A New Methodology for Line Scratch Restoration

DOI: 10.1685/CSC06102

Giuliano Laccetti
University of Naples Federico II
Via Cintia, 80126 Naples, Italy
giuliano.laccetti@dma.unina.it

Lucia Maddalena

National Research Council, Institute for High-Performance Computing and Networking
Via P. Castellino 111, 80131 Naples, Italy
lucia.maddalena@na.icar.cnr.it

Alfredo Petrosino
University Parthenope of Naples, Department of Applied Science
Via A. De Gasperi 5, 80133 Naples, Italy
alfredo.petrosino@uniparthenope.it

1 Introduction

With the recent advent of digital technologies and the ever increasing need for speed and storage, occluded or missing parts in images and movies is a more and more widespread problem. The problem can occur in several multimedia applications, such as digital movie restoration and wireless communication. The specific application we are concerned with is digital movie restoration, which is the set of image processing methodologies and techniques allowing to reproduce digital copies of damaged movies that are as much as possible similar to the uncorrupted lost original.

Several classes of defects can be distinguished that affect movies; in the present paper, we focus on the class of scratch defects, intended as long and thin vertical scratches that affect several subsequent images of a sequence, due to the abrasion of the film by dust particles in the slippage mechanisms used for the development, projection and duplication of the film.

Here we propose an approach to line scratch restoration, based on fusion techniques for both the stages of the automatic restoration process, which takes into account already existing promising algorithms and suitably combines the obtained results in order to provide a restored sequence as similar as possible to the original uncorrupted sequence. As we show, the results produced by the proposed approach upon different damaged movies greatly enhance those produced by each considered approach.

2 Line scratch restoration

A sufficiently general model of degraded video signal is the following for a pixel location $\mathbf{p} = (x, y)$:

(2.1)
$$I(\mathbf{p},t) = (1 - b(\mathbf{p},t))I^*(\mathbf{p},t) + b(\mathbf{p},t)c(\mathbf{p},t) + \eta(\mathbf{p},t),$$

where $I(\mathbf{p},t)$ is the corrupted signal at spatial position \mathbf{p} in frame $t, b(\mathbf{p},t) \in \{0,1\}$ is a binary mask indicating the points belonging to missing parts of the degraded video,

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 I^* is the ideal uncorrupted image. The (more or less constant) intensity values at the corrupted spatial locations are given by $c(\mathbf{p},t)$. Though noise is not considered to be the dominant degrading factor in the defect domain, it is still included in (2.1) as the term $\eta(\mathbf{p},t)$.

Here we focus on the class of line scratch defects, intended as long and thin vertical scratches that affect several subsequent images of a sequence, due to the abrasion of the film by dust particles in the slippage mechanisms used for the development, projection and duplication of the film.

Commonly, scratch restoration is a two-step procedure. In the first step the scratches need to be detected, i.e., an estimate for the mask $b(\mathbf{p},t)$ is made (detection step). In the second step the values of I^* inside the scratch, possibly starting from information about $c(\mathbf{p},t)$, are estimated (removal step). As usual, we consider scratch restoration as a missing data problem, i.e. we suppose that any information $c(\mathbf{p},t)$ has been lost within the scratch.

Even though many of scratch restoration methods reported in literature achieve very accurate results, none of them ensures a perfect restoration whichever is the image sequence to be restored and whichever is the kind of scratch by which it is affected; therefore scratch restoration is still considered an open problem.

3 LSR: Line Scratch Restoration algorithm

The proposed algorithm for scratch restoration in image sequences is based on a new methodology for the solution of classes of problems to be dealt with in digital movie restoration, which takes into account already existing promising algorithms and suitably combines the obtained results in order to provide a restored sequence as similar as possible to the original uncorrupted sequence [6]. In the case of line scratch restoration, the basic idea of the *compound algorithm* consists, for each sequence frame, in:

- 1. applying a set of d existing scratch detection algorithms;
- 2. combining obtained scratch masks to produce the final scratch mask;
- 3. applying a set of r existing scratch removal algorithms using the final scratch mask;
- 4. combining obtained restored images to produce the final restored image.

The combination of results is obtained through fusion techniques (see for instance [1]): input images, which provide alternative and complementary "views" and "characteristics" of a given area, are "fused" into a single image in such a way that all the important visual information found in input images is transferred into the fused output image, without the introduction of artifact distortion effects.

For the implementation of the LSR algorithm we have considered as underlying restoration modules d=3 detection algorithms (in the following denoted as DA1, DA2, and DA3) presented in [3, 4, 5], respectively, and r=2 removal algorithms (in the following denoted as RA1 and RA2) presented in [2, 7], respectively. Moreover, for the combination of detection and removal results we adopted two fusion techniques (in the following denoted as DF1 and RF1) described in [6]. A scheme for our implementation of LSR algorithm is given in Fig. 3.1.

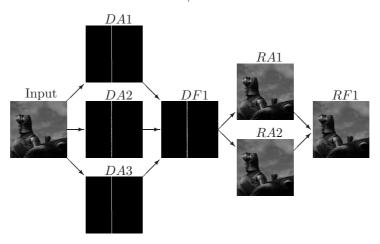


Figure 3.1: Scheme of the LSR algorithm.

4 Experimental results

The accuracy of the result of the detection algorithms taken into account is quite high, as it is shown by the scratch masks reported in Figs. 4.1(b-d) for the sequence frame of Fig. 4.1(a); nonetheless, the fused mask reported in Fig. 4.1(e) seems more appropriate for the successive removal phase.

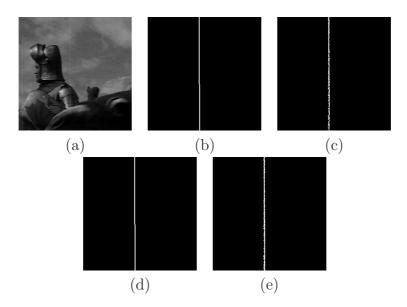


Figure 4.1: Detection results over the original frame (a) by adopting algorithms: (b) DA1, (c) DA2, (d) DA3, (e) DF1.

In order to obtain an objective estimate of detection algorithms, for each mask computed with anyone of the described algorithms we considered the correct detection rate r_C (rate of pixels of the scratch that are included in the computed scratch mask) and the false alarm rate r_F (rate of pixels not belonging to the scratch that are included in the computed scratch mask). Values for r_C and r_F obtained with all the algorithms for artificially scratched images are reported in Table 4.1, varying the scratch width w. Here we can observe that r_C values are generally very close to 1 for all detection algorithms

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	w =	= 3	w = 5		w = 7		w = 9	
	r_C	r_F	r_C	r_F	r_C	r_F	r_C	r_F
DA1	0.9984	0.0000	0.9991	0.0000	0.9991	0.0000	0.9991	0.0000
DA2	0.9684	0.0006	0.9565	0.0015	0.9697	0.0017	0.9765	0.0017
DA3	0.9984	0.0000	0.9991	0.0000	0.9996	0.0000	0.9995	0.0000
DF1	0.9984	0.0006	0.9991	0.0015	0.9996	0.0017	0.9995	0.0017

Table 4.1: Correct detection rates r_C and false alarm rates r_F for the detection algorithms applied to images corrupted with an artificial scratch of width w.

and that only few false alarms are generated, and, specifically, DF1 reaches the best r_C and the worst r_F values achieved by DA1, DA2, and DA3.

The results of the scratch removal algorithms taken into account for the sequence frame of Fig. 4.1(a) are reported in Figs. 4.2(a-c). From these results we can observe that, even though RA1 and RA2 algorithms perform quite well, their reconstruction accuracy can be enhanced; the fused result, instead, tends to smooth the inaccuracies, still retaining the good performance of the underlying algorithms.



Figure 4.2: Removal results for the image of Fig. 4.1(a) by adopting algorithms: (a) RA1, (b) RA2, (c) RF1.

Results in terms of Mean Squares Error (MSE), Peak Signal-to-Noise Ratio (PSNR), and Structural Similarity Index (SSIM) obtained with the removal algorithms for images artificially corrupted with scratches of varying width w are reported in Fig. 4.3, from which we can conclude that the fusion method is the most accurate among the considered removal methods.

5 Conclusions

This paper described a new methodology for the solution of classes of problems to be dealt with in digital movie restoration, which takes into account already existing promising algorithms and combines the obtained results through data fusion techniques in order to provide a restored sequence as similar as possible to the original uncorrupted sequence.

For the specific case of line scratch restoration, we presented the LSR algorithm, based on such methodology, and described its implementation using suitable restoration modules. Extensive testing on several corrupted and artificially corrupted real image se-

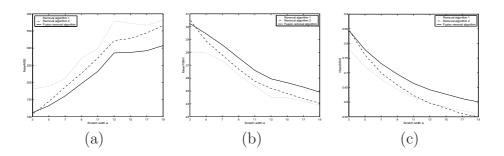


Figure 4.3: Accuracy measures of removal algorithms applied to images corrupted with an artificial scratch of width w: (a) MSE, (b) PSNR, (c) SSIM.

quences lead to the conclusion that LSR algorithm accuracy outperforms that of the underlying restoration methods.

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