# BLOTCH DETECTION AND REMOVAL FOR ARCHIVE VIDEO RESTORATION

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## ABSTRACT

**Blotch detection and removal is an important issue for archive video restoration. Spatial segmentation based post-processing has been proposed to increase the detection performance of the SDIa detector. Furthermore a novel pixel based new correction method that determines blotched pixels new values from spatio-temporal correlation is developed.**

## I. INTRODUCTION

Archive film materials are particularly degraded by blotch, scratch, flicker and noise. Blotches are significant degradations that mainly originate from the loss of film gelatine and dirt particles covering the film surface. Blotch is an impulsive noise and leads to discontinuity because this effect appears randomly in the image sequence and the probability of existence of blotch at the same place in succeeding frames is very low.

It is possible to consider the removal of blotch from image sequences as a two stage process, first detecting the missing locations, and correcting the detected regions using spatio-temporal methods. Several methods have been proposed for the detection stage in the literature [1-4]. The simplest method SDIa (Spike Detection Index) that detects blotch regions using motion compensated preceding and following frames, by thresholding the minimum of backward and forward squared pixel differences has been proposed in [1]. SDIa is capable of achieving a high correct detection rate however results in too many false alarms. To reduce the false alarms that arise from edges, morphological post-processing has been proposed in [2]. This post processing improves the detection rate of SDIa but false alarms caused from local object motion and incorrect global motion compensation are not eliminated adequately. In [3], a ROD (Ranked Order Difference) detector that arranges pixels from motion compensated previous and subsequent image regions and applies three stage thresholding to them has been proposed. These three thresholds control the number of correct detections and false alarms but the difficulty of determining these three thresholds constraints the effectiveness of this method. Therefore, a simplified ROD detector (S-ROD) that uses only one threshold has been proposed in [4].

In the correction stage, a multi-stage median filter (MMF) that is a concatenation of median filtering operations can be used to correct the missing data regions as proposed in [5]. A texture synthesis method for computer vision applications has been proposed in [6]. This method models texture as a Markov Random Field (MRF) and finds a new pixel value for each unfilled pixel according to the squared difference matching criteria. In [7], long-range correlation based image information restoration has been proposed. This method recovers lost image blocks using a long search region according to the luminance transformation based MSE criterion for a given block.

None of the aforementioned detection methods is able to detect blotches that occur at the same spatial location in subsequent frames (i.e. occluded blotches). This is the main drawback of these methods. In our work, segmentation based post processing is enforced to the SDIa detector output in order to improve correct detection rate while reducing false alarms. In the correction stage, a new pixel based correction method that determines the new values of blotched pixels from temporal correlation based on [6] and [7] is proposed.

## II. BLOTCH DETECTION AND REMOVAL

The degraded image $I(x)$ can be modelled as given (1).

$$I(x) = [1 - b(x)] \times y(x) + b(x) \times c(x) \tag{1}$$

where $b(x)$ is a detection variable which determines degraded ($b(x) = 1$) or clean ($b(x) = 0$) pixels, and $c(x)$ is the observed intensity value of blotched pixels. The detection stage intends to estimate $b(x)$ for each pixel. The aim of the correction stage is to find the new value $y(x)$ for blotched pixels ($b(x) = 1$).

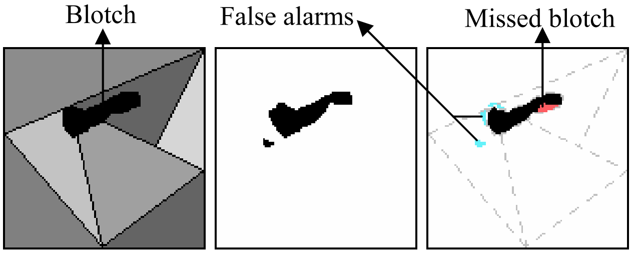
### *BLOTCH DETECTION*

The SDIa detector calculates the intensity value of each pixel from corresponding pixels of neighbouring frames and if the squared difference values of both differences are larger than a predetermined threshold, the pixel is flagged as blotch. This method can be expressed as in (2).

$$e_b(i) = \left(I_n(i) - I_{n-1}^{mc}(i)\right)^2$$
$$e_f(i) = \left(I_n(i) - I_{n+1}^{mc}(i)\right)^2$$
$$b(i) = \begin{cases} 1, & \text{if } e_b(i) > T \text{ and } e_f(i) > T \\ 0, & \text{otherwise} \end{cases} \tag{2}$$

where $e_b(i)$ is the backward, and $e_f(i)$ is the forward squared pixel difference and $T$ is the threshold that determines whether the pixel is a blotch or not.

This method gives comparably high correct detection rates but results in too many false alarms and is furthermore highly sensitive to global motion compensation accuracy. Another problem is that occluded blotches cannot be detected. To overcome these problems, segmentation based post processing is proposed in this paper and employed as shown in Fig. 1.



(a) (b) (c)

Figure 1. a) Observed (blotched) image frame, b) blotch detected pixels and, c) determining the blotch region using spatial segmentation

In Fig. 1-a, a synthetic image that contains 7 real image regions and a blotch is given. The binary detection image obtained with SDIa, which contains both missed pixels and false detected pixels from the detection process is shown in Fig 2-b. The proposed segmentation based post-processing that uses spatial segmentation and detection is shown to enforce accurate blotch detection. In the proposed approach, missed blotch regions are decided if the sum of blotch detected pixels in any segment is larger than a given completeness threshold ($T_c$). On the contrary, if the sum of blotch detected pixels in the segment is smaller than a given threshold, a false alarm is given and detected pixels are marked as clear. To eliminate false detections resulting from noise, each segments size is checked and if any segment size is equal to one pixel only, that pixel is marked as non-blotched.

Artificial white and black blotches are added to image sequences randomly to test the detection performance of the methods. Original, randomly blotched, SDIa blotch detected and segmentation based post processed image frames for the “Silent” test sequence are given to show the benefit of post processing in Fig. 2 and Fig. 3. False detections in SDIa arising from local motion and the effect of post processing are shown in Fig. 2-c and Fig. 2-d, respectively.

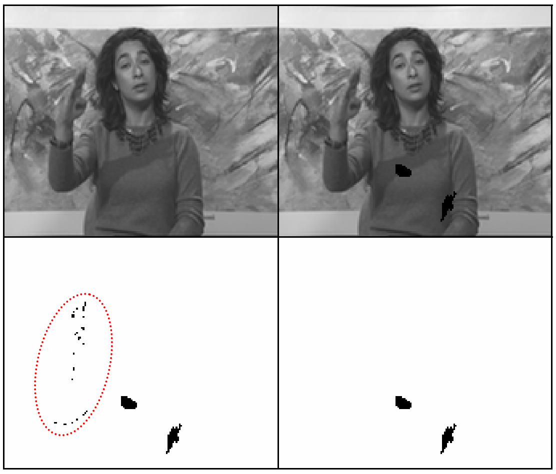


Figure 2. a) Original, b) Blotched, c) SDIa detection and d) segmentation based post processing results for frame #32 of the “Silent” sequence.

In Fig. 3-c, missed detection occurring as a result of occluded blotch regions is shown. Segmentation based post-processing helps to improve the correct detection rate of the detector and provides excellent detection results (See Fig. 3-d).

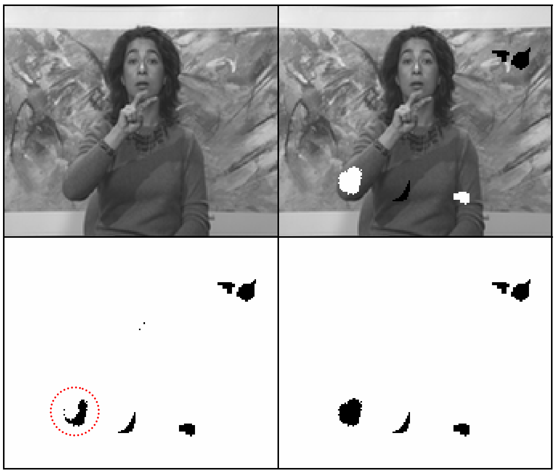


Figure 3. a) Original, b) Blotched, c) SDIa detection and d) segmentation based post processing results for frame #93 of “Silent” sequence.

### *BLOTCH REMOVAL*

It is proposed in this paper to utilize a new pixel based correction method that determines blotched pixels new values using spatio-temporal correlation. Our method uses a contour based correction strategy similar to [6] and uses luminance transformation based matching criteria as given in [7]. The proposed method is specified as follows:

If $b'(x)=1$ for current image (Note that $b'(x)$ shows the post-processed $b(x)$);

1. Take a square window around position x (local window).
2. Find the best matching luminance transformed remote window from large search windows of preceding and succeeding image frames for the local window skipping all blotched regions. Note that the centre pixel of the remote window should be non-blotched.
3. Put the centre pixel of the best matched luminance transformed remote window to the corrected image ( $y'(x)$).

In this work, MSE is used as a matching criterion as given in (3).

$$MSE = \frac{1}{p_u}\sum_{i=1}^{M}\sum_{j=1}^{M}\left[1-m^r(i,j)\right]\times\left[1-m^l(i,j)\right]\times\left[l(i,j)-v(r(i,j))\right]$$

$$p_u = \sum_{i=1}^{M}\sum_{j=1}^{M}\left[1-m^r(i,j)\right]\times\left[1-m^l(i,j)\right] \qquad (3)$$

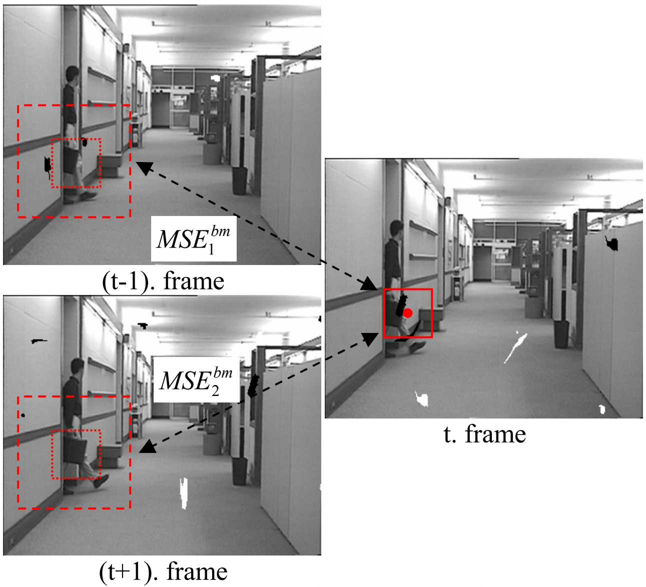
where $p_u$ is the total number of used pixels, $M$ is the window size, $m^r(i,j)$ is the remote window blotch mask, $m^r(i,j)$ is the local window blotch mask, $l(i,j)$ is the local window pixel, $r(i,j)$ is the remote window pixel, and $v(\ )$ is the luminance transform. The best matched remote window searching procedure is executed as shown in Fig. 4. To match the remote window to the local window using the $MSE$ criterion, first-order polynomial function is used as the luminance transform (4) similar to [7].

$$v(r(i,j)) = \alpha_0 + \alpha_1 \times r(i,j), \qquad \begin{array}{l} \partial MSE / \partial \alpha_0 = 0 \\ \partial MSE / \partial \alpha_1 = 0 \end{array} \qquad (4)$$

In this equation $\alpha_0$ and $\alpha_1$ can be denoted as additive and multiplicative luminance transform coefficients, respectively. The new value of a blotched pixel can be computed as

$$y'(i,j) = v(r_{bm}((M+1)/2,(M+1)/2)) \quad , M \text{ is odd number} \qquad (5)$$

where $y'(i,j)$ is the corrected pixel value, and $r_{bm}$ is the best matched remote window. Correction results for a part of frame #22 of the "Hall Monitor" sequence to give an idea about the visual performance of the proposed correction method is shown in Fig. 5.



$$MSE^{bm} = \min\left(MSE_1^{bm}, MSE_2^{bm}\right)$$

Figure 4. Best matched remote window searching strategy from preceding and succeeding image frames.

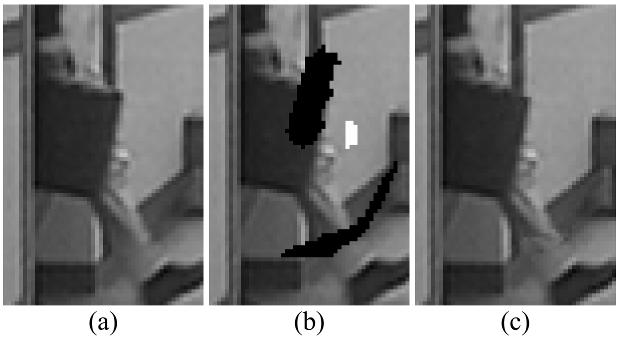

(a) (b) (c)

Figure 5. a) Original, b) artificially blotched, and c) corrected image part of frame #22 of the "Hall Monitor" sequence

## II. EXPERIMENTAL

Local and remote window sizes are taken as $M = 15$, and the search window size is set to 41. The completeness threshold $T_c$ is chosen to be 0.5.

## III. RESULTS AND DISCUSSION

Fig. 6 shows ROC (Receiver Operator Characteristics) curves obtained for the "Silent" test sequence using SDIa [1], SDIa with post-processing method proposed in [2], S-ROD [5] and SDIa with our segmentation based post-processing method. It is shown from Fig. 6 that our segmentation based post processing highly improves the correct detection rate of the SDIa and reduces the false detection rate, significantly outperforming all other methods.

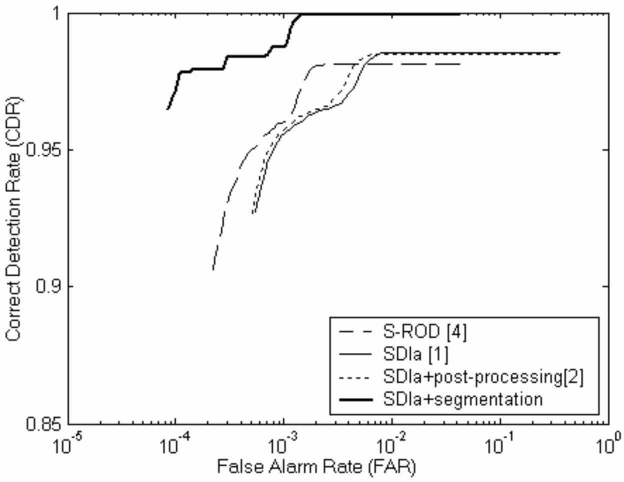
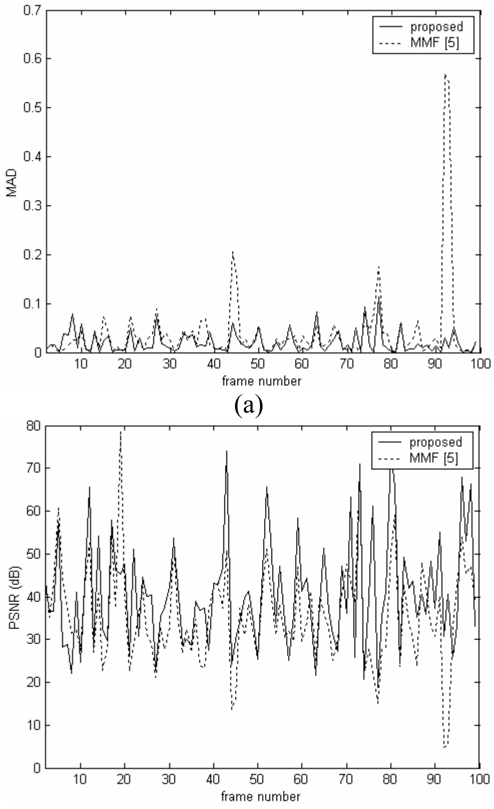


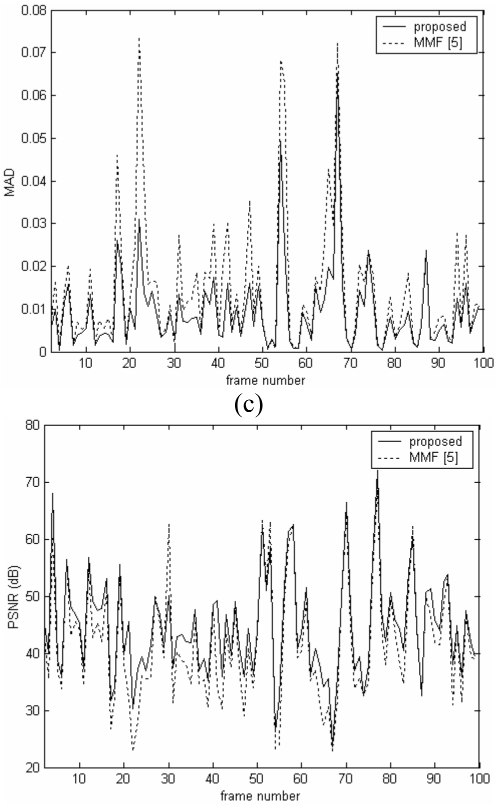
Figure 6. ROC curves results for blotch detection methods

For the correction stage, MAD (Minimum Absolute Difference) and PSNR (Peak Signal to Noise Ratio) results for original and corrected “Silent” and “Hall Monitor” test sequences are given in Fig. 7. These figures show that our correction method gives superb results in the overall.



(a)

(b)



(c)

(d)

Figure 7. MAD and PSNR results for a-b) “Silent”, and c-d) “Hall Monitor” test sequences.

In Table 1, average MAD and PSNR results for the “Silent” and “Hall Monitor” sequences are shown. The proposed method is shown to outperform MMF based correction.

Table 1. Mean values of the MSE and PSNR results for “Silent” and “Hall Monitor” sequences

| | |
|---|---|
| Silent | mean(MAD_MMF)=0.0392<br>mean(PSNR_MMF)=35.2878 dB |
| | mean(MAD_proposed)=0.0197<br>mean(PSNR_proposed)=40.2828 dB |
| Hall Monitor | mean(MAD_MMF)= 0.0143<br>mean(PSNR_MMF)=41.2092 dB |
| | mean(MAD_proposed)=0.0092<br>mean(PSNR_proposed)= 44.0769 dB |

## IV. CONCLUSION

Blotch detection and removal is an important issue for archive video restoration. For this purpose segmentation based post-processing has been proposed to increase the detection performance of the SDIa detector in this paper. Furthermore it is proposed in this paper to utilize a new pixel based correction method that determines the new value of blotched pixels using spatio-temporal correlation. Experimental results show that the proposed detection and correction methods clearly outperform previously proposed techniques.

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