

Threshold Free Technique to Detect the Blotches in Old Film Sequences

Meduri Chandra Sekhar

M.Tech, EE, IIT Kanpur,
cs_meduri2002@yahoo.com

Sumana Gupta

Professor, EE, IIT Kanpur,
sumana@iitk.ac.in

Abstract

A huge video repository of our past records is presently stored in a very fragile media. These records are of invaluable significance historically, politically, and culturally. Hence recovering and preserving them is a task of immense importance to us. The artifact that is most common in old films is Blotches. Since, blotches exist in a small portion of the image, it is always better to detect the blotches and apply reconstruction in those areas. Traditional techniques find blotches by choosing an empirical threshold. Manual retouching is necessary to completely remove the blotches, because of different pixel value distributions in different scenes of the same video sequence. Also fixed threshold may lead to many false alarms. Manual retouching is a gigantic task as amount of data is large. In this paper, we propose a threshold free technique to find the blotches that eliminates human interaction and which at the same time reduces the number of false alarms. The proposed method finds blotches pixel by pixel by setting maximum and minimum bounds using motion compensated 5X5sub images of the previous and next frames with respect to the 3X3sub image of the current frame, to validate the pixel of interest.

Index Terms— Dirt and Sparkle, Detection of blotches, Motion compensation.

1. Introduction

One of the most common and striking distortions in archived motion picture film is the presence of blotches. The blotches may look like a small coherent image area of pixels with almost constant brightness. Film blotches are characterized by the following two properties [3], as shown in Kokaram et al. [8] and Nadenau et al. [7]. The first property is related to temporal discontinuity of a brightness function of a moving image sequence. The first property is that blotches randomly appear at a burst in a moving image sequence and are rarely or never located in the same place over successive multiple image frames. The second property has relation to spatial coherency, and is that blotches appear at a coherent area with almost constant brightness that is uncorrelated with that of pixels in their neighborhood. Between the two properties temporal discontinuity is more important for blotch detection.

In films the blotches can be result from the two physical degradation processes of film [2, 4, 15]. Both

degradations lead to similar visual effects. The first degradation process is a result of dirt. Dirt particles covering the film introduce bright or dark spots on the picture. The second degradation process is the loss of gelatin covering the film, which can be caused by physical interaction of the film material with the projecting equipment as it is transported through the mechanism. This distortion will occur also in Telecine equipment since the mechanism of film transport is same.

The blotches are technically named as Dirt and Sparkle. Since the blotched areas are completely replaced by some other information this defect can be treated as missing data problem [1, 4, 8-9]. In the case of color images the blotches can easily found in the intensity channel (Y channel of the YUV representation). Since blotches represent the regions of missing information in the frame, In this work we used the model given by [2, 4].

$$Z(\vec{r}) = (1 - d(\vec{r})) \cdot y(\vec{r}) + d(\vec{r}) \cdot c(\vec{r}) + \eta(\vec{r})$$

Where $Z(\vec{r})$ and $y(\vec{r})$ are the observed and the original data at the location given by position vector \vec{r} , respectively. The binary blotch detection mask $d(\vec{r})$ indicates whether each individual pixel has been corrupted or not corrupted: $d(\vec{r}) \in \{0,1\}$. The values at the corrupted site are given by $c(\vec{r})$, with $c(\vec{r})$ not equal to $y(\vec{r})$. $\eta(\vec{r})$ is the zero mean additive Gaussian noise.

2. Existing Techniques: Overview

The attempt to detect the blotches at the first time was done by Storey [12-13]. This did not employ motion estimation and instead thresholded the forward and backward non motion-compensated frame differences to detect a blotch. The method to detect blotches was also given by N. R. Harvey et al. [6]. The proposed technique scan the each frame pixel by pixel and flags each pixel as blotched if it's value deviates considerably with the neighborhood values. Since, the blotches are not restricted to single pixel and occupy large number of connected pixels, this method fails to detect the blotches.

In 1999 a new method was proposed by T. Saito et al. [3]. In this method they proposed a filtering method based on spatio-temporal brightness continuity, in which the incorruption probability of each pixel is found from the fuzzy rule, which has to be trained by using some artificially corrupted moving image sequence.

Some of the other methods to detect the blotches are Markov Random Field (MRF) [8, 10, 14], and 3-D Auto Regressive (AR) models. Due to poor estimation of model coefficients in real situations, the methods based on AR approaches results in poor performance. They would miss the blotches with low intensity difference with preceding and next frames.

The most successful detectors which use motion compensated frames for the detection of blotches are Spike Detection Index (SDI), Spike Detection Index-p (SDIp), and Spike Detection Index-a (SDIa). These detectors are highly sensitive to noise and threshold chosen. Later Nadenau proposed a Rank Order Detector (ROD) based on ordered statistics, which is modified by Van Roosmalen by adding the post processing step to ROD, which works well than all the existing techniques. It was shown in [4, 8] that MRF detector performs slightly better than SDI and ROD methods. But the computational complexity is very high when compared to ROD and SDI. So the greater complexity does not necessarily lead to better results. So, in this work we are not dealing with MRF and AR models.

In the case of Spike detection methods and Rank order difference methods, the detection performance depends on the threshold. And the distribution of pixels varying from scene to scene a new threshold has to be chosen for new scene.

So, the manual threshold selection is very difficult because amount of data to be restored is very large. And even with in the frame, because of different pixel distributions, the false alarms are very high. ROD detector with post processing will detect the blotches at very high rate, but gives so many false alarms because of labeling with low threshold.

The proposed method detects the blotches for every pixel adaptively. The selection depends on the temporal and spatial neighboring pixels from motion compensated previous and next frames. So that detector performance depends only on the noise. The selections of defined sets reduce the effect of noise to some extent. Finally the post processing step reduces false alarms to greater extent.

3. Proposed Technique

An adaptive blotch detection scheme which eliminates the manual selection of threshold is proposed. Here we have used motion compensated 5×5 block from previous frame, and motion compensated 5×5 block from next frame to detect the blotch, which are shown in Fig. 1. In all the previous methods the selection of threshold is based on trail and error method which is very difficult at run time. The main goal of this proposed method is to increase the adaptive ness of the blotch detector at the same time decreasing the number of false detections. We have shown from the simulation results that it is equivalently good as SDI and ROD detector with post processing. It is successfully applied to so many sequences.

P ₁₁	P ₁₂	P ₁₃	P ₁₄	P ₁₅
P ₂₁	P ₂₂	P ₂₃	P ₂₄	P ₂₅
P ₃₁	P ₃₂	P ₃₃	P ₃₄	P ₃₅
P ₄₁	P ₄₂	P ₄₃	P ₄₄	P ₄₅
P ₅₁	P ₅₂	P ₅₃	P ₅₄	P ₅₅

(a)

N ₁₁	N ₁₂	N ₁₃	N ₁₄	N ₁₅
N ₂₁	N ₂₂	N ₂₃	N ₂₄	N ₂₅
N ₃₁	N ₃₂	N ₃₃	N ₃₄	N ₃₅
N ₄₁	N ₄₂	N ₄₃	N ₄₄	N ₄₅
N ₅₁	N ₅₂	N ₅₃	N ₅₄	N ₅₅

(b)

Fig. 1: Masks used in the threshold free method a) Motion compensated 5×5 block from previous frame b) motion compensated 5×5 block from next frame.

The pixel of interest I_c which corresponds to P_{33} in the previous frame and N_{33} in the next frame is decided as blotched or not blotched using the following statements:

$$\begin{aligned}
 T_{\min, p, 1} &= \min \{P_{11}, P_{22}, P_{33}, P_{44}, P_{55}, P_{15}, P_{24}, P_{42}, P_{51}\}, \\
 T_{\max, p, 1} &= \max \{P_{11}, P_{22}, P_{33}, P_{44}, P_{55}, P_{15}, P_{24}, P_{42}, P_{51}\}, \\
 T_{\min, p, 2} &= \min \{P_{13}, P_{23}, P_{33}, P_{43}, P_{53}, P_{31}, P_{32}, P_{34}, P_{35}\}, \\
 T_{\max, p, 2} &= \max \{P_{13}, P_{23}, P_{33}, P_{43}, P_{53}, P_{31}, P_{32}, P_{34}, P_{35}\}, \\
 T_{\min, n, 1} &= \min \{N_{11}, N_{22}, N_{33}, N_{44}, N_{55}, N_{15}, N_{24}, N_{42}, N_{51}\}, \\
 T_{\max, n, 1} &= \max \{N_{11}, N_{22}, N_{33}, N_{44}, N_{55}, N_{15}, N_{24}, N_{42}, N_{51}\}, \\
 T_{\min, n, 2} &= \min \{N_{13}, N_{23}, N_{33}, N_{43}, N_{53}, N_{31}, N_{32}, N_{34}, N_{35}\}, \\
 T_{\max, n, 2} &= \max \{N_{13}, N_{23}, N_{33}, N_{43}, N_{53}, N_{31}, N_{32}, N_{34}, N_{35}\}, \\
 T_{\min} &= \min \{T_{\min, p, 1}, T_{\min, p, 2}, T_{\min, n, 1}, T_{\min, n, 2}\}, \\
 T_{\max} &= \max \{T_{\max, p, 1}, T_{\max, p, 2}, T_{\max, n, 1}, T_{\max, n, 2}\}.
 \end{aligned}$$

The pixel I_c is flagged as uncorrupted if,

$$T_{\min} \leq I_c \leq T_{\max}.$$

From the above equations it is clear that the validity of the pixel of interest depends only on the defined sets from previous and next frames. Ideally, the detector uses $5 \times 5 \times 3$, which is constructed using motion-compensated previous, present and motion-compensated next frames to find out the maximum and minimum bound. Since the blotches may occupy larger areas spatially, the pixels from the present frame are omitted in finding the bounds. Since there is possibility for the corruption of the pixels which are from previous and next frames, we are selecting only two sets of values which are enough to detect the minimum and maximum bound. By doing this the noise in the omitted set does not effect the detection. But, if noise is present in the taken sets the detection process will fail. To remove these false alarms, the detected mask will be post processed, to make the detection more complete.

Improved Detection by Post Processing

The goal of this section is to improve the ratio of correct detections to false alarms of existing blotch detectors [2]. The strategy of post processing is to remove possible false

alarms and finds parts of the blotches missed by the detector due to noise. The idea here is blotches are not just random sets of individual pixels, but they are spatially coherent regions and can be manipulated as such. As a first step in the post processing, the detected mask using proposed technique is median filtered both vertically and horizontally to remove single pixel false alarms. In the second step, the median filtered mask is constrained dilated to fill the small holes in the candidate blotches and by adding parts of the blotches that may have been missed near the edges.

4. Results and Discussion

The proposed detector is tested on four real old sequences, namely tiger, zee1, zee2 and zee3. All sequences were degraded by adding artificial blotches. Each artificial blotch has a fixed gray value that was drawn between 10 and 240. Zee3 is a black and white sequence, where as tiger, Zee1 and Zee2 are color sequences. Motion was estimated by Block matching motion estimation. Fig.2 shows the frame from artificially corrupted tiger sequence, and reconstructed frame.

A useful summary of performance for detectors in general is Receiver Operating Characteristics (ROCs). The false alarm rate graph versus correct detection rate is shown in Fig.3. The probability of false alarm P_{fa} and correct detection P_{co} are defined as

$$P_{fa} = \frac{N_{fa}}{M \times N}$$

and

$$P_{co} = \frac{N_{co}}{N_{co} + N_{mi}}$$

Where N_{fa} is the number of false detections $M \times N$ is the number of pixels per frame, N_{co} is the number of correct detections, and N_{mi} is the number of missing detections. Fig.3 plots the ROCs for ROD detector, SROD detector, and the ROD detector with post processing. The results are plot by varying the threshold between 0 and 60. The figure makes it clear that the SROD detector performance similar to that of a ROD detector. The post processing applied to the detection masks obtained from the SROD detector detects blotches with high detection rate, but suffering from high false alarm rate.

Since, there is no threshold in the case of proposed method, the best result of the ROD detector with post processing is compared with the proposed method. Table 1.1 gives the post processing statistics for the four test sequences. In the case of ROD detector with post processing, the high sensitivity threshold forms large size labels which include so many false alarms. When these labels are validated with the mask detected with low sensitivity, these false alarms will also carry to the final detection mask. From the Table 1.1 it is clear that the ROD detector with post processing has higher number of false alarms than proposed method. And the proposed method's

correct detection rate is very much less than the ROD with post processing.

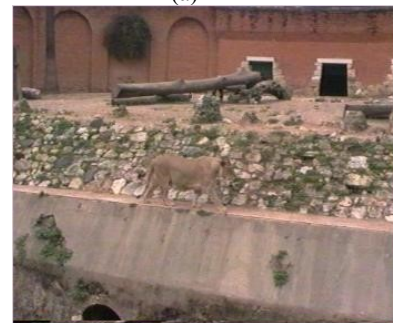
The relative complexity of the proposed technique is compared with the existing detection algorithms mentioned in this paper, and is given in Table 1.2. The time calculations are carried out on a typical Intel P4 processor with 512MB RAM using MATLAB6.5. SDIp takes less time because of sign comparison. Because of the heavy computations ROD, ROD with post processing and proposed methods are taking more CPU time to complete the task when compared to spike detection methods. Proposed method has approximately 50% lesser computations when compared to ROD with post processing. This is because proposed technique does not need any labeling procedure for post processing, which is compulsory for ROD with post processing.

5. Conclusion

In this paper, we have proposed a technique for the detection of blotches. The main advantage of our method is that it does not need any threshold for detection. To our knowledge, this is the first algorithm which detects the blotches automatically for any type of sequence. The validity of the proposed method is tested on four test sequences, and the results shown that it also reduces the number of false alarms greatly. The time complexity of the proposed method is reasonable. Further work is in progress for reducing the noise presented in the defined sets.

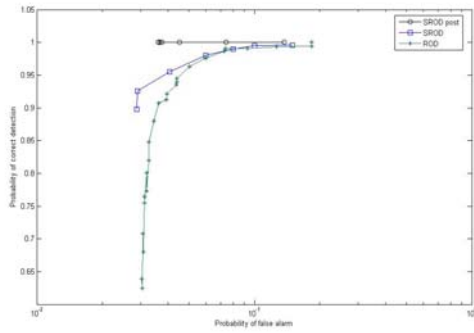


(a)

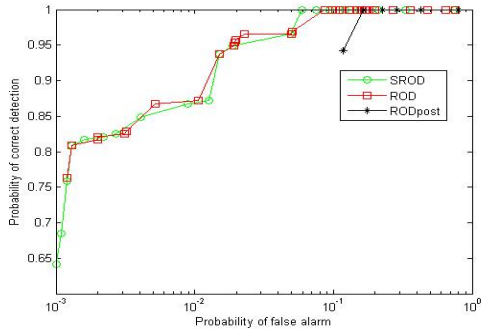


(b)

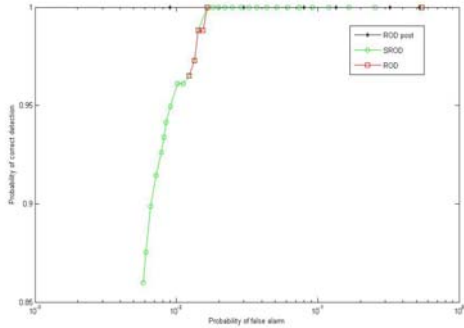
Fig. 2: a) artificially blotched frame, b) reconstructed frame



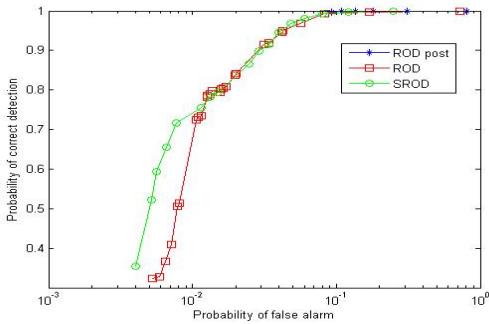
(a)



(b)



(c)



(d)

Fig. 3: ROCs for a) Tiger, b) Zee1, c) Zee2, d) Zee3 sequences.

Test sequence	Proposed method without post processing		Proposed method with post processing		ROD with post processing	
	FD	CD	FD	CD	FD	CD
Tiger	0.042	0.9675	0.0288	0.9675	0.036	1.0
Zee1	0.0064	1.0	0.0084	1.0	0.594	1.0
Zee2	0.0033	0.9805	0.0040	0.9922	0.0166	1.0
Zee3	0.0058	0.9961	0.0046	0.9961	0.2469	1.0

Table.1.1: The detection statistics for the proposed method with and without post processing for all test sequences. (FD – False Detection, CD- Correct Detection)

Method	CPU time (in seconds)
SDIp	4.9688
SDIa	5
SDI	5.1406
ROD	40.1406
Proposed	49.1875
ROD post	87.098

Table.1.2: Time statistics for SDI, SDIa, SDIp, ROD, ROD post and proposed methods.

6. References

[1] A. C. Kokaram, R. Bornard, A. Rares, D. Sidorov, J. H. Chenot, L. Laborelli, and J. Biemond, "Robust and Automatic Digital Restoration Systems: Coping With Reality," *Journal of the Society of Motion Picture and Television Engineers* (SMPTE), 2003.

[2] P. M. B. Van Roosmalen, *Restoration of Archived Film and Video*, PhD thesis, Technische Universiteit Delft, The Netherlands, 1999.

[3] T Saito, T Komatsu, T Hoshi and T ohuchi, "A practical filtering method for film blotch removal based on local robust analysis of spatiotemporal brightness continuity," In the Proceedings of Seventh IEE international conference on Image processing and its Applications, Volume No.1, Pages: 211-215, 1999

[4] A. C. Kokaram, *Motion picture restoration: Digital Algorithms for Artifact Suppression in Degraded Motion Picture Film and Video*. Springer Verlag, London, 1998.

[5] P.M.B. Van Roosmalen, J. Biemond and R.L. Lagendijk, "Restoration and Storage of Film and Video Archive material," NATO summer school, 1998.

- [6] N. R. Harvey, S. Marshall, "Application of Non-Linear Image Processing: Digital Video Restoration," In Proceedings of the IEEE International Conference on Image Processing, Volume No.1, Pages: 731-734, 1997.
- [7] M. J. Nadenau and S.K. Mitra, "Blotch and Scratch Detection in Image Sequences based on Rank Ordered Differences", In Proceedings of the 5th International Conference on Time-Varying Image Processing and Moving Object Recognition, Italy, 1996.
- [8] A. C. Kokaram, R. Morris, W. Fitzgerald, and P. Rayner, "Detection of missing data in image sequences," *IEEE Transactions on Image Processing*, Volume No.4, Pages: 1496-1508, 1995.
- [9] A. C. Kokaram, R. Morris, W. Fitzgerald, and P. Rayner, "Interpolation of missing data in image sequences," *IEEE Transactions on Image Processing*, Volume No.4, Pages: 1509-1519, 1995.
- [10] M. Chong, P. Liu, W. Goh, and D. Krishnan, "A new spatio-temporal MRF model for the detection of missing data in image sequences," In the Proceedings of the IEEE International Conference on Acoustics, Speech, and Signal Processing, Pages: 461-464, 1992.
- [11] M. Bierling, "Displacement Estimation by Hierarchical Block matching," In SPIE Visual Communications and Image Processing. Volume No.1001, Pages: 942-951, 1988.
- [12] R. Storey, "Electronic Detection and Concealment of Film Dirt", *SMPTE Journal*, Pages 642-647, 1985.
- [13] R. Storey, "Electronic Detection and Concealment of Film Dirt", *UK patent Specification No.2139039*, 1984.
- [14] J. S. Lim, "Image Restoration by Short Space Spectral Subtraction", *IEEE Transactions on ASSP*, Volume No.28, Pages: 191-197, 1980.
- [15][Online].Available:
http://brava.ina.fr/brava_public_impairments_list.en.html