lambda_1 + \lambda_2)^2 \tag{14}$$

κ is a constant and usually set to be 0.04. Only the specified numbers of Feature Points are chosen, where positive, locally maximum values given by Equation 14 are arranged in a descending order. The Feature Point is extracted only in the extracted vehicle area. The Feature Point for each object sometime differs frame by frame in the actual dynamic scene. The extracted Feature Point should be stable in the sense that it is found at the same position in the corresponding object even if the object is in motion.

(2) Tracking

In this paper, we use the Block Matching Algorithm (BMA) shown in Figure 2 to track the Feature Point in the vehicle area. Block Matching Algorithm has been used in practice since 1981. Among several feature points calculated by the Harris Operator, one with the largest value is chosen as Feature Point. The Feature Point is extracted for each vehicle in an initial frame in the measurement. After defining a block of 9*9 pixels, place the Feature Point at its center, Block Matching Algorithm is applied to find the position or displacement of the Feature Point in the next frame, where the displacement shows highest correlation. Thus, the new Feature Point is repeatedly found in successive frames to produce a trajectory representing a vehicle.
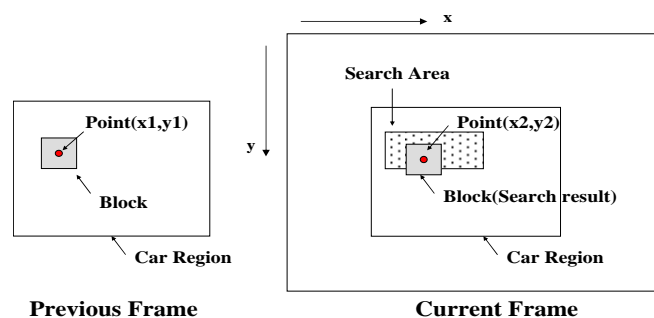

Figure 2. Block-matching Principle

3. Results and Analysis

The improved algorithm has been verified by experiment. Figure 3 shows three successive frames, Figure 3(a), 3(b), 3(c) respectively are Frame(t-1), Frame(t), Frame(t+1). Figure 4 shows the result of frames with symmetric difference, the detected vehicles contours can be seen clear, but inside of the image have some isolated points and small holes. Figure 5 shows the result of background difference, although the vehicles areas can be seen, the

contours of the vehicles are seen fuzzy and edge information is not clear. Figure 6 shows the result of the algorithm of this paper, the information of vehicles is more complete and clear. Figure 7 shows the extraction of moving vehicles.

(a) Frame(t-1)

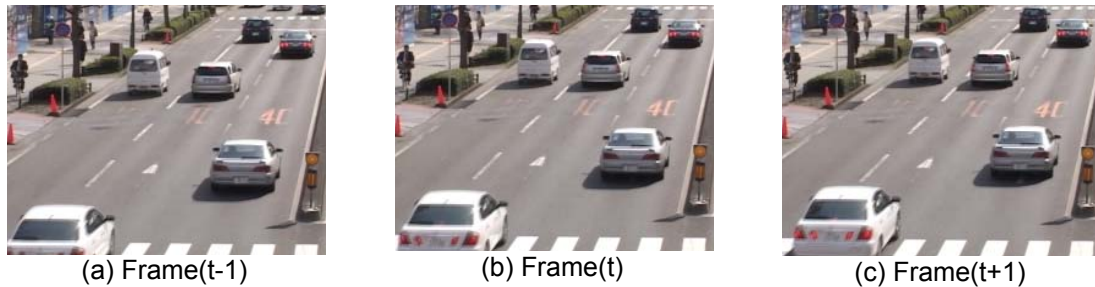(b) Frame(t)

(c) Frame(t+1)

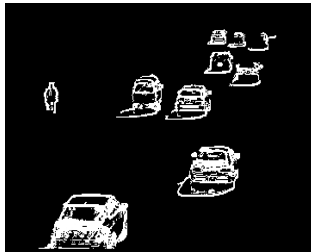Figure 3. Three Successive Frames

Figure 4. Frames with Symmetric Difference

Figure 5. Background Difference

Figure 6. Experiment Result of the Algorithm of this Paper

Figure 7. Extract the Moving Vehicles

4. Conclusion

Aiming at the defects and shortages frame difference and background difference. In this paper, we proposed an algorithm to detect moving vehicle by combine frames with symmetric difference and background difference, which is based on frame difference and background difference. The algorithm can not only overcome the shortages of the two algorithms, to realize the complementary advantages, and can accurately extract moving vehicles. We use Harris operator to extract the Feature Point and use BMA to track Feature Point. The effect of tracking is good and have a good real time even a part of the vehicle is screened. However, the algorithm is still exists inadequate, such as shades of the vehicles, the overlapped of the vehicles may be influence precision. Need to be further improved.

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