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A background modeling and foreground segmentation approach based on the feedback of moving objects in traffic surveillance systems

Qiang Ling *, Jinfeng Yan, Feng Li, Yicheng Zhang

Department of Automation, University of Science and Technology of China, Hefei 230027, China

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ABSTRACT

Background modeling and foreground segmentation are the foundation of traffic surveillance systems. The preciseness of the background model and the accuracy of the foreground segmentation will directly affect the subsequent operations, such as object detection, target classification and behavior understanding. Additionally, the processing time is limited for real applications. The background modeling and foreground segmentation approaches, unfortunately, often have to make two tough trade-offs, including the one between the robustness to background changes and the sensitivity to foreground abnormalities and the other between suppressing noise and reducing the erroneous holes and splitting in foreground segmentation. To deal with these problems, an improved background modeling and foreground segmentation approach based on the feedback of the tracking results of moving objects is proposed. According to the achieved object tracking results, a frame image is divided into four kinds of regions, then a dual-layer background updating is done for these different regions with appropriate operations, which can significantly improve the quality of the background model. Based on the spatial relationship among the tracked objects, the predicted object blocks are merged into regions, among which adaptive segmentation thresholds are used for foreground segmentation. This adaptive threshold approach can efficiently avoid the erroneous holes and splitting in foreground segmentation. Our proposed approach is validated with several public data sets, which confirm its advantages over many existing approaches.

1. Introduction

In recent years, intelligent video surveillance systems have caught the interests of many researchers. Some approaches have been proposed to build a robust video surveillance system [1,2]. However, in traffic surveillance systems, to build a precise background model and develop an accurate foreground segmentation strategy is still a challenging task. In this paper, we attempt to accomplish this task based on the feedback of the tracking results of moving objects. Note that we treat an object as part of the background when it enters into the scene and stops moving.

In intelligent video surveillance systems, the procedures in Fig. 1(a) are usually followed. Each of the module in Fig. 1(a) works consecutively. Background modeling and foreground segmentation have effects on the subsequent object extraction, recognition and tracking, but not vice versa.

Among various background modeling approaches [3–5], the Gaussian mixture modeling (GMM) is the most commonly used due to its robustness and effectiveness [3]. Now there are many improved approaches based on GMM [6–11]. The GMM based approaches, however, cannot well balance the model robustness and the model sensitivity due to the fixed learning rate. In the real road scene, it is often the case that the participates, such as cars, pedestrians, move in different speeds, and sometimes begin to move or stop moving suddenly. So if the learning rate is set too high, the slowly moving objects will be mistaken for the background. If the learning rate is set too low, it has to take a long time to get a good background model for the regions where objects suddenly sleep or wake up.[1] So many false alarms could be produced if the chosen learning rate is not appropriate.

To obtain a better trade-off in background modeling, the mode with feedback f_1 in Fig. 1(b) is taken in [9,17–21]. In [9,18], two GMM-based approaches consider high-level feedbacks, apply different learning rates for different regions in foreground background modeling, and achieve better foreground segmentation results. Some other GMM-based approaches in [17,19] propose different weight updating schemes based on object-level feedback to improve the performance. In [20], two complementary background models are proposed for detection of static and moving objects, then different model updating operations are

* Corresponding author. Tel.: +86 551 63600504.
E-mail address: qling@ustc.edu.cn (Q. Ling).

[1] "*Sleep*" in this paper means that a moving object begins to stop. "*Wake up*" in this paper means that a still object begins to move.

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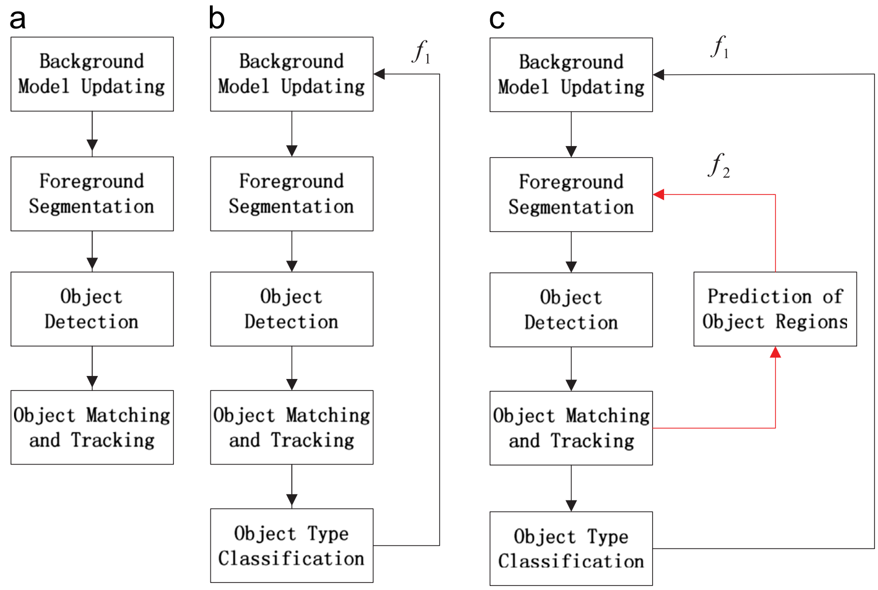

Fig. 1. The different procedures of intelligent video surveillance systems. (a) The traditional serial mode, (b) the feedback mode in [19] and (c) the feedback mode in the present paper.

executed in corresponding object regions. Beyond these GMM-based approaches, [21] is a nonparametric approach, where dynamic controllers are introduced to adjust the background updating parameter according to the object feedbacks.

There, however, still exist some problems. First of all, as discussed in [17,19], the major problem of using feedback for background modeling lies in that the mis-classification of pixel types in the current frame will propagate to subsequent frames. The mis-classification, unfortunately, is inevitable in such pixel based approaches. Second, it does little work in dealing with foreground segmentation, which will produce some problems in the subsequent operations. Furthermore, it establishes a complicated mixing Gaussian model for each pixel and needs to update the parameters of all pixels in each frame, which is time-consuming.

There are also many results focusing on foreground segmentation [12–16]. The typical foreground segmentation approaches determine that a pixel belongs to the foreground if the difference between the current frame and the background model in that position is larger than a given threshold. In [12,13], a precise foreground is obtained when the accuracy and robustness of the background model is high. In [14], the segmentation threshold for a pixel is a variable depending on whether its neighbors belong to the foreground. In [15], foreground segmentation is realized by fusing motion, color and contrast information. In [16], it first converts a given pixel-based segmentation into a probabilistic superpixel representation. Based on these probabilistic superpixels, a Markov random field exploits structural information and similarities to improve segmentation. The above approaches, however, cannot yet achieve a good trade-off between suppressing noise and reducing the erroneous holes and splitting in foreground segmentation.

To resolve the above issues, this paper proposes to feedback the object tracking results to improve both background modeling and foreground segmentation, as shown in Fig. 1(c). By feedback f_1, a dual-layer updating scheme achieves a better background model, which can not only be well adapted to the slow change of the scene, such as lighting change, but also respond fast when a foreground object blends into the background or an object escapes from the background. Moreover, the incorrect classification of object types almost has no harm on the background model. By feedback f_2, a better trade-off in foreground segmentation can be obtained, which can not only suppress noise, but also reduce the erroneous holes and splitting in foreground segmentation.

The contributions of this paper can be summarized as follows.

- A novel dual-layer background modeling approach based on the feedback of the tracking results of moving objects is proposed. It can well deal with the trade-off between model robustness to background changes and model sensitivity to foreground abnormalities. Moreover, unlike [9,19], the mis-classification of objects nearly have no harm to the performance under our approach.
- A novel foreground segmentation based on the object tracking feedback is proposed. It well handles the trade-off between suppressing noise and reducing erroneous holes and splitting in foreground segmentation.
- This paper takes a simpler model for background modeling and is much less time-consuming than conventional GMM based approaches with comparable performance in the traffic videos. So it is more suitable for real road surveillance applications.

The rest of the paper is organized as follows. Section 2 gives an overview of our approach. In Section 3, the details of object detection and tracking are proposed. Section 4 describes the background model updating based on the feedback of object tracking results. The foreground segmentation approach based on the feedback of object tracking results is explained in Section 5. In Section 6, experimental comparisons and analysis are presented. In Section 7, some final remarks are placed.

2. The overview of our algorithm

Our algorithm follows the procedure in Fig. 1(c), which has two feedbacks, f_1 and f_2, for background modeling and foreground segmentation. Now we give a brief overview regarding the main modules in Fig. 1(c).

2.1. Background model updating module

In the real road surveillance video applications, the background model must be robust to the noise. At the same time, the model must be sensitive to the foreground abnormalities. Especially when