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Background Modeling using PID Control

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Abstract. Methods for common background modeling and detection have been advanced based on the assumption that the extracts and scenes are at a stagnant state with a slight movement. This research delivers an algorithm based on the Proportional-Integral-Derivative (PID) controller to efficiently process an accurate detection of a real-time mobile object. In comparison, unlike the usual methods, the outcomes derived from experiments based on PID demonstrated that the suggested method acclimates swiftly to the changes of the dynamic background. This method was effective and successful in accomplishing precisely detecting mobile objects and suppressing lot of the false detections possibly produced by the dynamic changes in the background.

Keywords: Background modeling, background subtraction, Proportional-Integral-Derivative (PID), mixture of Gaussian

1 Introduction

Background detection is the process of separating out foreground objects from the background in a sequence of video frames. It is used in many emerging video applications, such as video surveillance, traffic monitoring, and object tracking. In recent years, numerous research projects have been carried out in developing traffic management systems [1]. Recognizing mobile objects from a video sequence is a fundamental and significant task in various applications regarding computer-vision. A commonly known approach is to perform a background subtraction, which identifies mobile objects from the portion of a video frame that differs significantly from a background model. A good background modeling algorithm must be robust against changes in illumination and must avoid detecting non-stationary background objects. A background removal system should adapt to changes in illumination regardless of gradual, sudden, global or local changes. Some of these challenges can be handled by costly computational methods; however, like the demands of the most newly developed applications, the primary concern is to shorten the processing time. The goal of the proposed method is computationally efficient enough for a commercial application and a worthy representation of background subtraction implementations in applications, such as a traffic monitoring.

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2 Background Detection

Many methods exist for background detection, each with different strengths and weaknesses in terms of performance and computational requirements. The techniques used to obtain information based on background objects are practical for collecting and gathering precise foreground information in a scene [2]. Since the cameras are installed at a fixed location, the information on the background can be collected from the image by the mixture of Gaussian models [3]. The probability that a pixel has a value x_N at a time N can be modeled by the sum of K weighted Gaussians:

$$p(x_N) = \sum_{i=1}^{K} w_i \cdot \eta(x_N; \mu_i, \Sigma_i) \tag{1}$$

where w_i is the weight of the i^{th} Gaussian. Also, η (.) is the normal distribution with its mean value μ_i and the covariance matrix Σ_i of the i^{th} Gaussian. For a given video image sequence, the gray scale of each pixel is modeled as time passes by a mixture of K Gaussian distributions. When a pixel matches any of the first B Gaussians decided by Eq. (1), it is classified as a background pixel, otherwise, a foreground pixel:

$$B = \arg\min_b \left(\sum_{k=1}^{b} w_k > T \right) \tag{2}$$

where T is a constant to determine the minimum portion of the background in the scene. Among the high-complexity methods, Mixture of Gaussian has a great performance results for the dynamic scenes; however, despite of its efficiency, the process itself is computationally complicated [4,5].

A Proportional-Integral-Derivative (PID) controller is a control loop feedback mechanism widely used in industrial control systems [6]. A PID controller consists of a proportional element, an integral element, and a derivative element, all three connected in parallel. The PID control scheme is named after its three correcting terms, whose sum constitutes the manipulated variables where all of them take the error as input. A PID controller calculates an error value as the difference between a measured process variable and a desired set-point. The controller attempts to minimize the error by adjusting the process through use of a manipulated variable. Defining $u(t)$ as the controller output, the final form of the PID algorithm is:

$$u(t) = K_p e(t) + K_i \int_0^t e(\tau) d\tau + K_d \frac{de(t)}{dt} \tag{3}$$

where K_p, K_i, K_d are the gains of proportional, integral and derivative, respectively. The variable being adjusted is called the manipulated variable which usually is equal to the output of controller. If a pixel in the current frame has a value larger than the corresponding background pixel, the background pixel is incremented by small value based on PID, or vice versa.

3 Experiments and Discussions

Fig. 1 shows the PSNR values for median, Mixture of Gaussians (MoG), and the proposed method. It was found that the PSNR value of 30dB was sufficient enough to be able to extract a good quality background image. As additional data sets of calculating the median were added, the values from the median method increased exponentially. In the case of MoG, the background model does not adapt quickly adequately; therefore, the values gradually increased up to 30dB. The proposed method converges very rapidly to 30dB. As well as being simple, it does not require setting parameters and since it only utilizes the previous and current frames, it does not need memory space. However, once the values near 30dB it begins to fluctuate primarily because it only uses two consecutive frames, at which point if there are fast moving objects, it undergoes a minor fluctuation, such as frames between 220 and 250 in Fig. 1. Experiments with urban traffic sequences have shown that our proposed algorithm produces performance that is comparable or better than other background subtraction techniques as shown in Fig. 2. It shows an example of an original video image and the background image after extraction. Instead of collecting the background information each and every time, the background images gathered will be saved in the dataset and will be used for several hours.

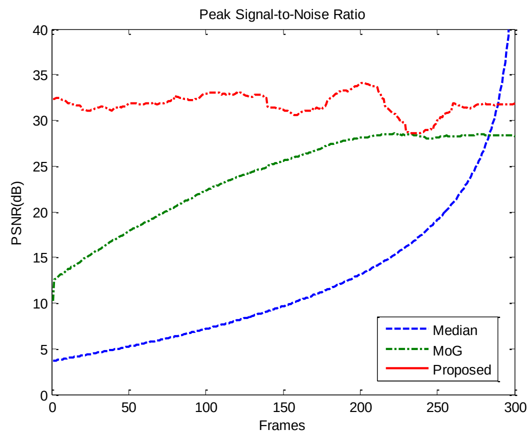

Fig. 1. PSNR values for median, Mixture of Gaussian (MoG), and the proposed method.

4 Conclusions

To overcome the complicated computational process of Mixture of Gaussian (MoG) method, during this research we presented an algorithm based on the PID controller to be able to efficiently process and detect a real-time mobile object. Unlike the widely known conventional methods, the proposed method is insensitive to especially for the traffic monitoring system. However, further research is deemed required to enhance robustness against environmental noises, sudden changes of illumination, and to provide a balance between a fast adaptation and robust modeling. The process for detecting background and minimizing errors is still ongoing.

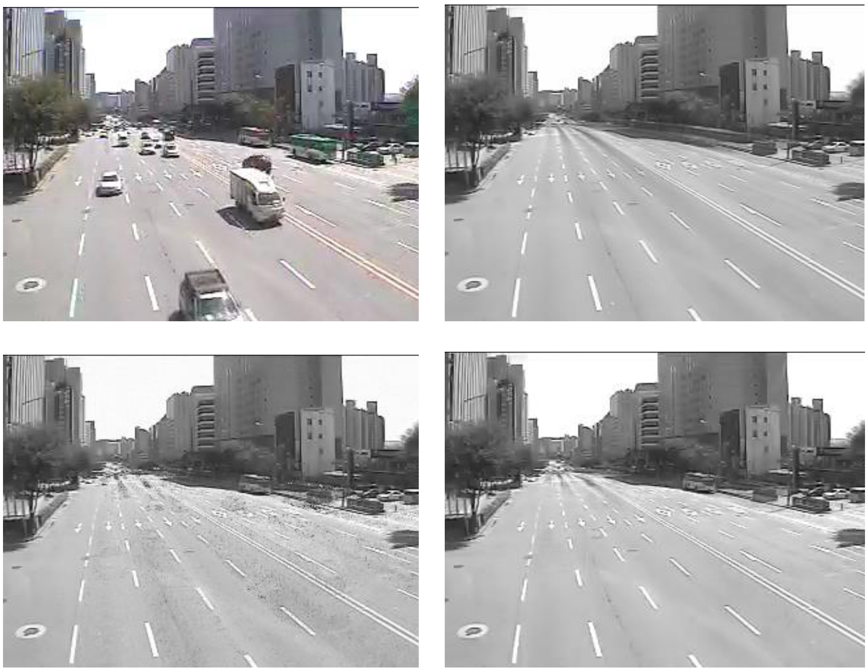

Fig. 2. Background models: original image (*top-left*), median (*top-right*), Mixture of Gaussian (*bottom-left*), and the proposed method (*bottom-right*).

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