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Multiple moving object segmentation using motion orientation histogram in adaptively partitioned blocks for high-resolution video surveillance systems

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ABSTRACT

We present an efficient, robust moving object segmentation method that fully utilizes block motion information for high-resolution video surveillance systems. A high-resolution video surveillance system should satisfy two conflicting goals: (i) higher computational efficiency to manage the increasing amount of data and (ii) enhanced functionality in analyzing moving objects. In pursuit of both efficiency and functionality, we first quantize the orientation of motion vectors and then segment moving objects using adaptive block partitioning algorithm. We also present motion orientation histogram-based moving direction estimation. Major contribution of this work is the fully utilization of block motion information provided by either an image signal processing (ISP) chip or a digital signal processor (DSP) built-in software and the optimal representation of moving objects by the block divide-and-merge algorithm. Comparative experiments with the conventional video analysis algorithms show that the proposed method provides better segmentation results with the regular, efficient computational structure that can be easily embedded in an ISP chip or DSP software.

1. Introduction

Segmentation and tracking of moving objects is a fundamental problem in high-level computer vision in such important applications as object-based auto-focusing, robot vision, human–computer interfaces, activity recognition, and intelligent surveillance systems [1–9].

Recently, video surveillance systems are being equipped with high-resolution cameras with high-performance image signal processing (ISP) chips or application-specific video processing software. In this context, it becomes necessary to reduce computational load of video analysis, while there is no limit in the quality and resolution of images. Thanks to the dramatic advances in semiconductor technology, ISP chips in the CCTV camera for surveillance systems are being developed for providing motion information of regularly partitioned blocks.

Background subtraction is a common approach that is used for moving object segmentation because of its computational simplicity, but it often leads to erroneously segmented regions due to noise and flicker dynamic illumination [10,11]. To address this problem, Kim employed RGB color-based background modeling [12], and Zin used a combination of periodic background models for object segmentation [13]. But, these methods are not suitable for real-time high-resolution video surveillance systems because they have high computational complexity for the background modeling. Another drawback is that they may fail in the presence of unpredicted illumination changes or camera motion. Temporal gap between the generated background and the current frame results in ghost artifacts and unstable segmentation under global illumination changes.

In this paper, we present an efficient moving object segmentation method using a motion orientation histogram (MOH) of adaptively partitioned blocks. A block diagram of the overall system is shown in Fig. 1. Specifically, given the motion vectors of a regularly partitioned image, each vector is classified into one of eight possible orientations in order to reduce memory space and computational load. In parallel, initial shapes of moving objects are estimated using frame differencing and local binary patterns (LBPs). We also partition the input image into 32×32 macroblocks, and

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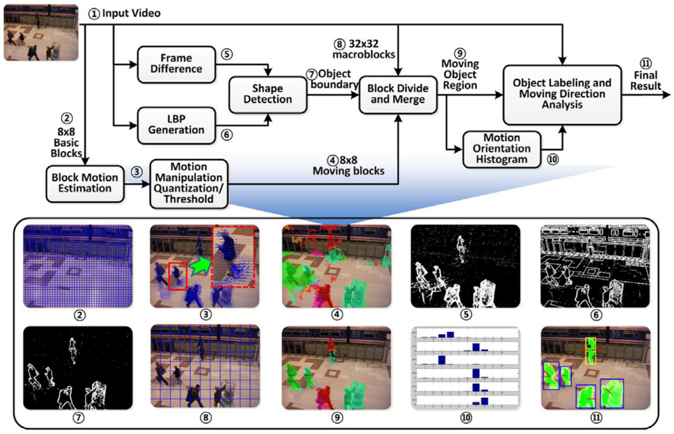

Fig. 1. The proposed moving object segmentation framework.

each macroblock is further divided into smaller blocks to fit the object boundary. The motion vectors of the moving objects that are detected are then analyzed using MOH. The final result is a real-time video with labels and directions of all moving objects.

Major contributions of the paper include: (i) Full utilization of block motion provided by an ISP chip or DSP's standard library, (ii) automatic, accurate boundary detection by combining frame differencing with LBPs, (iii) optimum representation of object region using adaptive block partitioning, and (iv) occlusion and moving direction analysis using MOH. Experimental results show that the proposed method can be embedded in an image signal processing (ISP) chip for high-level image processing functions such as object tracking and behavior analysis in high-resolution video surveillance systems.

The paper is organized as follows. Section 2 presents the block motion quantization method, and Sections 3 and 4 describe the LBP-based adaptive block partitioning and moving object segmentation algorithms, respectively. Experimental results are provided in Section 5 presents experimental results and conclusions are given in Section 6.

2. Quantization of block motions

Given the a set of motion vectors for each block in a regularly partitioned image, we begin by quantizing these motion vectors into one of P different directions. The reason for motion quantization is two-fold, (i) a small number of motion orientations are sufficient to identify and classify moving objects, and (ii) each motion vector that is estimated from a basic block is subject to noise. Lee has proposed a global motion estimation method for digital image stabilization in [14], where multiple local motion vectors are classified into one of eight orientations in order to reduce memory and computational load. Inspired by this work, we propose a generalized motion orientation classification method for block motion-based moving object segmentation. Specifically, let (m_x, m_y) be a motion vector that is estimated for a given block, and let θ be its orientation where

$$\theta = \tan^{-1}\left(\frac{m_y}{m_x}\right). \quad (1)$$

If we want to classify the estimated orientation into one of $P+1$ directions, such as $\{\theta_0, \theta_1, \theta_2, \ldots, \theta_P\}$, where θ_0 represents the zero motion vector and $\{\theta_1, \ldots \theta_P\}$ represents a set of P classified motion orientations.

Let $f_t(x, y)$ be the t-th frame of a video sequence of size $M \times N$, and B_t^i the i-th block of size 8×8 in frame $f_t(x, y)$, for $i = 1, \ldots, MN/64$. For convenience, it is assumed that both M and N are integer multiples of 8.

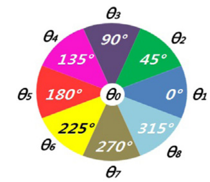

Fig. 2. Nine regions for classified motions with $P = 8$.

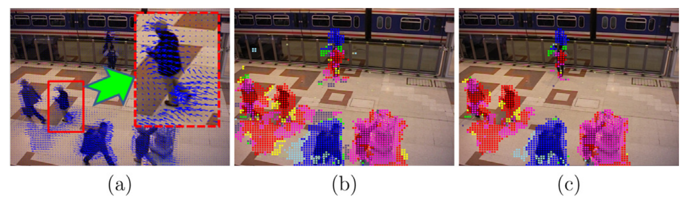

Fig. 3. Motion-based object segmentation; (a) basic motion vectors superimposed to the input image, (b) motion-based segmentation result using quantized motion vectors with T_θ=0.4, and (c) T_θ=1.0.

If $m^i = (m_x^i, m_y^i)$ is the estimate of the motion vector of block B^i, then the classified orientation is given by

$$\theta_c^i = \begin{cases} \theta_0, & \sqrt{(m_x^i)^2 + (m_y^i)^2} < T_\theta \\ \theta_j, & \dfrac{360}{P}\left(j - \dfrac{1}{2}\right) \le \theta < \dfrac{360}{P}\left(j + \dfrac{1}{2}\right) \end{cases}, \quad (2)$$

for $j = 1, 2, \ldots, P$, where T_θ represents the threshold for the minimum nonzero motion. Although P can be any number, we use $P = 8$ as shown in Fig. 2.

Fig. 3(a) shows the estimated motion vectors of basic blocks. Although there are many erroneous motion vectors having the small motion magnitudes as shown in Fig. 3(a), the quantization significantly reduces erroneous motions as shown in Fig. 3(b) and (c), which enables accurate estimate of the direction of moving objects.

3. Local binary pattern-based adaptive block partitioning

Basic information is provided from basic blocks such block motions are too elaborate to represent objects larger than the basic block, whereas they are too coarse to accurately represent details in object boundary. To solve this problem, we present an adaptive block partitioning algorithm that combines frame difference and LBP images as shown in Fig. 4.

The Frame difference image is given by

$$D(x, y) = \begin{cases} 1, & |f_t(x, y) - f_{t-1}(x, y)| > T_D \\ 0, & \text{otherwise} \end{cases}, \quad (3)$$

where T_D denotes a pre-specified threshold. Frame differencing is inherently sensitive to illumination changes and shadows, and results in ghosts and holes [15]. Therefore, we extract the boundaries of moving objects using LBP, which can efficiently describe

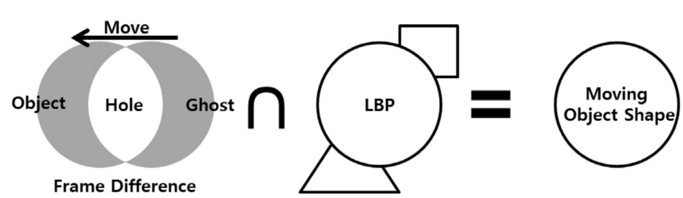

Fig. 4. The concept of the proposed shape detection algorithm combining frame difference and the LBP.