A fuzzy background model for moving object detection

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Abstract

Background modeling is a key step of background subtraction methods used in the context of static camera. The goal is to obtain a clean background and then detect moving objects by comparing it with the current frame. This paper describes a novel fuzzy approach for moving object detection which is capable of processing images extremely rapidly and achieving high detection rates. This work integrates the Local Binary Pattern texture feature and HSI color feature by a novel fuzzy way using the Choquet integral, which extends the moving object detection work for light illumination changing and shadowing. The results of several dataset videos show the robustness and effectiveness of the proposed method.

1 Introduction

Background subtraction is often one of the first tasks in machine vision applications, making it a critical part of the system. The output of background subtraction is an input to a higher-level process that can be, for example, the tracking of an identified object. The performance of background subtraction depends mainly on the background modeling technique used to model the scene background [1,2]. Especially natural scenes put many challenging demands on background modeling since they are usually dynamic in nature including illumination changes, swaying vegetation, rippling water, flickering monitors etc. A robust background modeling algorithm should also handle situations where new stationary objects are introduced to or old ones removed from the scene. Furthermore the shadows of the moving and scene objects can cause problems. Even in a static scene frame-to-frame changes can occur due to noise and camera jitter.

In this paper, we proposed a novel model for background maintenance and subtraction. The model aggregates color and texture features using fuzzy approach. The goal of the new model was to address all of the above-mentioned difficulties. This method integrates the Local Binary Pattern texture feature and HSI color feature by a novel fuzzy way using the Choquet integral, which extends the moving object detection work for light illumination changing and shadowing.

2 New approach

2.1 approach overview

Moving object detection is based on a comparison between current and background images. In general, a simple subtraction is made between these two images to detect regions corresponding to moving object.

Figure 1 Our approach overview

In this paper, we define a similarity measure between pixels in current and background images. In this case, pixels corresponding to background should
be similar in the two images while pixels corresponding to foreground should not be similar. In Figure 1, the moving object detection process is presented in details. First, the color and texture features are extracted from the background image $B_t$ and the current image $I_t$. The similarity measures are computed for each feature which is then aggregated by the Choquet integral. The Background/Foreground classification is finally made by threshold the Choquet integral’s result. In the following subsections, we describe the rationale for selecting and fusing the set of the adopted features.

2.2 Color feature similarity measure

In order to remove the shadows’ disturbance, pixels that could be part of a shadow have to be identified. RGB is the color space commonly acquired directly from a sensor or camera. HSI and YCbCr are closer to human interpretation of colors in the sense that brightness, for intensity, is separated from the base color. The best feature should decrease their sensitive to shadows. We choose HSI color space [3], and define the color features with HSI three components noted $C_1$, $C_2$ and $C_3$. Then, the color similarity measure $S_k(x, y)$ at the pixel $(x, y)$ is computed as:

$$S_k(x, y) = 1 - \frac{|I_k(x, y) - B_k(x, y)|}{255} \quad (2)$$

Where $k \in \{1, 2, 3\}$ is one of three color features. $B(x, y)$ and $I(x, y)$ respectively represent the background and current image at time $t$. Note that $S_k(x, y)$ is between 0 and 1. Furthermore, $S_k(x, y)$ is close to one if $B_k(x, y)$ and $I_k(x, y)$ are very similar.

2.3 Texture feature similarity measure

The proposed texture-based method for background subtraction is based on the Local Binary Pattern (LBP) texture measure. The LBP is a powerful means of texture description [4]. The operator labels the pixels of an image block by threshold the neighborhood of each pixel with the center value and considering the result as a binary number (LBP code):

$$LBP(x_c, y_c) = \sum_{i=0}^{K-1} f(p_i - p_c)2^i \quad (3)$$

Where $p_c$ corresponds to the pixel value of the center pixel $(x_c, y_c)$, such as gray, intensity value etc. and $p_i$ to the pixel values of the $K$ neighborhood pixels. The function $f(x)$ is defined as follows:

$$f(x) = \begin{cases} 1 & x \geq 0 \\ 0 & x < 0 \end{cases} \quad (4)$$

The original LBP operator worked with the $3 \times 3$-neighbourhood of a pixel [5]. See Figure 2 for an illustration of the operator, calculating the intensity value of pixel $x$. The histogram of the LBP codes calculated over an image block can be used as a texture descriptor for the block. As can be seen from (3), the LBP is invariant to monotonic changes in pixel value scale.

$$ST(x,y) = \frac{|I_{LBP}(x,y) - B_{LBP}(x,y)|}{255} \quad (5)$$

Where $I_{LBP}(x,y)$ and $B_{LBP}(x,y)$ are respectively denotes the texture LBP code of pixel $(x, y)$ in the background and current images. Note that $ST(x,y)$ is between 0 and 1. Furthermore, $ST(x,y)$ is close to one if $I_{LBP}(x,y)$ and $B_{LBP}(x,y)$ are very similar. In the false positive foreground areas caused by quick lighting...
changes, there are no texture changes between the current frame and the background. Hence, $S_t(x,y)=1$. The foreground mask will be removed for the areas with $S_t(x,y)\geq T_c$. For this operation, we have chosen the choquet integrals.

### 2.4 Aggregation of Features by Choquet Integrals

Many fusion techniques can be used to fuse the color and the texture features. We present brief necessary concepts around fuzzy measures and the Choquet integrals. Comprehensive treatments of this topic can be found in [6-8].

Let $\lambda$ be a fuzzy measure on a finite set $X$, and non-additive measure on a subset of $X$ is any function $\mu: X \rightarrow [0, 1]$. Let $\lambda$ be fuzzy measure on a finite set $X$, and non-additive measure on a subset of $X$ is any function $\mu: X \rightarrow [0, 1]$.

**Definition 1** The Choquet integral of $\mu$ with respect to $\lambda$ is defined by:

$$C_\lambda = \sum_{i=1}^{n} \left( \mu(x_{\sigma(i)}) - \mu(x_{\sigma(i-1)}) \right) \lambda(A_{\sigma(i)})$$

(6)

Where finite set $X = \{x_1, \ldots, x_n\}$, and $\sigma$ is a permutation of the indices such that $\mu(\sigma(1)) \leq \cdots \leq \mu(\sigma(n))$ and $A_{\sigma(i)} = \{\sigma(i), \ldots, \sigma(n)\}$.

In Background/Foreground classification, the more criteria provide information about the pixel, the more relevant the decision of pixel’s state.

For each pixel, color and texture similarity measures are computed as formula (2) (5) from the background and the current frame. We define the set of criteria $X = \{a_1, a_2, a_3, a_4\}$ with $(a_1, a_2, a_3)$ = three components color features of the chosen HSI color space and $a_4 = $ texture feature $LBP(x, y)$. To compute the fuzzy measure of the union of any two disjoint sets whose fuzzy measures are given, we use an operational version proposed by Sugeno [7] which called $\lambda$-fuzzy measure.

The pixel at position $(x, y)$ is considered as foreground if its Choquet integral value is less than a certain threshold $T_{c,t}$, which denote the threshold at time instant $t$, as follows:

If $C_{\mu}(x, y) < T_{c,t}(x, y)$ then pixel $(x, y)$ is foreground or moving object, else background.

### 3 Experimental results

The performance of the proposed method was evaluated using several video sequences. Both indoor and outdoor scenes were included.

We have compared our method with the improved GMM modeling. Algorithms were implemented under Microsoft Visual C++ using the OpenCV library. The experimental results demonstrate the effectiveness of our algorithm for motion detection in a variety of environments.

**3.1 Experiments on indoor dataset**

Fig. 4 compares a moving object detection result on the indoor test sequence from Wallflower [9], where a person is walking in a room, by GMM algorithm and our approach. Fig. 4a is the background model, and Fig. 4b is frame 650 (random choose) which after a person come in the office. The absolute color components change greatly with the illumination, even when no foreground object is present for the light changing. In Fig. 4c, large areas of false positive foreground were detected by the GMM method for light illumination change. As mentioned above, LBP is invariant to monotonic changes in gray scale. This makes it robust against illumination changes; Fig. 4d shows that our method successfully handles the light illumination changes by integrating texture information.

![Figure 4. Moving object analysis with a person come in the room: (a) background model (b) current frame (c) analysis result using GMM (d) analysis result using our method.](Image)
3.2 Experiments on outdoor dataset

Figure 5 shows the results of our algorithm for the outdoor test sequence, which contains changing environment and shadow. The original sequence has been taken from the PETS database [10]. The proposed algorithm successfully handles this situation. In HSI color space, the feature value changes of pixels in shadow region are very small, so most of the shadows can be removed by integrating HSI color information.

![Figure 5. Moving object analysis from an outdoor test sequence where several persons are walking in a subway station: (a) background model (b) current frame (c) analysis result using GMM (d) analysis result using our method](image-url)

4 conclusion

In this paper, we have presented a novel fuzzy background model for detecting moving objects from video frames. This method using Choquet integral for fuse color features and texture features. It chooses HSI color space instead of RGB, which remove most of the shadow, and aggregates LBP texture feature, which compute easily, to adapt the light illumination change. The proposed algorithm was tested against several standard benchmarks including both indoor and outdoor scenes. Further, the experiments results show that the proposed method is more robust and efficient.

Reference