Detecting Foreground Objects Under Sudden Illumination Change Using Double Background Models

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Abstract

In video sequences, foreground object detection being composed of a background model and a background subtraction is an important part of diverse computer vision applications. However, object detection might fail in sudden illumination changes. In this letter, an illumination-robust background detection is proposed to address this problem. The method can provide quick adaptation to current illumination condition using two background models with different adaption rates. Since the proposed method is a non-parametric approach, experimental results show that the proposed algorithm outperforms several state-of-art non-parametric approaches and provides low computational cost.

Keyword : background modeling, foreground detection, illumination change, double backgrounds

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could be mistakenly classified as the foreground yielding false positives. Conventional background modeling belongs to either parametric or non-parametric approach. In both, current pixels varying significantly from the background image are chosen as foreground pixels[1-4].

The performance of a foreground detection highly depends on a reliable background model. The state-of-art methods[5-11] are mostly devised for gradual illumination changes and fail to handle sudden changes such as light on/off. Illumination change condition (ICC) can affect the performance of the foreground object detection due to many false alarms and may lead to a system malfunction.

In this letter, a non-parametric background modeling employing double backgrounds as well as illumination compensation is proposed. Two main functionalities are the utilization of double backgrounds as well as the fast compensation of them to new illumination condition. Fig. 1 shows the overall flow of the proposed method.

\[ FG^L_t(i) = \begin{cases} 1, & \text{if } |I_t(i) - BG^L_t(i)| > T_L \\ 0, & \text{otherwise} \end{cases} \]

where \( T_L \) is the long-term background threshold. Similar thresholding method is performed for the STBM \( BG^S_t \) with a threshold \( T_S \) resulting in a binary mask \( FG^S_t \). Since \( BG^S_t \) is used to extract all pixels with significant temporal activities, a smaller threshold is chosen (\( T_S = 0.4T_L \)). \( T_L = 50 \), \( T_S = 20 \) are used in experiments.

Current LTBM is updated by integrating a current frame \( I_t(i) \) into a previous model \( BG^L_{t-1} \) and is computed by

\[ BG^L_t(i) = \alpha_1 I_t(i) + (1 - \alpha_1) BG^L_{t-1}(i) \]

where \( \alpha_1 \) is an adaption parameter. Similarly, a STBM is computed using an adaption parameter \( \alpha_S \).

Double backgrounds are utilized for ICC. The proposed method evaluates the responses of STBM and LTBM using the following thresholds:

1) \( T_{LU} = 2T_L \): Using this threshold, pixels that are changed drastically from the LTBM are extracted as foreground pixels whose binary mask is \( FG^L_U \).
2) \( T_{SU} = 2T_S \): This threshold is used to obtain a foreground mask \( FG^S_U \) from STBM with less false detection than \( FG^S \).

The proposed updating strategy is used only in ICC, where the ratio of the number of foreground and background pixels of \( FG^S_t \) is higher than a threshold \( T_k \). The updating process consists of computing average illumination change followed by illumination compensation of background models.
(a) Average illumination change: In order to estimate the amount of illumination change, the difference between \( m(BG_i^L) \) and \( m(BG_i^S) \) is computed using some selected pixels, where \( m(\bullet) \) is a mean value of (\( \bullet \)). Based on the responses of them, we exclude two pixel groups that are not suitable for average computation. 

Estimated average illumination change (EAIC) of the current frame from the STBM and LTBM are calculated by

\[
EAIC_i^L = m(I_i) - m(BG_i^L) \\
EAIC_i^S = m(I_i) - m(BG_i^S)
\]

(b) Illumination compensation: The aim of per-pixel illumination compensation is to update the pixel values by using EAIC as a gain value, however, some pixels may not show a considerable change. Thus, the pixels are divided into two categories for updating:

- \( |I_i - BG_{i-1}(i)| < EAIC \): The current pixels that are changed by less than average or remained unchanged are not updated. For this, an adaptive parameter \( \beta_d \) is computed for each pixel according to the distance of the current pixel from its co-located background pixel \( (I_i - BG_{i-1}(i)) \). Using \( \beta_d \), the LTBM is updated by

\[
BG_i^L(i) = BG_{i-1}^L(i) + \beta_d(i)(I_i - BG_{i-1}^L(i)) \tag{4}
\]

\[
\beta_d(i) = (\beta_{\text{EAIC}} - 1) \frac{|I_i - BG_{i-1}^L(i)| + \beta_0}{EAIC_i^L}
\]

where \( \beta_0 \) is set to 1 and \( \beta_{\text{EAIC}} \) to 0.5 in experiments.

- \( |I_i - BG_{i-1}(i)| \geq EAIC \): For pixels changed more than EAIC, the LTBM is updated by a constant gain by

\[
BG_i^L(i) = \begin{cases} 
BG_{i-1}(i) + \beta_{\text{EAIC}} \cdot EAIC_i^L, & \text{if } |BG_i^S(i) - I_i| < I_i \\
BG_{i-1}(i) - \beta_{\text{EAIC}} \cdot EAIC_i^S, & \text{if } |BG_i^S(i) - I_i| \geq I_i 
\end{cases} \tag{5}
\]

The selective updating methodology is similarly performed for STBM. From the updated background, a final foreground mask \( FG_i^L(i) \) is obtained by \( FG_i^L(i) \cdot FG_i^S(i) \).

III. Experimental Results

The performance of the proposed system is compared with five foreground detection methods; Double backgrounds (DBG)\(^6\), Eigen background\(^4\), MoG\(^3\), KDE\(^2\) and ViBe\(^6\). In Seq1, there are no moving objects during illumination change and humans enter a room after sudden changes while in two other sequences, moving humans exist during subsequent illumination changes. First we examined the performance of the algorithms during sudden illumination change in terms of FP (false positive) and TP (true positive) rates. The accuracy of foreground binary mask is evaluated through use of Recall=TP/(TP+FN) and Precision=TP/(TP+FP). F-score compares the binary masks with ground truth (GT).

표 1. 비고 방법들과의 성능 비교

<table>
<thead>
<tr>
<th>Method</th>
<th>F-score</th>
<th>Seq1</th>
<th>Seq2</th>
<th>Seq3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eigen</td>
<td>0.509</td>
<td>0.280</td>
<td>0.150</td>
<td></td>
</tr>
<tr>
<td>MoG</td>
<td>0.647</td>
<td>0.414</td>
<td>0.313</td>
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<tr>
<td>KDE</td>
<td>0.203</td>
<td>0.113</td>
<td>0.096</td>
<td></td>
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<tr>
<td>ViBe</td>
<td>0.276</td>
<td>0.229</td>
<td>0.158</td>
<td></td>
</tr>
<tr>
<td>DBG</td>
<td>0.614</td>
<td>0.508</td>
<td>0.480</td>
<td></td>
</tr>
<tr>
<td>Proposed</td>
<td>0.896</td>
<td>0.754</td>
<td>0.719</td>
<td></td>
</tr>
</tbody>
</table>

Table 1 compares the overall performance of the proposed algorithm with other methods in three sequences. As shown in the Table, our proposed approach significantly outperforms five methods in all sequences. The proposed method is able to detect the moving objects with high accuracy in three sequences and shows an acceptable performance. Fig. 2 shows the resulting foreground objects detected by five comparative methods and the proposed. The results show that our method outperforms other methods. The processing speed of the proposed method is
V. Conclusion

A novel foreground detection was proposed that can address the illumination change problem. The algorithm utilizes two background models with slow and fast adaptation rates for accurate illumination compensation. The proposed method delivers promising detection results in sudden illumination change and outperforms several state-of-art methods.

참 고 문 현 (References)