CFDL Model-Free Adaptive Control Background Image Extraction to Video

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Abstract. Video background image extraction plays a key role in target detection, and traditional background image extraction methods are easy to cause model distortion. In this paper, using the idea of model free adaptive control, a compact form dynamic linearization method is established to extract the video background. The proposed method is compared with the traditional background extraction methods through different video sequences. The experimental results show that the proposed method has the advantages of better background update, moderate calculation and strong robustness. Therefore, the compact form dynamic linearization model free adaptive control background image extraction method in this paper can provide technical supports and method selections for video background image extraction.

Keywords: background image extraction; model free adaptive control; compact form dynamic linearization.

1. Introduction

In modern society, people have depended on the visual impact of images and the security environment provided by video surveillance [1]. In a video, the image is usually divided into static background image and dynamic target image. For the detection algorithm, it mainly includes background extraction and moving target detection. People tend to pay more attention to dynamic objects, and have done a lot of research on accurately separating dynamic targets. However, the background image extraction is a very critical step in the detection of moving targets [2].

Traditional background image extraction methods mainly include median filter [3], Kalman filter [4], Gaussian Mixture Model [5], etc. Although the above methods have achieved good experimental results in the application of specific scenarios, they all rely on specific model assumptions. The real background is difficult to characterize due to the influence of illumination, detector noise, environment change and other factors, which easily leads to model distortion.

Model Free Adaptive Control (MFAC) firstly presented by Hou [6]. This method does not contain mathematical model information for the controlled process, only use the input and output (I/O) data of the system. Now, MFAC method is used in image field. In this paper, using the idea of compact form dynamic linearization (CFDL) MFAC to extract the video background image.

This paper is organized as follows. Section 1 is introduction. Section 2 is the CFDL MFAC background image extraction method. Section 3 discusses the results of the simulation. Section 4 concludes this paper.

2. CFDL MFAC Background Image Extraction Method

For the pixel (m,n) in the video background image, its value can be expressed as a nonlinear single input single output discrete time series $\{y(m,n,1), y(m,n,2), \cdots, y(m,n,k)\}$ about time k. The video background image are slowly affected by natural changes , and the generation of background image satisfying assumptions 1 and 2.

Assumption 1. The partial derivative of series with respect to system outputs and input is continuous.

Assumption 2. The system satisfy generalized Lipschitz, that is, for any $k_1 \neq k_2$, $k_1, k_2 \geq 0$ and $\mathrm{u}(k_1) \neq \mathrm{u}(k_2)$, there has $\|\Delta \mathrm{y}(k+1)\| \leq b\|\Delta \mathrm{u}(k)\|$ with $\Delta \mathrm{y}(k+1) = \mathrm{y}(k+1) - \mathrm{y}(k)$, $\Delta \mathrm{u}(k) = \mathrm{u}(k) - \mathrm{u}(k-1)$, and b is a positive constant.

Therefore, the generation mechanism of background image can be shown with a CFDL MFAC scheme as follows:

$$y(m,n,k)=y(m,n,k\text{-}1)+\phi_c(m,n,k\text{-}1)\Delta\mathrm{u}(m,n,k\text{-}1) \tag{1}$$

where $y(m,n,k)$ is the generation of background image at time k in pixel (m,n); $\phi_c(m,n,k\text{-}1)$ is slow time varying parameter in the background image; and $\Delta\mathrm{u}(m,n,k\text{-}1)$ is the input change of the background generation system.

The representation of $\Delta\mathrm{u}(m,n,k\text{-}1)$ are as follows:

$$\Delta\mathrm{u}(m,n,k\text{-}1)=\mathrm{u}(m,n,k\text{-}1)\text{-}\mathrm{u}(m,n,k\text{-}2) \tag{2}$$

where $\mathrm{u}(m,n,k\text{-}1)$ is the input of the background generation system, which contains the amount that affects the background change.

Thus, the CFDL MFAC background image extraction method can be derived according to the CFDL MFAC scheme as follows:

$$\mathrm{u}(m,n,k)=\mathrm{u}(m,n,k\text{-}1)+\frac{\rho\phi_c(m,n,k)}{\lambda+|\phi_c(m,n,k)|^2}\times(\mathrm{I}(m,n,k+1)\text{-}\mathrm{y}(m,n,k)) \tag{3}$$

$$\widehat{\phi_c}(m,n,k)=\widehat{\phi_c}(m,n,k\text{-}1)+\frac{\eta\Delta\mathrm{u}^{\mathrm{T}}(m,n,k\text{-}1)}{\mu+\|\Delta\mathrm{u}(m,n,k\text{-}1)\|^2}\times(\Delta\mathrm{y}(m,n,k)\text{-}\phi_c(m,n,k)\Delta\mathrm{u}(m,n,k\text{-}1)) \tag{4}$$

$$\hat{\phi}_c(m,n,k)=\hat{\phi}_c(1),\ \text{if}\ \left|\hat{\phi}_c(m,n,k)\right|\le\varepsilon\quad\text{or}\quad\|\Delta\mathrm{u}(m,n,k\text{-}1)\|\le\varepsilon \tag{5}$$

where $\mathrm{I}(m,n,k)$ is the pixel value of the current video image at time k. $\lambda>0$, $\mu>0$ are weight factors, and $\rho\in(0,1)$, $\eta\in(0,2)$ are the step factors. $\hat{\phi}_c(m,n,1)$ is the initial value of $\hat{\phi}_c(m,n,k)$, and ε is a small positive number.

The selective update mechanism can be used when real time update the background image. It can be described as follows:

$$y(m,n,k)=\begin{cases} y(m,n,k\text{-}1) & \text{if } \mathrm{Q}=0 \\ y(m,n,k\text{-}1)+\phi_c(m,n,k\text{-}1)\Delta\mathrm{u}(m,n,k\text{-}1) & \text{if } \mathrm{Q}=1 \end{cases} \tag{6}$$

where $\mathrm{Q}=0$ means that $\mathrm{I}(m,n,k)$ is detected significantly different from $y(m,n,k\text{-}1)$, which indicates pixel (m,n) at time k belong to the dynamic object. $\mathrm{Q}=1$ means that the difference between $\mathrm{I}(m,n,k)$ with $y(m,n,k\text{-}1)$ is small, which indicates pixel (m,n) at time k is belong to the background image.

3. Simulation and Results

3.1 Extraction Results

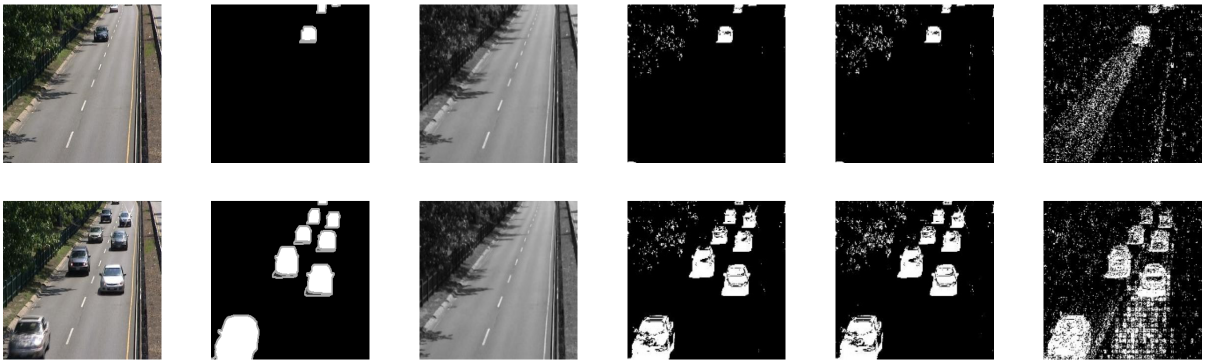
The proposed background extraction method have tested in different video sequences obtained from ChangeDetection.net [7]. The background extraction results of the proposed method are shown in Fig.1. There is a clear difference compared with the Kalman filter[4]. The CFDL MFAC method can extract the background image of the video faster than Kalman filter and maintain good robustness as the vehicle traveling. In contrast, the Kalman filter method produces ghosting as the vehicle traveling.

The processing effect of the video sequence “highway” (seeChangeDetection.net) is shown in Fig.2. The selected test video is the video on the highway. The two traditional methods of Kalman filter [4], Gaussian Mixture Model method (GMM) [5] are compared with proposed method. The experimental results show the separated foreground by the proposed method is closer to the artificially recognized target true value, which further shows that the method has better suppression effect on interference noise. The choice of each parameter in the control schemes (3) and (4) will also affect the experimental results, so it should be carefully select. After experimental selection, the paper finally selects: $\hat{\phi}_c(1)=0.2$, $\rho=0.1$, $\lambda=1$, $\mu=1$, and $\eta=1$.

(a) (b) (c)

(a) Current video image; (b) Background image by the Kalman filter; (c) Background image by the proposed method; The video frames are #10, #126.

Fig.1 Background image extraction of the proposed method and Kalman filter method in video sequence “freeway”.



(a) (b) (c) (d) (e) (f)

(a) Current video image; (b) Artificially recognized target true value; (c) Background image by the proposed method; (d) Target by the proposed method; (e) Target by the Kalman filter method; (f) Target by the GMM method; The video frames are #600,#800.

Fig.2 Target detections of the proposed method and other methods in video sequence “highway”.

3.2 Extraction Evaluations

The background image extraction method is often evaluated for moving target detection. Using the processing effect of the video sequence "highway", we carried out a comparative study of the Kalman filter, GMM and the CFDL MFAC method. The criteria of Recall, Precision, Percentage of Correct Classification (PCC), and F-measure are used to test the representation of different background image extraction methods, which can be defined as follows:

$$\text{Recall} = \frac{\text{TB}}{\text{TB} + \text{FF}} \tag{7}$$

$$\text{Precison} = \frac{TB}{TB + FB} \tag{8}$$

$$PCC = \frac{TB + TF}{TB + TF + FB + FF} \tag{9}$$

$$\text{F-measure} = 2\frac{\text{Precison} \times \text{Recall}}{\text{Precison} + \text{Recall}} \tag{10}$$

where TB stands for the accurately identified background image pixel number, TF represents the number of foreground that are accurately identified, FB is the number of foreground that are misidentified as the background, the FF represents the wrong number of background point identified as foreground.

Comparison and quantitative analysis of video sequence highway from ChangeDetection.net have been shown in Figs. 3-6, which gives a quantitation of 500 to 1690 frames of this video sequence. As shown in Figs. 3-6, The CFDL MFAC method stay at a high level in all four aspects, which indicate that the proposed method has an excellent overall performance compared with traditional methods.

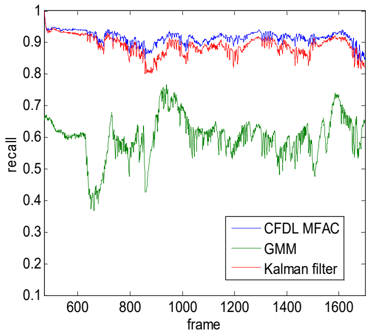


Fig.3 Comparison of recall

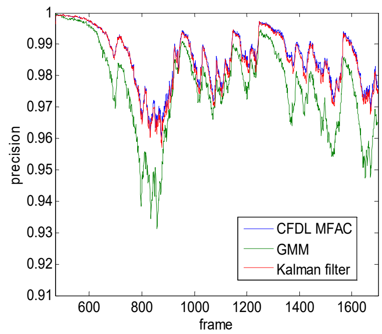


Fig.4 Comparison of precision

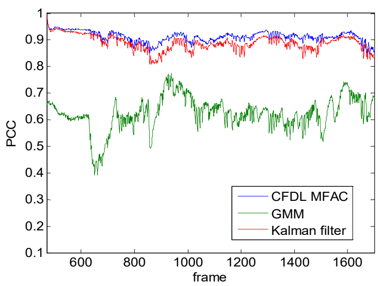


Fig.5 Comparison of PCC

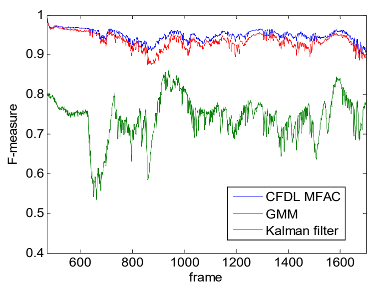


Fig.6 Comparison of F-measure

4. Summary

Based on the CFDL MFAC method, this paper establishes a background image extraction method which can obtain the background intuitively and improve the accuracy of target detection compared with traditional methods.

In the future, the background obtained by this method can provide basis for other research that needs background information.

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