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Comparison of different image denoising algorithms for Chinese calligraphy images

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ABSTRACT

Rubbing is one of the most universal and perhaps the oldest of the techniques that have been used in printmaking. A carefully made rubbing provides an accurate and full-scale facsimile of the surface reproduced. However, many rubbing have been destroyed or lacked a good ways to identify them by certain events, while some other contained a large white background, or have become illegible due to erosion. In order to correct interpretation of these images, some image restoration techniques are employed. Image denoising is one of the important fields in the restoration arena. But, a great challenge of image denoising is how to preserve the edges and all fine details of a rubbing image while reducing the noise. This paper presents a comprehensive comparative study of image denoising techniques relying on Anisotropic Diffusion filter, Wiener filter, TV (Total Variation), NLM (Non-Local Means, NLM), Bilateral filtering. A quantitative measure of comparison is provided by the PSNR, MSE, SNR, UQI and SSIM of the image. Finally, the paper also analyzes its effect of denoising on rubbings with various algorithm and points out the advantages and disadvantages in application.

1. Introduction

A rubbing is a reproduction of the texture of a surface created by placing a piece of paper or similar material over the subject and then rubbing the paper with something to deposit marks, most commonly charcoal or pencil, but also various forms of blotted and rolled ink, chalk, wax, and many other substances as well [1]. Rubbing is a technique which invented in Wei, Jin, South and North Dynasties (220–589 AD), to make copies of inscribed records, using paper and ink. We can say that, rubbing is a unique way of documentation in China. It has made great contribution to the preservation of the Chinese culture, which is of high historical and aesthetic value and used in many ways in today's scientific research, and whose aesthetic feeling cannot be replaced by photographs. The use of rubbing was initially limited to making copies of stone inscriptions and then gradually expanded to bronze ware, jade ware, coins, ink stones, seals, tiles, wood ware, and even to oracle bones, objects dating from the Qin Dynasty (221–207 BCE) to the Ming Dynasty (1368–1644 CE).

The rubbings were made on ancient stone stelae and tomb tablets are not only important carriers of China ancient civilization but also are a classical template to research and learn the art of calligraphy. For the study of the history of writing and calligraphy, from the earliest script on shell and bone down to the running and cursive styles of later masters, inscriptions are irreplaceable sources. They have been tracing the evolution of writing, century after century, also.

Many Chinese ancient calligraphy work created by former famous calligraphers were carved on stone tablets, and calligraphy documents were produced by rubbing. Stone rubbings taken from them have been reproduced and reprinted widely and studied by generations of students, used models to learn and practice the art of calligraphy. Rubbings of engraved models of calligraphy, known as model writing (*fa tie*) are the most widely reproduced and consulted genre of rubbings in China, Japan, and Korea today.

In recent years, with the development of the scanning equipment and digital library technology, huge amount of rubbing from a stone inscription documents are scanned into the computer and stored as digital images, and have been made available to the general public through specialized web portals. Here are many Chinese rubbings sets often used by researchers. Such as, the East Asian Library's collection of Chinese rubbings in Berkeley University is second in number, outside of East Asia, only to that of the Field Museum of Natural History in Chicago. The Fine Arts Library currently houses 2602 individual East Asian rubbings, the majority of which are from China. Compared with paper rubbings, digital rubbings are more convenient for people to study.

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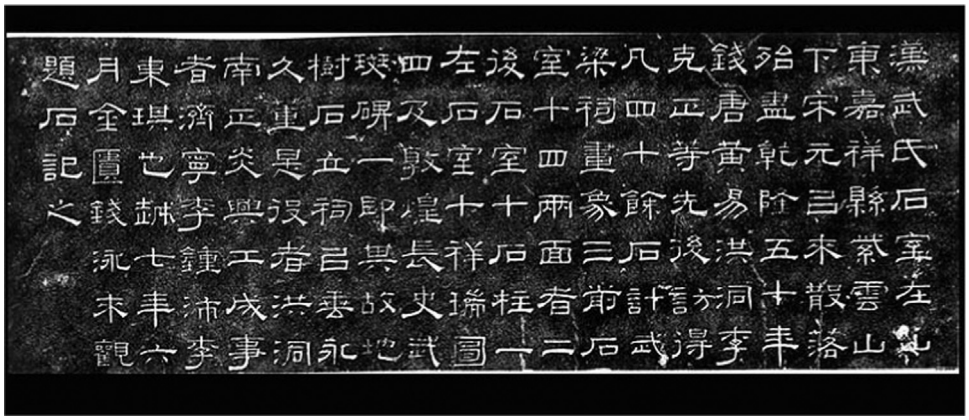

Fig. 1. Inscription in the clerical style by the scholar Qian Yong (Ch'ien Yung) recording the discovery of lost Wu family stones and the building of "Wushi zi tang/Wu-shih tz'u-t'ang" at Jiaxiang Xian/County (Chia-hsiang hsien) to store the stones. Shandong (Shantung) Province [2].

Fig. 2. Congratulatory inscription made by court officials to the Prince of Zhao (Chao). Cliff site. Juan (Chuan). Hebei (Hopeh), west of Yongnian Xian/County (Yung-nien hsien), Loushan (Lou-shan) [3].

Because the stones are not smooth originally and these inscriptions might have suffered from natural erosion during for thousands of years' storage or serious destruction when they are excavated and moved, most of them are not integrated and the original characters have been covered by many maculas, let alone the damage caused by having been tamped in the process of taking thousands of rubbings. Owing to the characteristics of stone inscriptions and the acquisition of objective factors of the environment, the original inscription images are filled with so much image noise that it may seriously affects the observation and research for inscription images, as shown in the two examples of rubbed calligraphy documents in Figs. 1 and 2. In addition, there are other kinds of difficulties appearing in these images as different font types and sizes in the words, underlined and/or crossed-out words, etc. The combination of all these problems contributes to make the recognition process become very difficult, and hence, the preprocessing module quite essential.

The degradation of Chinese calligraphy images aesthetically affects the human perception and concomitantly the processes of feature recognition, segmentation, edge detection, etc. For correct interpretation of these images, restoration techniques are employed. Image denoising is one of the important fields in the restoration arena. The purpose of denoising is to obtain a good estimate of the original image from its degraded version and at the same time to preserve complex structures of images such as edges and textures. It is a difficult task to undertake, because the noises are randomly distributed in size and shape, and denoising sometimes may destroy simultaneously the characteristic parts of strokes simultaneously, such as the stroke tips and corners.

In the paper, we formulate this difficult rubbing image deblurring problem as an image denoising problem, using a pair of really rubbing images. The six classic denoising algorithm have been researched and compared, which are Anisotropic Diffusion filter, Wiener filter, TV(Total Variation, TV) minimizations, NLM (Non-Local Means, NLM), Bilateral filtering and Wavelet denoising. Finally, really rubbing images validate image denoising and analyzed the performance of the various algorithms have been described.

The article is organized as follows. Section 2 briefly describes the theory basis that different denoising methods and the relative researches are summarized. Five assessment parameters for image denoising have been explained in Section 3. Section 4 gives the experiments results of five different denoising methods, and five performance measurement criteria, such as PSNR, MSE, SNR, UQI and SSIM, are discussed. Section 5 gives a simple conclusion.

2. Relative works and image denoising algorithms

2.1. Relative works

In the late 1980s, the prevalence of fast computers, large computer memory, and inexpensive scanners fostered an increasing interest in document image analysis. An increasing number of Chinese calligraphy document images of different qualities are being scanned and archived. After document input by digital scanning, pixel processing is first performed (also called preprocessing and low-level processing in other literature) [10]. This level of processing includes operations that are applied to all image pixels [13]. These include noise removal, image enhancement, and segmentation of image components into text and graphics (lines and symbols) [56]. Feature-level analysis [21,23,34] treats groups of pixels as entities, and includes line [6] and curve detection [19], and shape description. Text analysis includes optical character recognition (OCR) and page format recognition. Graphics analysis includes recognition of components of engineering drawings, maps, and other diagrams. The OCR must also be tolerant to the range of image distortions that occur in practice. With help from advanced image processing methods [36,39] pattern recognition techniques [25,4], one of the most common and popular approaches is based on neural networks [17,15] to deal with optical character recognition problem.

Document image noise occurs from image transmission, photocopying, or degradation due to aging. Salt-and-pepper noise