

# Blotch Detection and Removal for Archive Video Restoration

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**Abstract.** Blotch detection and removal are important subjects for archive video restoration. In this work, spatial segmentation based post-processing has been proposed to increase the detection performance of the SDIa blotch detector. Furthermore a novel pixel based correction method that determines the new values of blotched pixels from spatio-temporal correlation is developed. Experimental results show that the proposed approach gives significant detection and correction performances and outperforms previously proposed techniques.

## 1 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 basically impulsive noise and leads to discontinuity because it appears randomly in the image sequence and hence the probability of existence of blotch at the same place in succeeding frames is very low.

It is possible to consider the removal of blotches from image sequences as a two stage process, firstly detecting the missing locations, and then correcting the detected regions using spatio-temporal methods. Several techniques 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 usually 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 or 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 a 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], which 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 to recover 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.

## 2 Blotch Detection and Removal

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

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

where  $b(x)$  is a detection variable that 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 (i.e. pixels for which  $b(x)=1$ ).

### 2.1 Blotch Detection

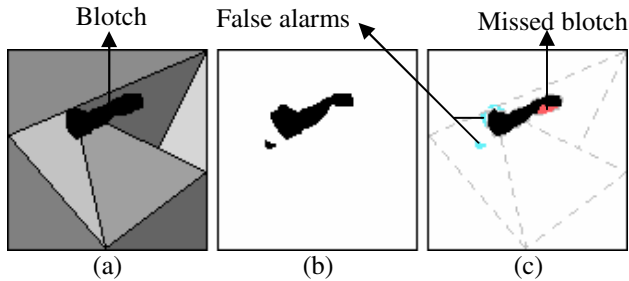
The SDIa detector calculates the intensity value of each pixel from corresponding pixels of neighbouring frames and if the squared difference values of both differences are larger than a predetermined threshold, the pixel is flagged as a blotch. This method can be expressed as in (2).

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

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 to improve performance as shown in Fig. 1.

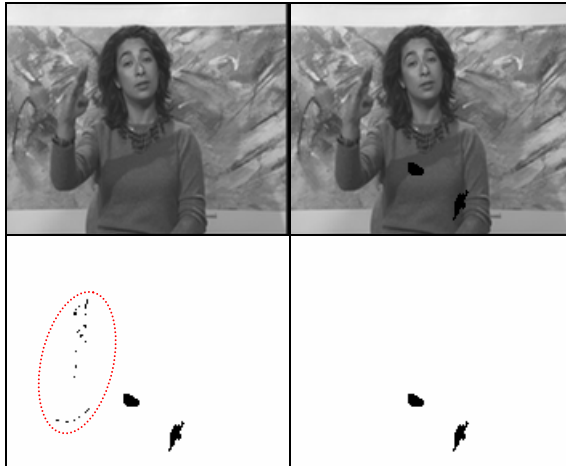


**Fig. 1.** a) Observed (blotched) image frame, b) blotch detected pixels and, c) determining the blotch region using spatial segmentation

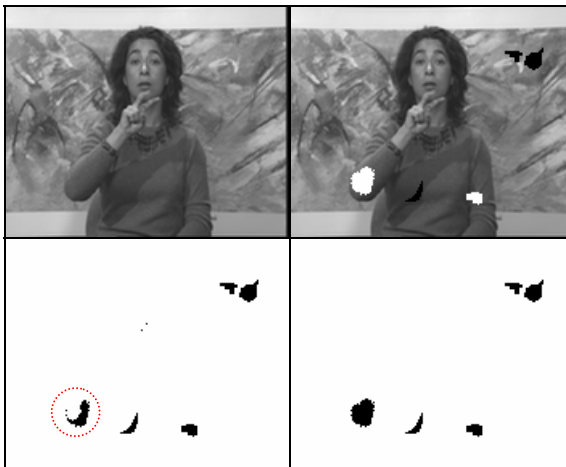
In Fig. 1-a, a synthetic image that contains 7 real image regions and one blotch is given. The binary detection image obtained with SDIa, which contains missed pixels as well as incorrectly detected pixels in the detection process, is shown in Fig 2-b. The proposed segmentation based post-processing that uses spatial segmentation and detection is shown to enforce accurate blotch detection. Controlled segmentation is performed in place of segmenting whole image frame to reduce the computational load. Segmentation is enforced around each detected pixel to establish its correct shape according to a segmentation threshold ( $T_s$ ). If the absolute difference between the detected pixel and any pixels around the detected pixel is smaller than  $T_s$ , these pixels are labelled as part of the segment. This operation goes on recursively along the labelled pixels until there are no pixels that satisfy the condition. If any detected pixel has already been labelled along the process, that pixel is skipped and the process continues with the other detected and unlabeled pixel. In the proposed approach, missed blotch regions are decided if the ratio of the sum of blotch detected pixels to the total number of pixels within the segment is larger than a given completeness threshold ( $T_c$ ). Otherwise, i.e. if this ratio is smaller than the threshold, a false alarm is given and detected pixels in the segment are marked as clear. Furthermore, 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 introduced to image sequences randomly in order to test the detection performance of the methods. Example original and randomly blotched frames, as well as SDIa blotch detection and segmentation based post processed detection results for the “Silent” test sequence are given in Fig. 2 and Fig. 3 to show the benefit of post processing. 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.

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 correct detection results (See Fig. 3-d).



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



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

## 2.2 Blotch Removal

In this paper a new pixel based correction method that determines blotched pixels new values using spatio-temporal correlation is proposed. 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 operating as follows:

If  $b'(x)=1$  for the 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 in the form of

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

$$p_u = \sum_{i=1}^M \sum_{j=1}^M [1 - m^r(i, j)] \times [1 - m^l(i, j)]$$
(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,  $m^l(i, j)$  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, a first-order polynomial function given in (4) is used as the luminance transform similar to [7].

$$v(r(i, j)) = \alpha_0 + \alpha_1 \times r(i, j), \quad \begin{aligned} \frac{\partial MSE}{\partial \alpha_0} &= 0 \\ \frac{\partial MSE}{\partial \alpha_1} &= 0 \end{aligned}$$
(4)

In this equation  $\alpha_0$  and  $\alpha_1$  can be denoted as additive and multiplicative luminance transform coefficients, respectively and these coefficients are computed as given in (5).

$$a_1 = \frac{p_u \sum_{i=1}^M \sum_{j=1}^M (1 - m^r(i, j)) \times (1 - m^l(i, j)) \times r(i, j) \times l(i, j) - \left[ \sum_{i=1}^M \sum_{j=1}^M (1 - m^r(i, j)) \times (1 - m^l(i, j)) \times r(i, j) \right] \times \left[ \sum_{i=1}^M \sum_{j=1}^M (1 - m^r(i, j)) \times (1 - m^l(i, j)) \times l(i, j) \right]}{p_u \sum_{i=1}^M \sum_{j=1}^M (1 - m^r(i, j)) \times (1 - m^l(i, j)) \times r^2(i, j) - \left[ \sum_{i=1}^M \sum_{j=1}^M (1 - m^r(i, j)) \times (1 - m^l(i, j)) \times r(i, j) \right]^2}$$

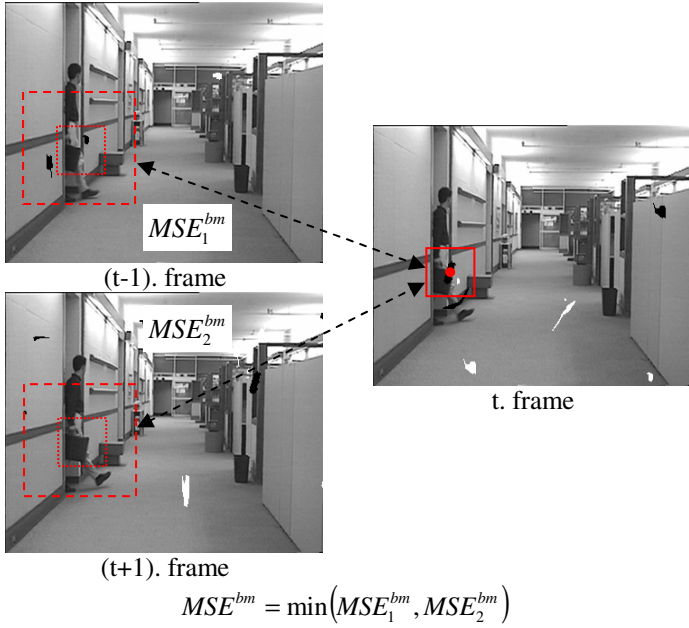
$$a_0 = \frac{1}{p_u} \left[ \sum_{i=1}^M \sum_{j=1}^M (1 - m^r(i, j)) \times (1 - m^l(i, j)) \times l(i, j) - a_1 \times \sum_{i=1}^M \sum_{j=1}^M (1 - m^r(i, j)) \times (1 - m^l(i, j)) \times r(i, j) \right]$$
(5)

The new value of a blotched pixel is then computed as

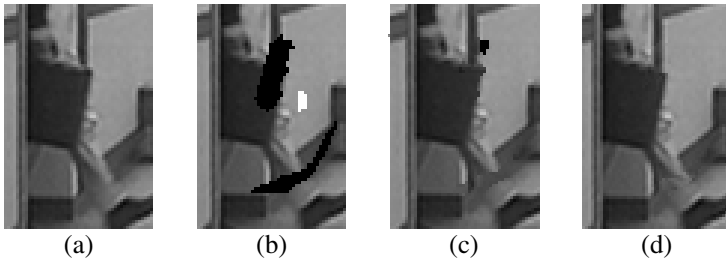
$$y'(i, j) = v(r_{bm}((M + 1)/2, (M + 1)/2)), \quad M \text{ is odd number}$$
(6)

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 are shown in Fig. 5 to give an idea about the visual performance of the proposed correction method.



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



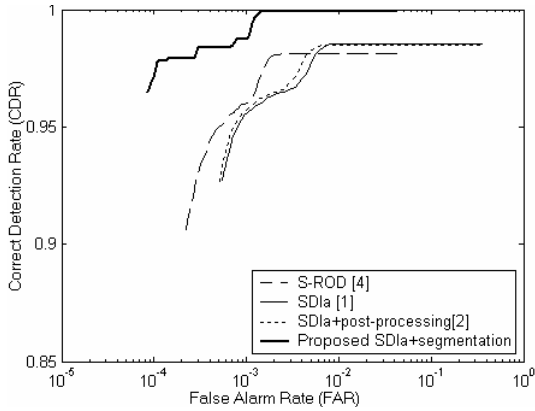
**Fig. 5.** a) Original, b) artificially blotted, c) MMF [5] corrected, and d) proposed correction of the image part of frame #22 of the “Hall Monitor” sequence

It is shown in Fig. 5-c that MMF can not correct occluded blotch areas (the black blotch region) and gives unsatisfactory results in cases of local motion. The proposed method presents superior performance in this manner.

### 3 Experimental Results

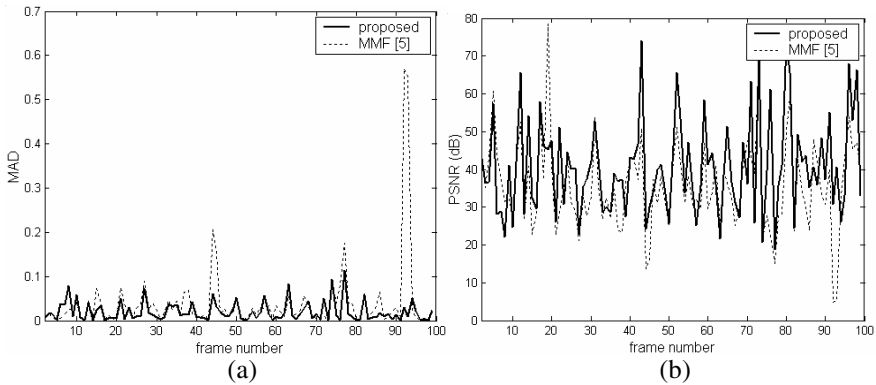
Fig. 6 shows ROC (Receiver Operator Characteristics) curves obtained for the “Silent” test sequence using SDIa [1], SDIa with post-processing method proposed in [2], S-ROD [5] and SDIa with our segmentation based post-processing method. It is

seen in 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.



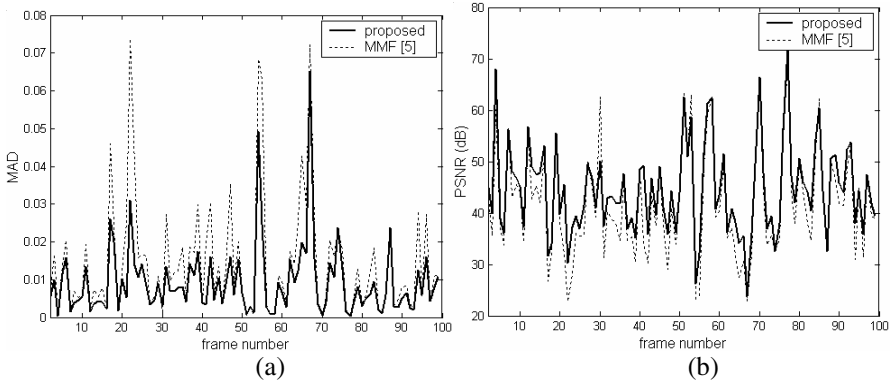
**Fig. 6.** ROC curves results for blotch detection methods

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 and Fig. 8, respectively. These figures show that our correction method gives enhanced results in the overall.



**Fig. 7.** a) MAD, and b) PSNR results for the “Silent” test sequence

In Table 1, average MAD and PSNR results for the “Silent” and “Hall Monitor” sequences are shown. These results also confirm that the proposed method outperforms MMF based correction.



**Fig. 8.** a) MAD, and b) PSNR results for the “Hall Monitor” test sequence

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

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

Note that in the presented results the following parameters are used: local and remote window sizes are taken as  $M = 15$ , and the search window size is set to 41. The segmentation threshold is taken  $T_S = 10$  and completeness threshold  $T_c$  is chosen to be 0.5.

In future works, it is planned to adaptively change the completeness threshold  $T_c$  according to segment size.

## 4 Conclusion

New methods for the detection and removal of blotches are proposed in this paper to improve the visual quality of archive film sequences that are degraded as a result of blotches. Initially, a segmentation based post-processing approach has been proposed to increase the detection performance of the SDIa detector in this paper. Additionally a new pixel based correction method that determines the new value of blotched pixels using spatio-temporal correlation is implemented. Experimental results demonstrate that the proposed detection and correction methods outperform previously proposed techniques.

## Acknowledgement

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## References

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