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Restoration Techniques for the Enhancement of Stone Inscriptions

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Abstract: *Characteristics and scenes of historical events were recorded by ancient inscriptions. As the time passes and due to weather conditions and improper handling, the ancient inscriptions may degrade. This paper reports the image processing methods in restoration and Enhancement of ancient inscriptions. Image restoration means recovering original image from degraded image. Image restoration represents basic problems in image processing with many applications such as reconstruction of missing data, recover ideal inscription image. Depending on different types of inscription image different restoration technique is used. The restoration techniques preserve the ancient inscriptions. In different types of images noise plays very important role. If noise in image is less then quality of image is high. Different filtering techniques are used to remove different types of noise from an image. This paper presents different restoration filters with some quality metrics for the inscriptions.*

Keywords: Image Restoration, Inscriptions, Mean filter, Median Filter, Noise Model, adaptive filter, PSNR, F-Measure

I. INTRODUCTION

Digital image is represented by two dimensional function f(x, y), where x and y are plane co-ordinates. Digital image is composed from components of image called as pixels. Every pixel represents some amount of information. In the image enhancement, the goal of restoration is to improve image in particular sense[1][2][3]. Restoration is used to reconstruct or recover image degraded image using prior knowledge. So the restoration techniques are used for degradation and apply inverse process to recover original image. Ancient inscription contains valuable information about time, place and languages of ancient time[4]. These inscriptions coming from hundred years ago, have degraded due to various reasons such as age of inscription, bad storage etc. All these factors make inscriptions condition deteriorate[4][5].

Figure 1: Sample images of historical degraded Marathi Inscription Images written on stone

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1.1 Noise in Inscriptions

Inscription contains several types of noise. Some of the types of noise are listed below.

1.2 Salt and Pepper Noise (Impulse Noise)

It refers to these pixels which are very noisy [6] [7]. The effect of salt and pepper noise is black and white dots are present in the image. The salt and pepper noise is the type of heavy tailed noise [8]. It can be represented as

$$P(z) = \begin{cases} P_a & \text{for } z=a \\ P_b & \text{for } z=b \\ 0 & \text{otherwise} \end{cases} \quad (1)$$

If a < b, gray level b appears as a light dot in the input image. The gray level a is represents dark dot. If the P_a or P_b isl zero then impulse noise is called as unipolar noise.

1.3 Gaussian Noise

Mostly the additive Gaussian noise is found in old picture. The averaging is the suitable method for the Gaussian noise. This noise model used in both spatial and frequency domain [9] [11] [12].

1.4 Photographic Grain Noise

Photographic grain noise is part of photographic film. The film is made up of millions of tiny grains [6].

1.5 Noise Models

Noise is unwanted part of image. Gaussian noise is one kind of natural noise. Noise models are used to deal with noisy image. Let f is noisy image and g is image component, the noise component q. The commonly used noise model is additive noise model given by

$$f = g + q \quad (2)$$

In image restoration focus is on removing noise from image without losing the important details of an image. Suppose that the true image is X and it has been corrupted by additive noise N with 0 mean and standard deviations[10][13]. The corrupted image is

$$Y = X + N \quad (3)$$

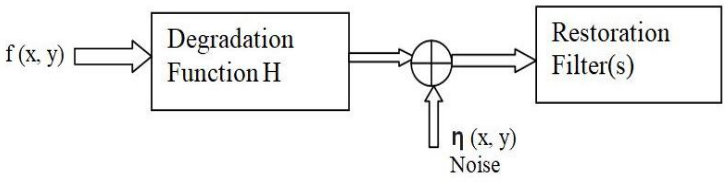

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Figure 2: Image degradation/ restoration process model

Fig.2. shows the degradation and restoration process. Degradation model use degradation function with additive noise. If H is linear process then the degraded image in spatial domain is given by

$$g(x, y) = h(x, y) * f(x, y) + \eta(x, y) \quad (4)$$

Where, h (x, y) represents degradation function in spatial domain. Convolutions are represented by *. The convolution in spatial domain is same multiplication in frequency domain [13] [15] [17].So the same model in frequency domain is given by

$$G(x, y) = H(u, v)\, F(u, v) + N(u, v) \quad (5)$$

II. Image Restoration Techniques

Image restoration techniques are beneficial for reconstruction of degraded image in ideal form[10]. Thus the restoration rebuild image in which quality is reduced by the presence of noise. There are several reasons that causes degradation of image like noise created during the capturing the image, some natural conditions, etc. There are two ways to restore image. One way is to apply different filters on image to increase the quality of image. And another way

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is to use degradation model to increase quality of image[10][12][14].Different enhancement techniques for degraded inscription are involved in restoration techniques. Many researchers are contributed in the area of restoration in literature are, Old Manuscripts Restoration Using Segmentation And Texture Inpainting by Insaf Setitra[19]. This paper present restoration method for Algerian Script. Thresholding and KNN classifier is used in this system.
Restoration of Degraded Kannada Handwritten Paper Inscriptions (Hastaprati) using Image Enhancement Techniques by Chandrashekar Gudada[20]. This proposed method is tested on different Kannada handwritten script and performance was measured using MSE (Mean Square Error) and PSNR (Peak Signal Noise Ratio).

III. FILTERING TECHNIQUES

The degraded inscription image is reconstructed by using reconstruction filter. The below fig3 shows the restoration model.

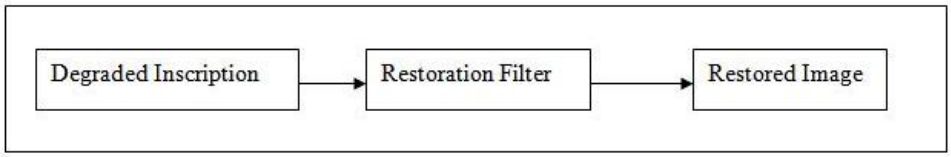

Figure 3: Restoration model

The degraded image in presence of noise is given as

$$g(x, y) = f(x, y) + \eta(x, y) \quad (6) \text{ and}$$

$$G(u, v) = F(u, v) + N(u, v) \quad (7)$$

So, this noise can be removed by using following filtering techniques.

3.1 Mean Filters

Following are the some mean filters used in spatial domain

A. Arithmetic Mean Filter

This is the simple type of mean filter. The rectangle sub image window of size m * n is created at point (x, y). The average values of noisy image g (x, y) is calculated in arithmetic mean filter. [5] [14]. The arithmetic mean filter is given by

$$f'(x,y) = \frac{1}{mn}\sum_{(s,t)\in Sxy} g(s,t) \quad (8)$$

B. Geometric Mean Filter

The Geometric Mean Filter is given by the expression

$$f'(x,y) = \left[\prod_{(s,t)\in Sxy} g(s,t)\right]^{\frac{1}{mn}} \quad (9)$$

Each restored pixel is represented as the product of the pixels in sub image window, with power 1/mn. The geometric mean filter can achieve smoothing but here is possibility to lose details of image [24].

C. Harmonic Mean Filter

The harmonic mean filter is represented by the equation

$$f'(x,y) = \frac{mn}{\sum_{(s,t)\in Sxy}\frac{1}{g(s,t)}} \quad (10)$$

The harmonic mean filter is effective in the salt noise but it not good for pepper noise. Also it is effective for Gaussian noise.

3.2 Order Statistical Filter

Order statistical filters are based on order or ranking and these filters are used in spatial domain. The response of the filter is determined by ranking [14] [21].

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A. Median Filter

It replaces the value of pixel with median of the gray level in the neighbour pixel. This filter is represented as

$$f'(x,y) = \text{Median}_{(s,t)\in \dot{S}xy}\{g(s,t)\} \quad (11)$$

Median filter is best suited for different random noise.

B. Max and Min Filters

This max filter is used to find the brightest point in the given image. The max filter is represented by the given expression

$$f'(x,y) = \text{Max}_{(s,t)\in \dot{S}xy}\{g(s,t)\} \quad (12)$$

The min filter is used to find out dark pixel in given image. The min filter is represented by the given expression

$$f'(x,y) = \text{Max}_{(s,t)\in \dot{S}xy}\{g(s,t)\} \quad (13)$$

C. Midpoint Filter

Midpoint filter is used to compute midpoint between maximum and minimum value in the given area. This filter is given by

$$f'(x,y) = \frac{1}{2}\left[\text{Max}_{(s,t)\in \dot{S}xy}\{g(s,t)\} + \text{Min}_{(s,t)\in \dot{S}xy}\{g(s,t)\}\right] \quad (14)$$

This filter is used to remove uniform noise.

D. Adaptive Filters

Adaptive filters are linear filters used according to different optimization algorithm. The adaptive filter that has transfer performs controlled by variable parameter. The adaptive filter uses color and grey to remove pepper and salt noise in the inscriptions[10].

E. Weiner Filter

The Weiner filter is used as restoration techniques with degradation model. This filter is suitable for blurred image [15].

IV. Performance Metrics

After developing the restoration method there is need to measure the efficiency of restoration method in the term of evaluation and comparison. The accuracy measured using some metrics are given below.

4.1 Peak-Signal-to-Noise Ratio (PSNR)

Peak-Signal-to-Noise Ratio (PSNR) is a measure of the amount of signal with the available noise in the image. The high value of the PSNR shows a better signal than the noise from the image [4] [19]. In the inscription image, the PSNR is calculated using the following formula [16].

$$\text{PSNR} = 10 \times \log_{10}.\left\langle\frac{MAX_I^2}{MSE}\right\rangle \quad (15)$$

Where MSE (Mean Square Error) is calculated using the formula.

MSE= sum (sum (Squared Error Image)) / (rows * columns) (16)

Where SquaredErrorImage = (double (Gray Image) - double (Output Image)) ^{2}

4.2 F-Measure

F-Measure [8] is calculated using recall and precision, and the combined result will perform the given method. The equation given below is used to calculate F-Measure.

$$F - \text{Measure} = \frac{2\times\text{recall}\times\text{precision}}{\text{recall}\times\text{precision}} \quad (17)$$

Where recall and precision is calculated using the formulas

$$\text{Recall} = \frac{\text{TP}}{\text{TP}+FN}$$

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$$\text{Precision} = \frac{\text{TP}}{\text{TP} + FP}$$

Where TP represents True Positive Rate, FN represents False Negative and FP represents False Positive Rate values.

V. Comparison of Restoration Methods

Table 1

Author	Title of Research Paper	Image Data Set/ Image Type	Quality Metric (PSNR) /other Metric
A. Prochazka, I. Sindelarova [21]	Image De-Noising And Restoration Using wavelet Transform	PIM (JPG)	52.83
Keith T. Knox, Roger l. Easton [19]	Image Restoration Of Damaged Or Erased Manuscripts	JPG	NA
Yi-bing Li, Qiang Fu, Fang Ye, and Qi-diWu [13]	Blind Image Restoration via the Integration of Stochastic and Deterministic Methods	BMP Images	32
Hilda Deborah and Aniati Murni Arymurthy [4]	Image Enhancement and Image Restoration for Old Document Image using Genetic Algorithm	JPG	10
Parashuram Bannigidad, Chandrashekar Gudada [5]	Restoration of Degraded Kannada Handwritten Paper Inscriptions (Hastaprati) using Image Enhancement Techniques	JPG	12.89
Ankita, Er. Lavina [14]	Research Paper on Image Restoration using Decision Based Filtering Techniques	JPG/PNG	27.03
Keyong Shao, Yun Zou, Yuanhong Liu, Cheng Li, Bosi Fu [3]	Based on Total Variation Regularization Iterative Blind Image Restoration Algorithm	JPG	82.74
Khadidja Kaibiche, Slami Saadi, Djamel Chikouche, Zoubida Messali [11]	Restoration of Stained Old Manuscripts via a Hybrid Wavelet and Bilateral Filtering System	TIF/PNG	27.01
Jianfang Cao , Yanfei Li, Qi Zhang and Hongyan Cui [20]	Restoration of an ancient temple mural by a local search algorithm of an adaptive sample block	JPG	48.06

VI. Conclusion

Image restoration is always challenging problem. The restoration is useful in both spatial and frequency domain. The geometric mean filter achieves smoothing but there is possibility to lose important details of an image. The harmonic mean filter is best suited for salt noise but not effective in case of pepper noise. Median filter is used to remove different types of uniform noise in restoration. Min filter and Max filter are used to find dark point and brightest point in the image respectively. Adaptive filters also best suited for the salt and pepper noise. Wiener filter is also used in restoration with degradation model. The wiener filter works well for the blurred image. The noise type of inscription image is unknown. The best result obtained in signal based noise model in ancient images. The noise model is used for identifying the effective filtering technique. This paper also presents comparative study of some traditional methods and filtering methods used for the enhancement of inscription image.

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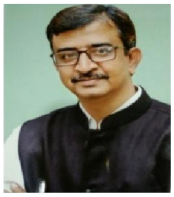
Bapu Chendage has completed B.Sc.(ECS) from Solapur University, M.Sc.(Computer Science) from Solapur University, He also Qualified National Eligibility Test (NET)-Dec. 2019 and State Eligibility Test (SET)- Jan. 2021. Currently he is research scholar and pursuing Ph.D. (Computer Science) from Solapur University. His research area includes Image Processing, Computer Vision and Pattern Recognition.



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