Scratches Removal in Digitised Aerial Photos Concerning Sicilian Territory

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Keywords: Scratch removal, scratch detection, image restoration

Abstract - In this paper we propose a fast and effective method to detect and restore scratches in aerial photos from a photographic archive concerning Sicilian territory. Scratch removal is a typical problem for old movie films but similar defects can be seen in still images. Our solution is based on a semiautomatic detection process and an unsupervised restoration algorithm. Results are comparable with those obtained with commercial restoration tools.

1. INTRODUCTION

Mechanical scratches are typical defects in old movie films. This specific damage is caused by the lost of the emulsion of the film surface, due to contacts with mechanical parts of film projector or other devices in the film development process. Bright or dark scratches run all over the frames of a movie film. Reconstruction of damaged information is a fundamental task with the purpose of digitalization and preservation of old photos or movies archives. Manual restoration is the standard method to reconstruct damaged information, but is expensive and time consuming, because of the typical huge amount of data to be restored. Automatic or semiautomatic methods are needed to help the user in this task.

In this paper we will focus on detecting and removing scratches in digitized aerial damaged photos from a Sicilian territory photographic archive .

The problem of scratch removal has been addressed in many papers in scientific literature for old movies film restoration. Since some authors[4] used a spatio-temporal point of view to restore scratches, many of them proposed static removal approaches using information from a single frame, so these methods can be used as they are to process also still images. Kokaram[7] proposed a 2-dimensional autoregressive model to interpolate missing information consistently with the local neighborhood, without using information from adjacent frames. Bretschneider et al[1] proposed a technique based on wavelet decomposition. Bruni et al[2] generalized the Kokaram's model for scratch detection on the hypothesis that scratch is not purely additive on a given image. The same authors[3] also presented a method based on the Weber's law to detect and restore damages. Tegolo et al[8] proposed a detection method based on statistical information extracted from the whole image, and adopted a genetic algorithm for the restoration phase.

In this paper we propose a fast and effective method to detect and remove scratches in still images, with a semiautomatic detection method and an unsupervised restoration process.

The paper is organized as follows. The next Section presents the scratches characteristics of the photos in our photographic archive. Section 3 shows the proposed method, while experimental results are shown in Section 4. Some concluding remarks are then given in the final section.

2. SCRATCHES CHARACTERISTICS

Within our photographic archive (2500 color images of digitized aerial photos of Sicilian territory, with average resolution of 15000x15000) scratches occur as long bright lines that run more or less horizontally along the image. These specific scratches features are caused by the manual inspection of the photos negatives with a mechanical device. They can occupy the whole image, with or without interruptions, or only a part of it. Typical line width values are 3-7 pixels vertically and a maximum slope value of 10 degrees is measured, with possible smooth changes of slope along the photo. Intensity value of a scratch is different in darkest and brightest areas of the image. Lines brightness is lower in darkest regions, because of the natural interpolation process of a digital scanner.

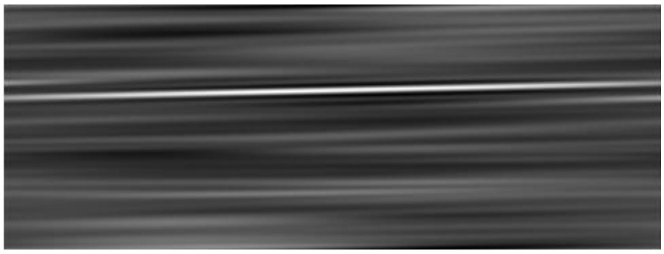
3. PROPOSED METHOD

The scratch removal problem could be divided into two sub-problems: detection and restoration. The detection phase consists in searching defects which are not natural lines in the image. The output of this process is a binary mask in which pixels are labeled as good or damaged. This mask is strictly tied with the precision of the detection algorithm. In fact, this region has to be neither too small, since it can still not contain degraded pixel, nor too large, since good information of the image could be destroyed. The restoration step has the purpose to reconstruct lost information using pixels close to the scratch. The key point for this phase is the choice of the appropriate neighborhood. Our algorithm is based on a semiautomatic detection method and an unsupervised restoration process.

3.1 Scratch detection

Our dataset is corrupted by scratches like straight lines with a quasi horizontal displacement, so their main feature is the orientation. Kass and Witkin [6] affirm that a line is $\pi/2$ shifted in the frequency domain and suggest the use of a pass band filter to select it. Indeed, the band-pass avoids

a. original image

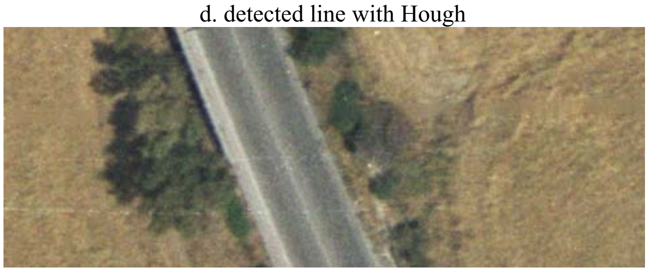


b. after bandpass and homomorphic filtering

c. after thresholding

d. detected line with Hough

e. binary mask



f. restored image

Figure 1. Processing steps for scratch detection

illumination problems, due to low harmonics, and noise corruption, due to high ones.

$$H(u,v) = \frac{1}{1 + 0.414 \cdot \left(\sqrt{\left(\frac{u^*}{D_h} \right) + \left(\frac{v^*}{D_v} \right)} \right)^{2n}} \qquad (1)$$

where D_h and D_v are the two cutoff frequencies while u^* and v^* are the translated and rotated frequency coordinates as follows:

$$\begin{cases} tx = center \cdot \cos(\theta) \\ ty = center \cdot \sin(\theta) \end{cases};$$
$$\begin{cases} u^* = \cos(\theta) \cdot (u + tx) + \sin(\theta)(u + ty) \\ v^* = -\sin(\theta) \cdot (u + tx) + \cos(\theta)(u + ty) \end{cases} \qquad (2)$$

so that the center of the sub-band has *tx, ty* coordinates and it is rotated with the same angle. The sub-bands must be symmetric with respect to the origin, so the angle θ must be shifted of π.

The filter order n can control the slope of the sub-band, so that we chose n=4 to concentrate the filtering in a precise zone of the spectrum. This explains the use of this bandpass filter instead of a Gabor one. A homomorphic filter is applied to enhance the scratch and to produce a dark uniform background. The result after the bandpass and the homomorphic filter can be seen in fig 1.b. Now a threshold is applied on the image (fig 1.c) with the aim to obtain a binary image containing the scratch position. The threshold value is computed as mean plus standard deviation of the image intensity.

Once the input image has been preprocessed we apply the Hough transform to the filtered binary image to extract any relevant lines. Hough transform [4] maps each pixel (x,y) into the parameter space (a,b), where a and b are the slope and intercept of a generic line y = ax + b. Usually, a normal representation of the line is used, and the parameter space is subdivided into a number of accumulator cells in order to reduce the computational complexity. Each pixel in the binary image is processed and a counter in the accumulator cell is incremented. The algorithm outputs the cell with the highest score. The detected scratch line and the resulted binary mask are shown in fig. 1.d and 1.e. The method has proven to be robust to noise and suitable for our purposes.

3.2 Restoration phase

The proposed restoration method is a pixel-by-pixel filling process. It takes as input the previous detected binary mask and uses pixels close to the mask to reconstruct lost information.

It can be divided into two steps:

- Estimation of the direction of the information propagation vector
- Pixel filling

3.2.1 Direction estimation

A block-matching method is used to estimate the direction toward which information is propagated from above to below the scratch area. In this step we use the brightness component of the image. Pixels are processed in scan order. For each pixel into the scratch mask, two rectangular areas are considered, one above and one below the mask. Their positions, related to the pixel to fill, depend on the scratch mask width, while their size depend on the gradient vector computed at the pixel-to-fill position. Within this two areas our method tests all the possible candidate vectors that link a block in the area above the scratch with a block in the area below, centred in the pixel position. The vector that minimizes the Sum of Absolute Differences (SAD) of the pixels in the two end-point blocks is chosen as the most probable direction vector toward which information is propagated .

$$(d_x, d_y) = \arg\min_{k_x, k_y} \sum_{k_x=0}^{D_x} \sum_{k_y=-D_y}^{D_y} SAD(x, y, k_x, k_y)$$

$$SAD(\ ) = \sum_{i=-1}^{1} \sum_{j=-1}^{1} \left| p\left(x - k_x - \frac{w}{2} + i, y - k_y + j \right) - p\left(x + k_x + \frac{w}{2} + i, y + k_y + j \right) \right| \quad (3)$$

where w is the scratch width, k_x k_y are the candidate direction vector components, D_x and D_y the vertical and the horizontal size of the area into which matching is searched. Mask width w is updated after each horizontal scan. D_x and D_y depend on the mask width and on the gradient vector computed at the pixel-to-fill position. If the horizontal component of the gradient is greater than the vertical one, D_y is set to a higher value. Similarly for the vertical component. Blocks to be matched must be symmetrical with respect to the pixel position, in order to avoid annoying distortion artefacts in the reconstructed area. Blocks inside the lower part of the scratch mask are allowed to be used for matching. We observed that the damaged area holds some residual information, so partial overlapping between blocks and scratch mask is useful to recover that information. No pixel from the real scratch line is used, because no matching can be found between upper blocks and blocks with the high brightness value of the scratch.

3.2.2 Pixel filling

The pixel filling phase works in the three RGB color channels. It uses the estimated direction vector to find below and above the scratch two pixels, for each color channel, along that direction, with the same distance from the pixel to fill. The value to be assigned to the pixel, for each channel, is the median value between this two point and a further value, computed as the average of the two vertically closest pixels outside the scratch mask:

$$\begin{aligned} up &= p\left(x - d_x - \frac{w}{2}, y - d_y \right) \\ down &= p\left(x + d_x + \frac{w}{2}, y + d_x \right) \\ v &= \frac{(p(x-1, y) + p(x+w, y))}{2} \\ p'(x, y) &= median(up, down, v) \end{aligned} \quad (4)$$

d_x and d_y are the components of the estimated direction vector. If *up* and *down* are similar, the new pixel value is assigned as one of them. If they are much different, new value is computed with a simple vertical interpolation, introducing no artefacts but only few blurring.

Finally, a median filter is applied to the edge pixels of the scratch mask, to remove some residual artefacts.

4. EXPERIMENTAL RESULTS

Our algorithm has been tested on a subset of 105 cropped images from a photographic archive composed of 2500 aerial photos of the Sicilian territory. It has been implemented in Matlab for the detection step, and in ANSI-C for the restoration phase.

We measured a percentage of 85,7% of line scratch correct detection and an average execution time, for the single detection step, of 1,2 sec per scratch (maximum crop size 500x500).

Our method works well to reconstruct straight or curve lines, with no false edges, chromatic aberration or distortion. Some blurring is introduced where scratch lines cross areas which have much different information below and above the scratch. Figg. 1.c,1.f and 2 show some of our results. We measured an average restoration time of much less than 1 sec per scratch. No objective measure is possible to evaluate the restoration quality of our reconstructed images, because we didn't have a reference undamaged image to compare with.

We observed that our results are comparable with those obtained with commercial restoration tools, but much less user intervention is required (only confirmation and mask width setting).

5. CONCLUSIONS

In this paper we presented a fast and effective method to detect and remove scratches in still images. We propose a semiautomatic detection method, based on band-pass filtering and Hough transformation, to detect candidate scratches. Our method needs the user to confirm the candidate scratch and to set the scratch mask width. Restoration phase reconstruct lost information in automatic way. We estimate the direction toward which information is propagated into the scratch mask with a block-matching method. Pixels in the mask are filled with information along the estimated direction. Our method had been tested on a photographic archive composed by aerial photos concerning Sicilian territory. Results, comparable with those obtained manually with some commercial tools, are obtained as discussed in the section on experimental results. Future works are concerned with the development of a fully automatic batch procedure for scratch removal in huge photographic archives.

ACKNOWLEDGEMENTS

This work has been partially funded by the MIUR (Italian Ministry of Education, University and Research) project FIRB 2003 D.D. 2186 - Ric December 12th 2003. The authors wish to thanks the SAS s.r.l. in Palermo for having permitted the use of their photos in this research.

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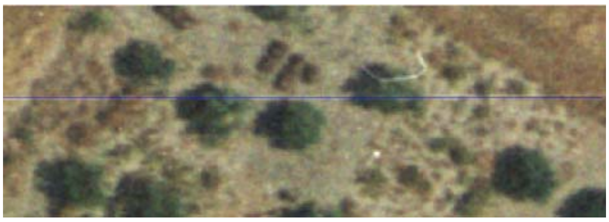
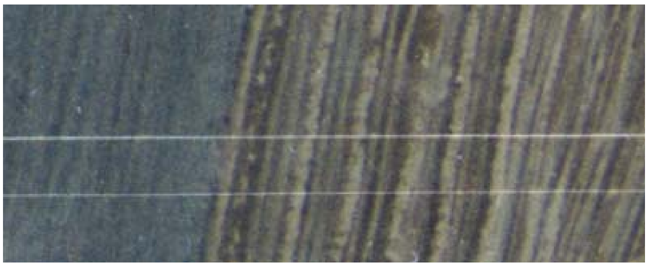
a.original image



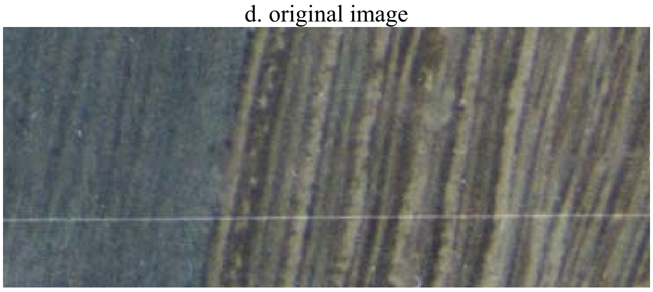
b. detected scratch

c.restored image

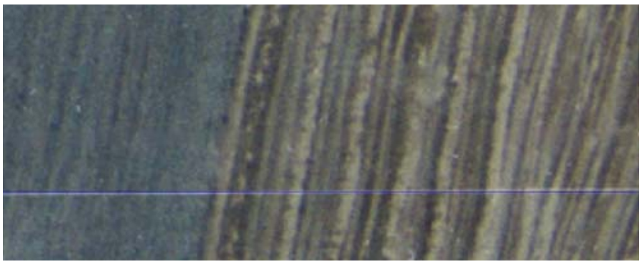


d. original image

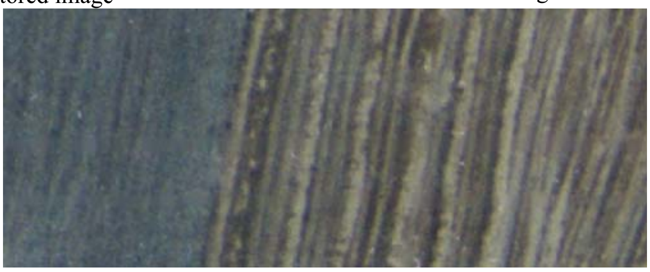
e. first detected scratch



f. partially restored image



g. second detected scratch



h. restored image

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