Improved Illumination Independent Moving Object Detection Algorithm in Infrared Video Sequences

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Abstract – **Performance of moving objects detection algorithm on infrared videos is discussed. The algorithm consists of two phases: the noise suppression filter based on spatiotemporal blocks including dimensionality reduction technique for a compact scalar representation of each block and on the moving object detection algorithm resistant to illumination changes that detects and tracks the moving objects. The proposed method is evaluated on monochrome and multispectral IR videos.**

Keywords – **Video surveillance; Motion detection; Infrared videos.**

I. Introduction

In this paper, we evaluate the performance of motion detection algorithm introduced in [1]. Our main goal is to demonstrate that this novel technique is capable of successfully detecting moving objects in infrared videos.

Most of the moving object detection techniques are pixel based [2-5]. Recent approaches [6] are based on the spatiotemporal blocks. The pixel based techniques are resistant to the illumination changes [7] and prone to the influence of noise, while block-based methods are noise resistant [8,9]. We combined both approaches in our new improved method. The novelty introduced is image preprocessing similar to that used in the block-based method. We combine the pixel and region levels to a single level texture representation with 3D blocks and than we continue the image processing on such spatially-temporally filtered pixels. We decompose a given video into overlapping spatiotemporal blocks, e.g., 7x7x3 blocks centered at each pixel, and then apply a dimensionality reduction technique to obtain a compact representation of color or gray level values of each block as a single scalar value. We apply the principal component analysis and use the dominant eigenvector (corresponding to the largest eigenvalue) to obtain the coefficients of 3D filter, that we employ on every current frame. Such filtered images are subsequently treated with the moving detection algorithm based on pixel value [7].

The application of principal component projection instead of original pixels is expected to retain useful information while suppressing successfully the destructive effects of noise [10]. Proposed technique provides motion detection robust to various types of noise that may be present in infra-red video sequences.

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II. Methodology

The technique for moving object detection consists of two major phases: 1) image filtering of a current frame with the noise removal filter coefficients extracted with the PCA analysis [10]; and 2) detection of moving objects applying the pixel based method for moving object detection resistant to illumination changes [1,7].

We treat a given video as three-dimensional (3D) array of gray pixels with two spatial dimensions X, Y and one temporal dimension Z. We use spatiotemporal (3D) blocks represented by N-dimensional vectors, where a block spans $(2T+1)$ frames and contains N_{BLOCK} pixels in each spatial direction per frame $N=(2T+1)\times N_{BLOCK}\times N_{BLOCK}$. To represent the block vector by a scalar while preserving information to the maximal possible extent, we use principal component analysis [10]. For principal component analysis, we estimate sample mean and covariance matrix of representative sample of block vectors corresponding to the considered types of movies and use the first eigenvector of the covariance matrix **S** (corresponding to the largest eigenvalue) that represents the coefficients of the 3D filter that suppresses the noise. The 3D filter can be emulated by three 2D filters applied on frames z-1, z and z+1.

The fourth phase of the proposed method implies the application of a pixel based algorithm for moving object detection and tracking. We calculate the pixel variance in order to estimate the potential movement in the observed area incorporating the illumination compensation coefficient. The algorithm performs the analysis in time and space domains simultaneously, contributing to its resistance to the illumination changes and reducing the false detection, i.e. artifacts. We average estimated pixel variances for three successive pairs of frames and threshold this average to determine the presence of moving objects. This represents temporal aspect of analysis. The time analysis, additionally to space analysis, helps with correct moving object detection and augments the precision of the algorithm. Details of the algorithm are provided in [1,7].

III. Results

In this paper, we demonstrate the performance of the proposed approach on two infrared video sequences. The first sequence, *RoofCam*, is obtained from Ohio State University Thermal Pedestrian Database [11]. Video was captured using a Raytheon 300D thermal sensor core with 75 mm lens.

Camera was mounted on an 8-story building overlooking a pedestrian intersection on the OSU campus. Image size is 360x240 and was captured at varying sampling rates. The second sequence, *RocketLaunch*[1], is false color thermal infrared sequence of Spitzer Telescope launch (25 August 2003 at 1:35:39 a.m. EDT from Cape Canaveral Air Force Station in Florida) taken from 3km distance. The original 45s video shows the rocket passing through a cloud including cooling of the rocket plume after the rocket flies out of flame. In our experiments we use T=1 and N_{BLOCK} = 5 for *RoofCam* and *RocketLaunch*. Processed video-sequences are available on our website: http://ist.temple.edu/~pokie/data/ICEST2005/.

Fig.1 contains two characteristic frames (40 and 194) with the results of the proposed moving objects detection for *RoofCam* video. The identified moving pixels are denoted by red. In the frame 40, four pedestrians appear in the "red" color in the scene. The algorithm is able to identify all four moving objects. The algorithm successfully identifies again all four pedestrians in the frame 194.

It should be pointed out that the proposed algorithm worked with no false alarms in spite of the relatively high level of noise in the considered IR video.

Fig. 2 contains two frames (350 and 450) of the *RocketLaunch* video sequence with indicated results obtained by the application of our moving objects detection algorithm. The frames show two characteristic phases of rocket launch. In the frame 350, the clouds are reflecting the bright infrared light of the hot rocket engines below so that clouds appear to light up and come down to meet the rocket. In this frame, this reflection is clearly identified by our algorithm (red-colored ellipsoid above the rocket top). The algorithm is also able to identify the base of the rocket flame in the frame 450, where the base of the jet appears through the cloud.

The proposed algorithm can identify movement in particular region of interest. To accomplish this, we first define rectangular spatial windows corresponding to the regions of interest and compute the following spatial-windows based evaluation statistics. We count the number of identified moving block within the spatial window and normalize it with the window size.

In Fig. 3a, we show the computed statistics for *RoofCam* sequence on the rectangular block [120:140, 110:130], annotated on Fig. 1. Visual inspection of the video sequence indicates the existence of two moving objects in the block: one in frames 6-65 and another in the frames 242-284. The values of motion statistics correspond to these two intervals, indicating two peaks of motion activity. Observe that the motion statistics value in the frame 40 is large, corresponding to the moving objects actually appearing in the frame within the observed rectangular block (see Fig. 1). Observe that the inertia of the proposed method is minimal; moving blocks cease to be identified in the observed rectangular regions as soon as the actual motion stops. Also, by thresholding the motion statistics, it is possible to get clear indication of the factual presence of the moving object in the rectangular region.

In Fig. 3b, we show the computed statistics for *RocketLaunch* sequence on the rectangular block [70:140, 70:140], annotated on Fig. 2. On frame 260, the base of the flame enters the block, which results in increase of the motion statistics. On frame 342, the cloud reflection appears and grows which results with rapidly augmenting motion statistics value. The reflection disappears at frame 370 and the level of the motion statistics becomes negligible. As we can see, the proposed motion statistics not only could be used to accurately detect the presence/absence of the moving object in the frame but also to distinguish different *phases* of motion.

IV. Conclusion

In this paper we have demonstrated that our illumination and noise-resistant moving object detection algorithm based on principal component filtering and spatiotemporal analysis can perform successful detection of moving objects in infrared videos. As a performance measure we, in addition to a visual evaluation, used spatial-windows based evaluation statistics and hand-labeled ground truth moving objects detection. The inertia of the proposed algorithm is negligible which make it suitable for detecting fast and sudden movement.

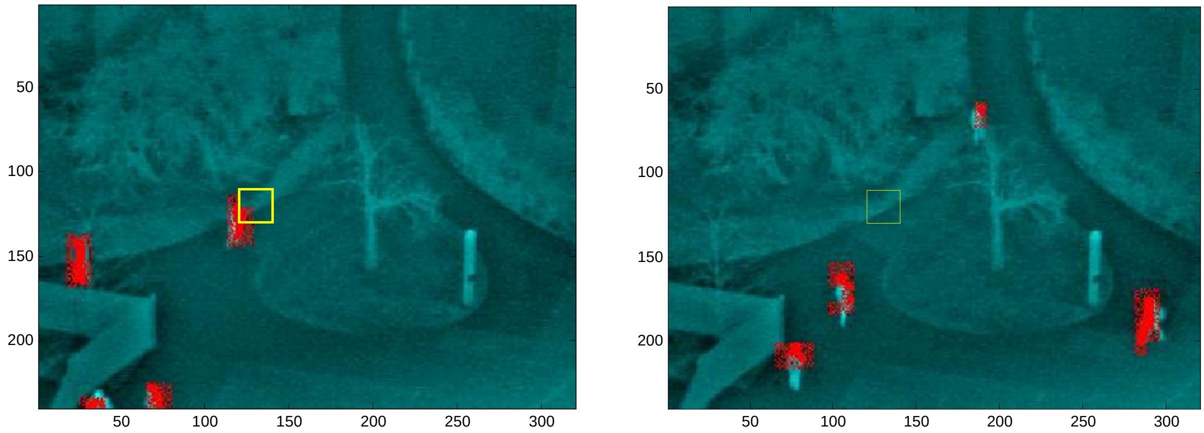
Our work in progress is concentrated on testing and improving its performance when background changes.

Acknowledgement

V. Zeljkovic has been partially supported by DoD HBCU/MI Infrastructure Support Program (45395-MA-ISP Department of Army).

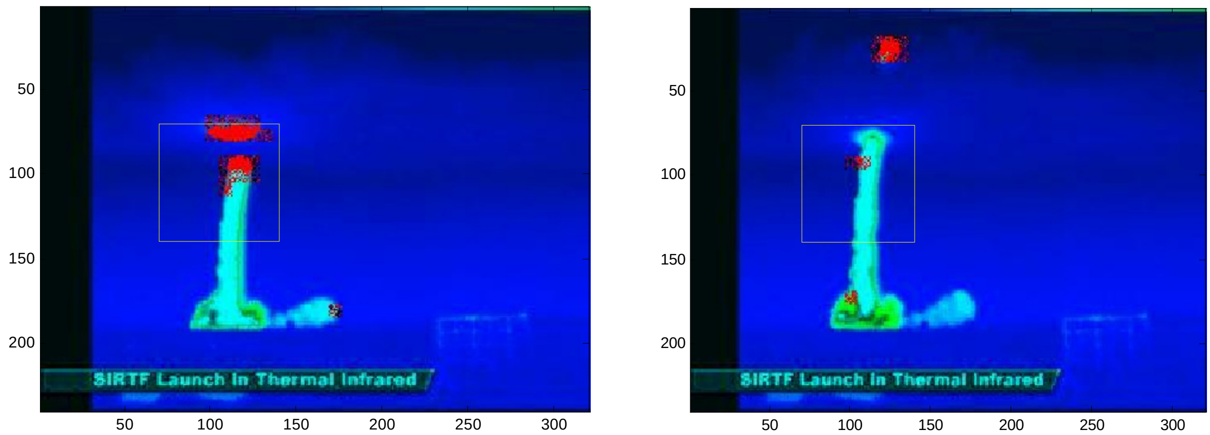
D. Pokrajac has been partially supported by NIH-funded Delaware IDeA Network of Biomedical Research Excellence (INBRE) Grant, DoD HBCU/MI Infrastructure Support Program (45395-MA-ISP Department of Army), National Science Foundation (NSF) Infrastructure Grant (award # 0320991) and NSF grant "Seeds of Success: A Comprehensive Program for the Retention, Quality Training, and Advancement of STEM Student" (award #HRD-0310163).

[1]Video courtesy NASA/JPL-Caltech. Available at http://www.spitzer.caltech.edu/picturegallery/ir_launch.shtml



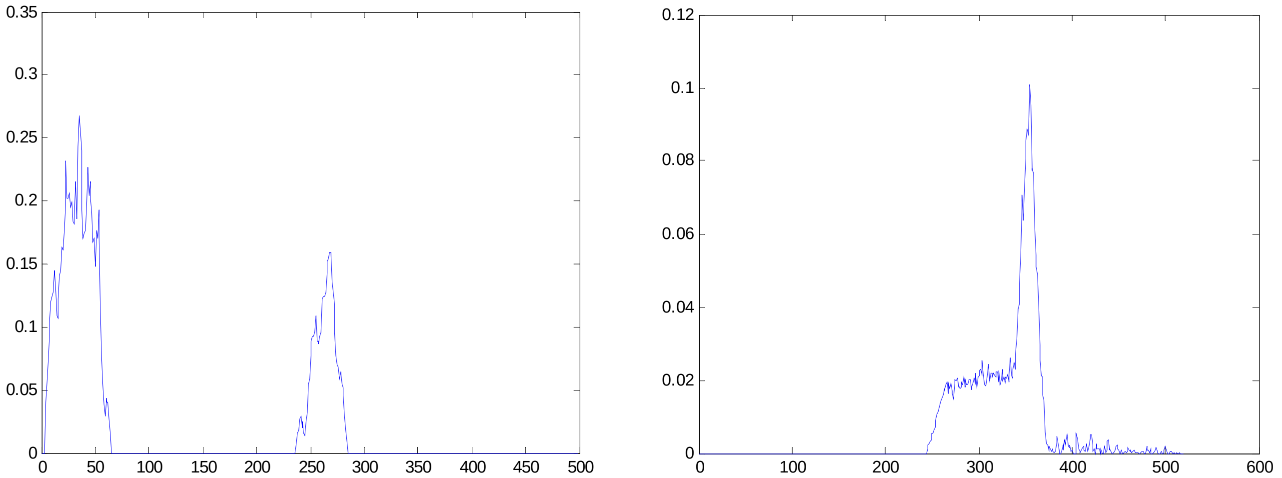
Frame 40 Frame 194

Fig. 1. Original frames 40 and 194 of *RoofCam* video with spatial block [120:140, 110:130] (yellow) and the result of moving objects detection (moving objects—red: background—navy).



Frame 350 Frame 450

Fig. 2. Original frames 350 and 450 of *RocketLaunch* video with spatial block [70:140, 70:140] (yellow) and the result of moving objects detection (moving objects—red: background—blue).



a) *RoofCam* b) *RocketLaunch*

Fig. 3. Motion statistics—Percentage of identified moving objects—at spatial blocks [120:140, 110:130] and [70:140, 70:140] calculated for the *RoofCam* and *RocketLaunch* sequence, respectively.

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