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Comparative study on digital image enhancement for virtual restoration of mural painting

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Abstract—Digital restoration of mural painting estoration is very important for the continuation of world civilization and cultural management. In this paper, some virtual multitasking mixed enhancement algorithms are compared in enhancing painting images combining several classic methods of image denoising and sharpening. In experiments some excellent algorithms are identified, and some techniques, principles and understandings guiding a successful enhancement are discussed for better retrieval and interpretation of implied value information of cultural heritage.

***Index Terms*—Cultural heritage, mural painting, virtual restoration, information retrieval, image enhancement, noise removal, edge sharpening, contrast enhancement.**

I. INTRODUCTION

The cultural relics are witness of world history and civilization and important part of cultural management. However, they usually can not be exhibited completely in front of people because of many irresistible factors such as some inevitably physical or chemical reactions, etc. The cultural relics with the loss and incomplete information bring negative impact on convenient and perfect communication, appreciation and research of cultural relics [1-4].

For a long time, the experienced workers full of rich experience and perception repair damaged cultural relics through manual operation, cleaning and complementing colour, doing their best to make cultural relics display completely in front of everyone. However, once restoration results are finished, they can not be changed again. Just as the case of the repair work of fine arts in the Renaissance period, a slight negligence may lead to the loss of great collection value of precious cultural relics. Thus, there is a huge risk in this repair way [5].

At the same time, there are bigger differences in personal accomplishments among individual restorers, and each restorer must has his own cognition of every cultural relic, so repair results of cultural relic from different restorer are certainly different.

In today's information age, the rapid development of computer technology afford the digital protection and preservation of cultural relics for the continuation of civilization. An image is a visual record of different material or intangible cultural objects with combined regions of similar texture and gray levels. The virtual restoration of cultural relics is a technology based on digital image enhancement and restoration, whose aim is to restore the missed and damaged part in digital scanned relic images using existing image information, imaging context and prior knowledge, in order to make the restored image close to the original one as much as possible [5,6].

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Virtual restoration of cultural relic images can greatly shorten the cycle of the manual restoration process by virtually guiding and evaluating the process with the help of powerful computer tools, and can largely prevent the damage of cultural relics in the process. In addition, virtual restoration results of cultural relic provide the possibility of permanent preservation free from natural and artificial damages, and convenient communication, appreciation and research for people from different fields.

As a fundamental ill-posed inverse problem in image processing and low-level vision, digital image enhancement and restoration aims to reconstruct the latent high-quality image from its degraded observation [7-15]. In this paper, a comparative study on digital image enhancement and restoration for virtual restoration of mural painting is done to facilitate the display of information of traditional cultural heritage contained in relic images [9].

II. RELATED METHODS

The acquired relic images are often a degraded observation of real image, while the imaging degradation comes from various factors, such as noise corruption, natural environment, artificial damage, resolution limit, colour fading, scan errors, or a combination of them [9]. A satisfied restoration of scanned image still remains a challenging task with lots of unsolved problems.

In the following part, we will only discuss and analyze gray mural image enhancement by image denoising and contrast improvement in order to better display important information contained in relic images.

Image denoising. Image noise degrades visual quality of an image and spoils important information required for pleased display. Hence, noise removal is often a necessary and the first step in the image enhancement process. Removal of these noise components from the image without destroying the useful information is highly challenging. To achieve the finest possible details required for perfect display it is necessary that relic images to be sharp, clear and free of noise and artifacts. Designing an algorithm to eliminate noise and enhance the contrast of relic images is very important. Denoising algorithms are generally classified into two types: spatial domain ones and transform domain ones [9].

In spatial domain processing, the basic principle of most algorithms is to suppress the noise using weighted averaging processing of pixel intensities directly. Some of classic spatial domain algorithms are: Gaussian smoothing, mean filter, median filter, wiener filter, anisotropic diffusion filter, total variation filter, bilateral filter, non-local means filter (NLM), etc [9,10,12,15].

In transform domain processing, the basic principle of most algorithms is to shrink transform coefficients to discriminate noise from image signal for ease of noise suppression. Some of classic spatial domain algorithms are:

Fourier transform, wavelet soft and hard thresholding techniques, block matching collaborative filtering (BM3D), etc [9,10,12,13,15].

Image contrast improvement. Most of relic images are complex with blur, fuzziness and low contrast due to insufficient illumination in nature. Highlighting important detail features in relic images is a challenging task. The main aim of image contrast improvement is to improve visual perception and to identify details of interest of degraded relic images. Various image contrast improvement methods have been suggested in literature to improve the appearance of relic images for better visual interpretation, understanding, appreciation and research. They can also be classified into two major categories: spatial domain techniques and transform domain ones [9].

For classic spatial domain techniques, there are power filter, histogram equalization and its adaptive improvements such as contrast limited adaptive histogram equalization (CLAHE), unsharp mask filter, etc. For classic transform domain techniques, there are Fourier transform, wavelet domain enhancement, etc [9,10,15].

Generally speaking, an enhancement algorithm needs simultaneously suppressing noise and increasing image contrast in order to achieve a better image quality. Thus, for enhancing a degraded relic image without magnifying its noise, an excellent multitasking mixed enhancement algorithm first uses a smoothing filter to remove image noise; then, a sharpening filter is employed to enhance image.

III. Results and Analysis

A number of mural painting images have been enhanced and restored to compare multitasking mixed enhancement algorithms, including mean and median filters, NLM and BM3D filters, power filter, histogram equalization and CLAHE filters and unsharp mask filter (based on Laplace differential operation). Examples shown in Figs. 1-2 are old mural painting and ancient painting image. All methods are implemented using the MATLAB programming with gray scale range from 0 to 1. We rely on subjective evaluation to assess the visual quality of the enhanced images in this paper.

In Figs. 1-2, a mural painting images of Chinese character and an old Chinese painting image are enhanced to restore implied information of traditional cultural heritage.

First, image denoising methods are used to remove noise in the image to avoid enhancing image noise: mean filter (3×3 window), median filter (3×3 window), NLM (7×7 search window, 3×3 similarity window and 0.03-0.12 smoothing factors), and BM3D (default parameters, 25 noise deviation). As one can observe that, both NLM and BM3D denoise images well preserving most important image features. The NLM preserves fine details of images well, while the BM3D preserves and even repairs edges of images well, except producing annoying artifacts. Both mean and median filters do not smooth images well so that many fine details have been lost.

Then, image enhancement methods are used to highlight important image features after having removed noise in the images by NLM filtering: power filter (0.6 adjustment factor), histogram equalization, unsharp mask filter (0.3 adjustment factor), and CLAHE filter (17×17 window, 0.003 adjustment factor). It is obvious that, both power filter and histogram equalization do not produce pleasing image effects with local parts of either too bright or too dark in sharpened images. The unsharp mask filter enhances image edges and details effectively, but it also produces annoying overshoots around image edges, which can be avoided using the confined Laplacian enhancement method [14]. The CLAHE produces overall pleasing images though its sharpening is worse than that by the unsharp mask filter in edges and details of images.

To enhance real mural painting image is not an easy task, and there is not a unified optimal method of image enhancement: different image has different hue range, gray level distribution, histogram and features such as textures, details and edges, etc. Here, the feature detection of image is very critical to a successful image enhancement method: to enhance image features of interest, while, on the contrary, to weaken other features. However, which features of image are important, and which are not?

At the same time, one can see that the effect of image enhancement by enhancing contrast is not the same as that by sharpening edge. Moreover, for some images data both correction and filling up are necessary to perfectly restore the broken areas, where one needs deep professional knowledge and rich experiences of painting restoration.

IV. Conclusion

To enhance mural painting images for retrieving and evaluating of important information of cultural heritage, some multitasking mixed enhancement algorithms are compared including image denoising, contrast enhancement and edge sharpening. In experiments on damaged painting images some excellent enhancement methods are identified, and deep understanding of image enhancement will further guide this challenging problem. In the future to enhance colour painting image will be carried out owing to more information contained in colour channels.

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References

[1] Mingquan Zhou, Guohua Geng, Zhongke Wu, *Digital Preservation Technology for Cultural Heritage*, Berlin: Springer-Verlag, 2012.

[2] Filippo Stanco, Sebastiano Battiato, Giovanni Gallo, *Digital Imaging for Cultural Heritage Preservation,* CRC Press, Taylor Francis Group, 2011.

[3] Clifford Lynch, "Digital collections, digital libraries & the digitization of cultural heritage information," Microform & Digitization Review, 2012, 31(4), 131.

[4] Naci Yastikli, "Documentation of cultural heritage using digital photogrammetry and laser scanning," Journal of Cultural Heritage, 2007, 8(4), pp. 423-427.

[5] Mauro Barni, Franco Bartolini, and Vito Cappellini, "Image processing for virtual restoration of artworks,"IEEE multimedia, 2000, 7(2), pp. 33-37.

[6] Fengling Wang, "A study of digital image enhancement for cultural relic restoration," International Journal of Engineering and Technical Research, 2017, 7(11), pp.41-44.

[7] Rong Zhu, Li Zhu, Dong-nan Li, "Study of color heritage image enhancement algorithms based on histogram equalization," OPTIK, 126(2015), pp. 5665-5667.

[8] Oana Gui, "Aspects regarding the use of image processing for tangible cultural heritage conservation-restoration," IEEE International Conference on Optimization of Electrical and Electronic Equipment (OPTIM) & Intl Aegean Conference on Electrical Machines and Power Electronics (ACEMP), 2017, pp. 833-838.
[9] R.C. Gonzalez, R.E.Woods, *Digital Image Processing* (Third Edition). Beijing: Publishing House of Electronics Industry, 2016.
[10] Kenneth R Castleman, *Digital Image Processing*, Prentice Hall, 1995.
[11] Shujun Fu, Qiuqi Ruan, Wenqia Wang, Fuzheng Gao, Heng-Da Cheng, "A feature-dependent fuzzy bidirectional flow for adaptive image sharpening," Neurocomputing, 2007, 70(4-6), pp. 883-895.
[12] A. Buades, B. Coll, J. Morel, "A review of image denoising algorithms, with a new one," SIAM Multiscale Modeling & Simulation, 2005, 4(2), pp. 490-530.
[13] K. Dabov, A. Foi, V. Katkovnik, and K. Egiazarian, "Image denoising by sparse 3-D transform-domain collaborative filtering," IEEE Transactions on image processing, 2007, 16(8), pp. 2080-2095.
[14] Lu Wang, Guohua Liu, Shujun Fu, Lingzhong Xu, Kun Zhao and Caiming Zhang, "Retinal image enhancement using robust inverse diffusion equation and self-similarity filtering," PLoS ONE, 2016, 11(7): 1-13.
[15] Shujun Fu, Caiming Zhang, Xuecheng Tai, "Image denoising and deblurring: non-convex regularization, inverse diffusion and shock filter," SCIENCE CHINA Information Sciences, 2011, 54(6): 1184-1198.

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Fig. 1 Digital enhancement of a Chinese character mural painting (from top-left to bottom-right). Original image, results by mean, median, NLM and BM3D filters, respectively.

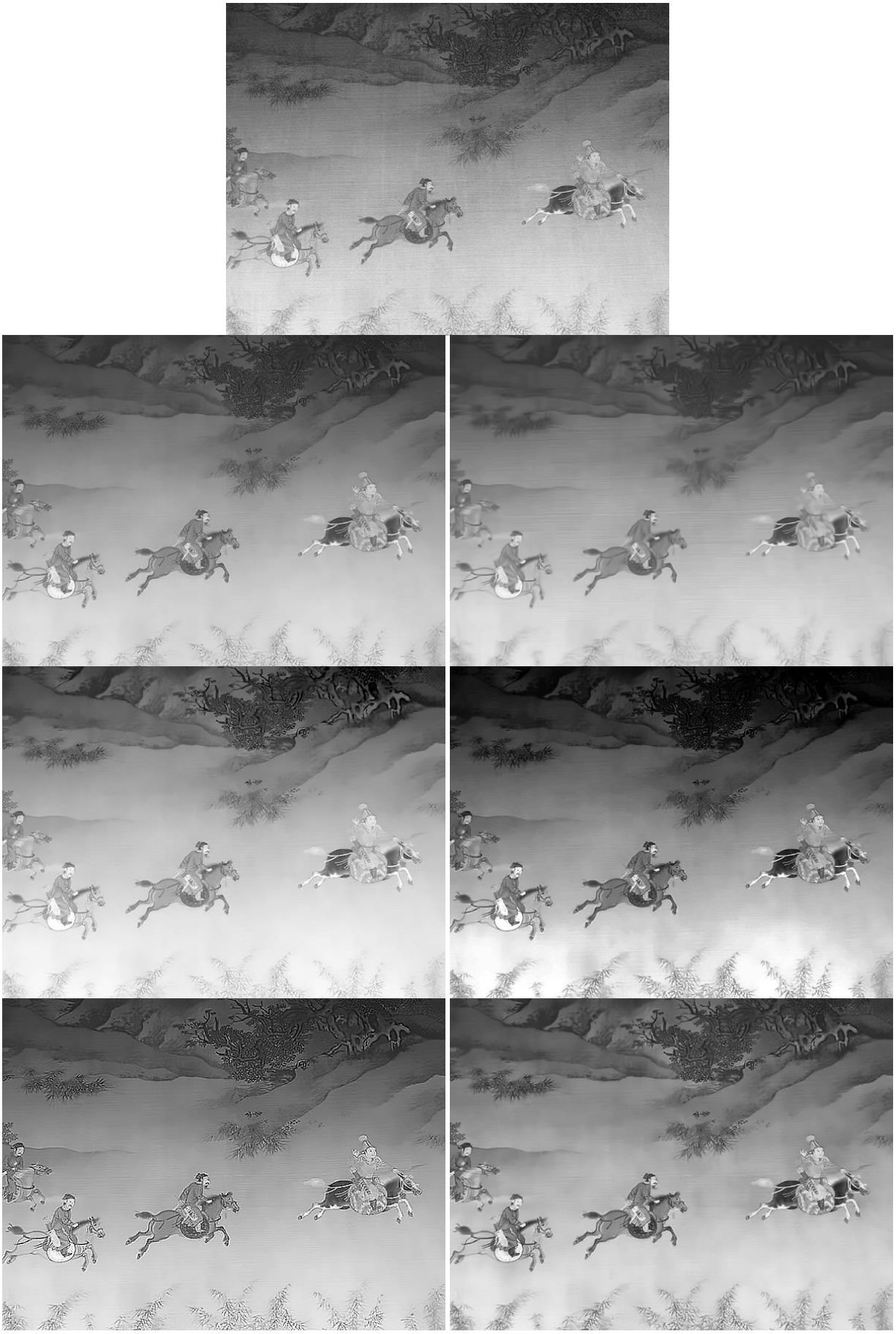

Fig. 2 Digital enhancement of a Chinese character painting (from top-left to bottom-right). Original image, results by smoothing (mean, median, NLM and BM3D filters), and by sharpening (power, histogram equalization, unsharp mask and CLAHE filters after nonlocal means filtering), respectively.