CHANGE DETECTION BASED ON COLOR EDGES

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ABSTRACT

This paper discusses a novel approach for change detection robust to illumination variations. The proposed technique makes use of a color edge detection scheme applied to the difference between a current and a reference image. Simulation results and comparisons to techniques in literature are reported and show that the proposed scheme offers a good detection performance, while providing robusteness to illumination variations.

1. INTRODUCTION

Many computer vision problems require change detection as their preliminary step. Change detection is a process of identifying differences in the state of objects or phenomena by observing them at different times. Applications that benefit from change detection are multimedia, advanced video surveillance, remote sensing, interactive and immersive gaming to mention a few. They require efficient and accurate procedures to detect and to label the changes in image sets or image sequences.

The most trivial method to perform change detection is by taking the difference between two images. Locations of changes correspond to large values in the difference map which is computed as the absolute values of the difference between corresponding pixels in the two images. To obtain the classification, the difference map is usually binarized by thresholding. The value of the threshold is critical: spurious changes due to various noise will be detected if the value is too low, while structural changes will be neglected if the value is too high. The correct value of the threshold depends on the scene, on the camera noise, and on the illumination conditions. The illumination of the scene is not under control in many applications. In these cases, traditional approaches to change detection which are based on the differentiation of intensity images fail. The fluctuations of the luminance values are in fact responsible of false detections.

To overcome this problem, features which are invariant to changes in the illumination conditions can be used. Pixel ratios [9], level lines [2], edge maps [7] and vector differences [4] are examples of features which are more robust than intensity images for change detection under varying illumination. In [9] structural changes are detected by using the ratio of the intensities of each pixel in two corresponding regions in two images. A structural change in the region is found when the intensity ratios vary inconsistently. This approach allows a certain independence to variations in illumination conditions, but it is computationally expensive and does not provide accurate contours. In [2] a method based on level lines image representation is presented. The motivation for this approach is that a global illumination change does not affect the geometry of the level lines, and will just create or remove some level lines. A drawback of this method is its computational complexity. To overcome this problem a simplification of the computations is proposed which severely decreases the system performance. An intrusion detection algorithm based on moving edges is presented in [7]. The method is characterized by a low computational cost, but has the limitation of dealing with only one moving object in the scene because of the procedure used to close the contours. An approach based on a local characterization of structures invariant to changes in illuminations in images is presented in [4]. This technique provides a good computational complexity, but suffers from accuracy in detecting the contour of objects.

To overcome these limitations, we propose an illumination independent change detector which provides a good spatial accuracy and allows for detection of multiple objects. The proposed method is a Color Edge Change Detector (CECD). The use of edges provides the system with the independence from the illumination conditions. The use of color information allows the correct detection of real edges so as to provide a good spatial accuracy. Experimental results indicate that the proposed method detects changes accurately under time-varying illumination. For the evaluation, a direct comparison of change detection masks based on an automatic method is used.

The paper is organized as follows. In Sec. 2, we describe the strategy for the exploitation of color edges for change detection. Then, in Sec. 3, we discuss the evaluation procedure that is used to rank different change detection results. Experimental results are presented in Sec. 4 and in Sec. 5 we draw some conclusions.

2. OVERVIEW OF THE SYSTEM

2.1. Edges for change detection

A change detection algorithm is ideally expected to extract the precise contours of the moving objects contained in the scene. This is especially desired when detected objects are to be included in other scenes. An approach to change detection which is based on edge maps appears therefore to be promising for this purpose.

Early edge based change detection algorithms perform two successive steps. First the edges in the background reference image and in the current input image are extracted. Then the obtained edge maps are compared by using some logical operators. Let $\mathcal{E}$ be the edge filter, I_r and I_c the reference and current luminance images, then the change detection mask C can be expressed by

$$C(I_r, I_c) = \mathcal{E}(I_r) \;\oplus\; \mathcal{E}(I_c) \tag{1}$$

where $\oplus$ denotes the *exclusive or* operator. Beside providing a good spatial accuracy, the use of edges avoids illumination variations to be interpreted as structural changes. In addition, since edges are bi-level images, they are convenient from computation and storage viewpoint.

On the other hand, a simple subtraction of the edges of the reference frame and the edges of the current frame may provide false results. If the reference frame is characterized by a high amount of edges, the detection task becomes more difficult. An example is reported in Fig. 1(e).

To overcome this limitation, we propose to compute the edges after image differencing. Instead of comparing the edge maps of the current and of the reference frame, we detect the edges in the image obtained by pixel differentiation of the two frames. The change detection mask C is therefore given by

$$C(I_r, I_c) = \mathcal{E}(|I_r - I_c|) \tag{2}$$

In such a way, we overcome the limitations of the traditional methods, while preserving the good spatial accuracy of the edge detection process (Fig. 1(f)).

A second limitation of change detectors based on luminance edges is related to the fact that the extracted contours are usually not closed. A change detector is expected to provide a binary mask indicating all the pixels that changed their state in the current image with respect to a reference. The contours provided by the edge detector should therefore be filled. For this reason, complex postprocessing techniques must be used to close the contours. This limits the flexibility of the method. In the intrusion detection algorithm presented in [7], for example, the procedure to close the contours does not allow more than one object in the scene.

To improve the contour detection phase and to maintain the generality of the approach, we propose the use of color edges.

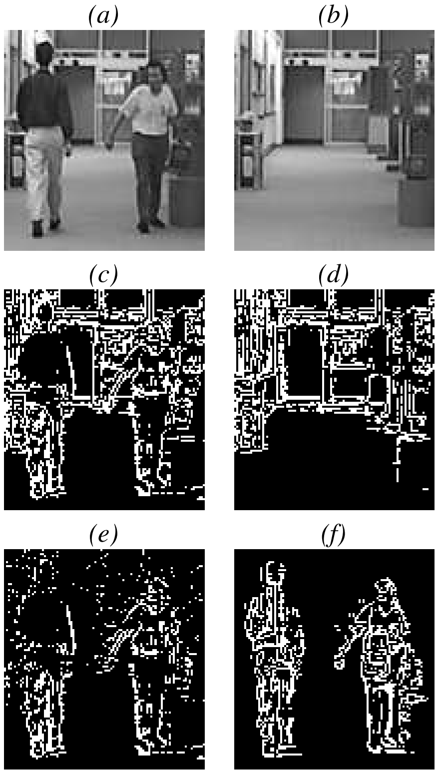

Figure 1: Detection of changes by using edge maps: (a) current frame (zoom on original images), (b) reference frame, (c) edges of current frame (d) edges of reference frame, (e) *exclusive or* between edges maps of current and reference frame, (f) edge map of the absolute difference between current and reference frame.

2.2. Color edge detection

In a monochrome image, an edge is defined as an intensity discontinuity. In case of color images, the additional variation in color may be considered in order to obtain a more complete edge information. Monochrome edge detection, in fact, may not be sufficient for certain scenes. For instance, an object with different hue value from the background but equal intensity can be detected only by taking into account color information.

There are different possibilities to use color for edge detection purposes [5, 10]. The most straightforward approaches to color edge detection represent extensions from monochrome edge detection. These techniques are applied to three color channels independently and then the results (an edge map for each color channel) are combined by using a certain logical operator. We adopted this apprach which has the advantadge of speeding up the computations if the different channels are processed in parallel. The edge information of the three channels is then fused by means of an *or* logical operator. To extract the edge information from each channel, a Sobel edge filter is used. A Sobel edge extractor provides thick edges which are useful for application in change detection by allowing to lighten the postprocessing for filling the contours. The filling is constituted by a morphological filtering with two successive eight connected dilations and erosions. The block diagram describing the proposed color edge change detector is depicted in Fig. 2.

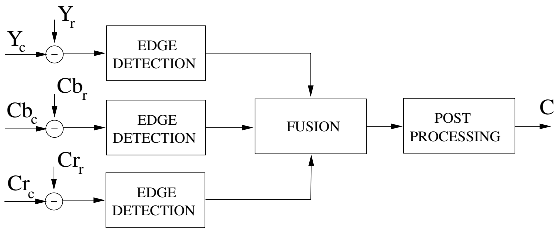

Figure 2: Block diagram of Color Edge Change Detector.

3. EVALUATION

The evaluation of masks resulting from different change detectors is fundamental for ranking different approaches. The masks can be evaluated subjectively by human observers, but the process associated to this evaluation is extremely time consuming. To avoid systematic subjective evaluation of the results, we use a procedure for objective and automatic evaluation. The procedure assumes the existence of a reference change detection mask. The reference mask is obtained by manual segmentation and represents the ground truth. The deviation from the reference mask is considered in the evaluation: the figure of merit consists in the number of misdetected pixels.

To provide a fair comparison of methods requiring the tuning of a threshold, the best value obtained empirically is selected.

4. EXPERIMENTAL RESULTS

The results of the tests of the proposed CECD algorithm and a comparison with state-of-the-art methods are presented in this section. Extensive experiments have been carried out on different test sequences. In this section, the MPEG-4 test sequence *Hall Monitor* will be considered. The spatial resolution is 288×352 (CIF format) and the temporal resolution is 25 images per second. The reference image for change detection is the first frame of the sequence, acquired before the objects enter in the field of view. First methods are tested in controlled light conditions, then illumination changes are considered.

Figure 3 shows the results obtained under controlled light conditions by applying different change detection algorithms. Three techniques are considered in the comparison. The statistical approach described in [1], that represents the state-of-the-art method in controlled light conditions (Fig. 3(b)); the shading model proposed in [9], that is robust to changes in the illumination conditions (Fig. 3(c)); and the proposed color edge change detector (Fig. 3(d)). It is possible to notice that the proposed method provides results that are very close to that of statistical approach, and much more accurate than the shading model. It is possible to notice a spike in correspondance to frame 200 which is due to a flickering in the original sequence. The objective evaluation in terms of detection error with respect to the ground truth is given in Fig. 4.

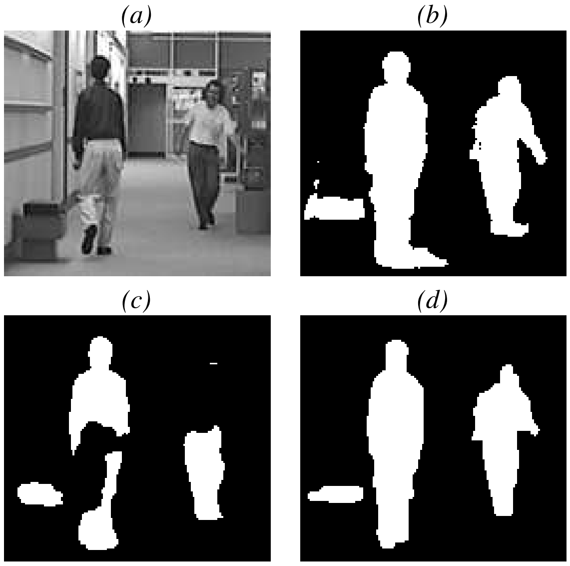

Figure 3: Change detection results under controlled light conditions: (a) current frame (zoom), (b) statistical change detector, (c) shading model, (d) color edge change detector.

The shading model and the CECD are then tested under varying illumination conditions. The statistical change detector is not considered in this second comparison, since it is not robust to changes in illumination. An illumination change is simulated by a variation in the luminance channel. This approach has been extensively used in literature ([3, 6, 7]). The shading model is stable in terms of number of misdetected pixels due to the changes in illumination, but

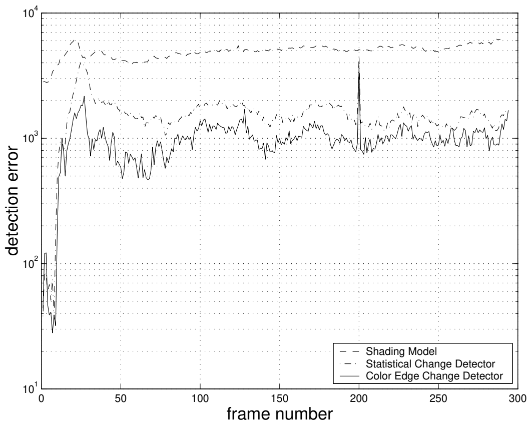

Figure 4: Objective evaluation of three change detectors under controlled light conditions. The plot reports the detection error (number of misdetected pixels) of each method with respect to the reference ground truth for the sequence *Hall Monitor*

the results of the CECD are better in terms of object extraction as can be noticed from the visual comparison of Fig. 5 and from the objective evaluation of Tab. 1.

(a) *(b)*

Figure 5: Change detection results under varying illumination. (a) shading model, (b) color edge change detector

5. DISCUSSION AND CONCLUSIONS

Simulation results and comparisons between CECD, statistical change detection and shading model show that the proposed CECD perfoms well in both controlled illumination and situations where changes in illumination conditions occur. This is not the case with statistical change detection which performs well in controlled illumination only, while shading model provides a good invariance but not a good detection. The exact degree of improvement obtained by CECD depends on the application under consideration and this is one of the possible directions for further development. Although no in-depth study of memory requirements and computational complexity was performed, one can state that based on the operations used in the algorithm

	change detector		
test conditions	SCD	SM	CECD
controlled light	1.57e+03	4.97e+03	9.86e+02
varying light	–	5.10e+03	2.99e+03

Table 1: Objective evaluation of the change detection masks under controlled and varying light conditions for statistical change detector (SCD), shading model (SM), and color edge change detector (CECD). The reported values are the mean detection errors for the entire sequence *Hall Monitor*.

its computational complexity and memory requirement remain very reasonable. A more rigorous evaluation of memory requirements and computational complexity is another direction for future.

6. REFERENCES

[1] T. Aach, A. Kaup, and R. Mester, "Statistical model-based change detection in moving video", Signal Processing", Vol. 31, pp. 165-180, 1993.

[2] D. Aubert, "Passengers Queue Measurement", Proc. of 10th International Conference on Image Analysis and Processing, Venice (Italy), pp. 1132–1135, 27-29 September 1999.

[3] F. Bartolini, V. Cappellini, A. Mecocci, "Automatic Detection of Intrusions by Image Processing", Proceedings of DSP and CAES Conference, Nicosia (Cyprus), pp. 468-472, 14-16 July, 1993.

[4] E. Durucan and T. Ebrahimi, "Robust and Illumination Invariant Change Detection Based on Linear Dependence for Surveillance Applications", Proc. of X European Signal Processing Conference, Tampere (Finland), pp. 1041–1044, 5-8 September, 2000.

[5] A. Koschan, "A Comparative Study on Color Edge Detection", Proc. of 2nd Asian Conference on Computer Vision, Vol.III, pp. 574-578, Singapore, 5-8 December 1995.

[6] S.Z. Liu, C.W. Fu, and S. Chang, "Statistical change detection with moments under time-varying illumination", IEEE Trans on Image Processing, 7(9), pp. 1258–1268, 1998.

[7] A. Makarov, J.M. Vesin and F. Reymond, "Intrusion detection robust to slow and abrupt lighting changes", Real Time Imaging, vol. 266, pp. 44-54, San Jose (USA), January 29-February 2, 1996.

[8] P. L. Rosin, "Thresholding for change detection", Proc. of International Conference of Computer VIsion (ICCV-98), pp. 274–279, 1998.

[9] K. Skifstad and R. Jain, "Illumination independent change detection for real world image sequences", Computer Vision: Graphic and Image Processing, 46, pp. 387–399, 1989.

[10] K.N. Plataniotis and A.N. Venetsanapoulos, "Color Image Processing and Applications". Springer, 2000.