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Digital Restoration for Antique Documents

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Abstract

Different advantages stem from the digital restoration of documents of high cultural value. In this paper different techniques to digital restoration of antique documents are reported. In particular, we address the problem of virtual restoration of photographic prints. We propose a classification of defects related to their origin presenting also some non linear techniques able to restore the more diffused ones. In particular we briefly report some restoration results of water blotches, foxing and creases with some more details for a novel methodology to obtain a continuous tone image starting from an halftoned one, without no knowledge of the original halftoning technique.

1 Introduction

Paintings, frescos, antique photographic prints, incunabolas, old books, and handwritten documents represent a valuable and immense historical patrimony. In order to share this patrimony and to preserve the original materials, libraries, museums and archives devote large financial and intellectual resources in their digital reproductions. By digitization and subsequent virtual restoration, we can try to improve the usability of the object, by obtaining a better image that helps the "official restorer" in planning future work and appraising the final result.

To summarize the defects of antique artwork on paper support, we can divide them in different sets according to their origin: mechanical damage and chemical damage [3, 4]. All these defects have been studied to produce dedicated ad-hoc restoration algorithms. In this paper, due to the lack of space, we report only one restoration algorithm. In particular, we treat a novel technique to create a continuous tone image starting from an halftoned one. This is an important image processing process that allows the restorer to reconstruct the original image when this is lost or destroyed. Moreover, this algorithm improve the performances of the image processing operators since they work better if applied on a continuous tone image.

The rest of the paper is organized as follows. Section 2 shows how to generate a typical screened image and reports some descreening techniques. In Section 3 our algorithm is proposed, while some experiments are reported in Section 4. Conclusions end the paper.

2 Descreening

A grayscale photograph has hundreds of shades of gray, while black-and-white display devices requires only binary images. Hence, when an image is reproduced, the continuous tone image is converted in a binary image. This converting process, called *screening* or *halftoning*, breaks an image into a series of dots with different sizes. Each size approximate a shade of color: a group of large dots placed closely together appears black; a group of smaller dots with larger spaces between them produces a weaker gray shade; while a group of even smaller dots spaced widely apart appears almost white (Fig. 1).

Usually, the image processing operators work better if they are applied over a continuous tone image. To enable these operations, gray images need to be reconstructed from the halftones through *inverse halftoning* or *descreening*. However, the screening operators lost some information, and there is no way to reconstruct a perfect gray image from the given halftoned image.

In literature there are many methods to invert the halftoning. The main problem of these approach is that they first create a smoothed image and then enhance the quality of the result. The regular pattern of the screen can also be considered as a periodic noise (shot noise) of a digital images. These artifacts can be revealed in Fourier space as high amplitude at specific frequencies in the spectrum using notch filters. Despite this approach preserves the uncorrupted regions, it can not used in descreening problem, since the screening dot is not exactly added noise but it is the information itself. More general methods are desired.

3 The proposed algorithm

The descreening algorithm proposed in this paper works in the frequency domain. It is an extension of the algorithm proposed in [1]. The basic idea is that the screen pattern can be detected and properly removed because it is intrinsically regular and periodic. In some sense, the screen signal can be associated with some kinds of periodical noise. The main differences is that such "noisy" values cannot be completely removed because it carry out also the original signal. Preserving, of course, the right amount of low frequencies component it is possible to properly search the anomalous peaks and delete them in a suitable way (Fig. 2). These peaks are properly characterized by some peaks located at a given distance from the DC component. In such manner the main low pass component are preserved and the final recovered image is not too blurry. For this purpose, we use a new filter derived by classical Chebyschev filter with some slight modification. The classical bandreject filter based on a Chebyschev polynomial of degree n [2] for an image whose size is $M \times M$, and with a noise peak at distance r_k than DC (the subscript k as reported below is referred to a specific peak with $k = 1, 2, \ldots, K$), is expressed as

$$Cheb_{ij}^{k} = \left(\sqrt{1 + \varepsilon^2 C_n^2 \left(\frac{D_{ij} * W_k}{(D_{ij}^2 - r_k^2)} \right)} \right)^{-1} \tag{3.1}$$

the proposed filter is

$$H_{ij}^{k} = \begin{cases} 1, & D_{ij} < (r_k - \frac{W_k}{2}) \\ Cheb_{ij}^{k}, & (r_k - \frac{W_k}{2}) \le D_{ij} \le (r_k + \frac{W_k}{2}) \\ 1, & D_{ij} > (r_k + \frac{W_k}{2}) \end{cases} \tag{3.2}$$

where $i, j = -M/2, \ldots, M/2$, n and W_k are the degree and the width of the filter, respectively; ε is a constant less than 1; and D_{ij} is the Euclidian distance between the value with the coordinate (i, j) and DC. The Chebyschev polynomials are reported in

Table I. Fig. 3 reports the plot of the proposed filter and the ones of other filters of the same degree for 1D signal. In particular, the black one is the filter proposed in this paper, the red one is the Chebyschev filter, and in blue there is the Butterworth filter.

This filter uses the Fourier symmetry, hence all the peaks at distance r_k from the center are removed. Anyway, in the descreen problem, the regular peaks in the frequency domain are numerous (Fig. 2(b)). We have observed that the screen pattern is eliminated if all the points in K different rings are removed. If the peaks far from DC component are situated as distance r_k, with $k = 1, \cdots, K$, the proposed filter is described by the following equation:

$$H_{ij} = 1 - \sum_{k=1}^{K} \left(1 - H_{ij}^{k}\right) \tag{3.3}$$

4 Experimental results

The algorithm proposed in this paper needs the specification of parameters n and W_k. For old manual screened images, we have chosen to put the former equal to 2 and $W_k = 30$ for $k = 1, 2, 3$. K is experimentally fixed equal to 3, and the radii r_k in Eq. 3.3 are automatically determined using a simple but effective heuristic. We use as r_1, r_2 and r_3, the position of the higher peaks far from DC, and with $r_3 \neq r_1$ and $r_3 \neq r_2$. Using these parameters, the filtered frequency domain in Fig. 2(a) is reported in Fig. 5.

The set of 30 images processed in our experiments are real scans of screened images that belong to the *Candiani* collection of the Pordenone Museum, Italy. Since an "original" version without defects does not exist, the performances of the algorithm cannot be quantitatively compared using MSE or PSNR. Fig. 4 reports some descreened images.

5 Conclusions

A new algorithm to reconstruct a continuous tone from an halftoned image has been proposed. It automatically removes the higher peaks in the frequency domain out of the central area around the DC. The proposed algorithm ensures fast and effective results, and can be used also by non-qualified operators.

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