Image Restoration on Copper Inscription Using Nonlinear Filtering and Adaptive Threshold

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Abstract. Inscription is an important document inherited by history of kingdom. Inscription made on hard stuff such as stone and copper. Therefore it is necessary digitizing documents, to keep the authenticity of the document. But the document of the historical heritage have disruption on inscription plate which be called noise. So that, it is necessary to reduce the noise in the image of the inscription, to ease the documentation of historical digital. Then, separation between the background and the writing object carved on inscription is conducted so easy to read. This research is using nonlinear filtering method to reduce the noise and adaptive threshold to separate between the background and letter inscription. Nonlinear filtering method used is median filter, harmonic mean filter and contra harmonic mean filter, whereas in the adaptive threshold using adaptive mean and adaptive median threshold. The results of this research is using measurement methods MSE (Mean Square Error), PSNR (Peak Signal to Noise Ratio) and SNR (Signal to Noise Ratio).

Keyword. Inscription, Digital Documentation, Nonlinear Filtering, Adaptive Threshold, MSE, PSNR and SNR.

1. Introduction
Inscription is an important document inherited by history of kingdom. Inscription made on hard stuff such as stone and copper. The script on inscription usually uses sculpture. Inscription, mostly found in Asian countries, such as Indonesia, India, Bangladesh, and Thailand. For maintaining the ancient heritage, especially inscription, It is necessary to document for research purposes, as well as publications on the content of the inscription. Documentation in the form of digital image, is more appropriate effort because it is easier to be saved and published. The previous research had done digital documentation on an old china calligraphy object, which was carved on stone. Then the improvement using digital technology is conducted, which is the script on the calligraphy stone scanned and save in the computer. The purpose is to compare paper rubbings and digital rubbings to be used to learn to people\cite{1}.

In this research, using a type of copper inscriptions. Type of inscription used is Adan-adan inscription. This inscription came from Indonesia and found in Mayangrejo village, Kalitidu District, Bojonegoro on March 2, 1992. It was found buried in the ground in depth about 50cm from ground surface. It was 17 pieces made from copper with length 37.5cm, wide 12 cm and thickness 4mm. This inscription has two types emerging patina, such as dark brown patina and green patina. As you can see on figure 1 are copper inscriptions which have dark brown patina and green patina.
On Figure 1, there is a defect where the dark brown patina and green patina cover the inscriptions sculpture, so that the alphabets on the inscription become incomplete and difficult to read. Physically, there are various attempts to fix the copper inscription. But many concerns, one of which increased more damage. To repair the image interpretation, some image restoration techniques on previous research has been conducted [2][3]. The previous research had done edge preserving and unseen able details on stone and decreasing noises. Conducted comparison to some denoising image method with relying anisotropic diffusion filter, wiener filter, TV (total variation), NLM (non-local means, NLM), bilateral filtering. A quantity comparison uses PSNR, MSE, SNR, UQI and SSIM [1]. Then, doing improvement of script textures on inscription and ancient script. One of the method is repaired and segmented automatically or manually [2]. On this research, we will do image improvement, to reduce noise on inscription image then doing separation between background and object on inscription image. The method which is used for reducing noise on image is non-linear filtering and adaptive threshold to separate between background and object on inscription image.

2. Related Work
Noise that has been added into image generally has a higher frequency spectrum than image components. Generally, noise reduction can be done with linear or non-linear approach. Linearly noise reduction can be done either in spatial or frequency. Whereas, Nonlinear approach is on spatial such as Mean filter, Median filter, Harmonic mean filter, contra harmonic mean filter[6][7]. There are many types of threshold method, such as global threshold[8][9][10][11]. Some research utilized colour intensity value from foreground and background by using adaptive local threshold method[12]-[13]. The inscription made from being carved has a less different colour than foreground and background which needs different separate technique[15].

3. Method
On this research, we will compare the proper method to reduce noise and separate between background and object on inscription image. Part of reducing noise on inscription, researcher use nonlinear filtering method. Researcher used a variety of methods from nonlinear filtering such as median filter, harmonic mean filter, and contra harmonic mean filter. While in the part of separation background and object on inscription image, researcher used adaptive mean threshold and adaptive median threshold.

3.1 Median Filter
Median filter is a window which contains amount of odd pixel filter shifted per-pixel point on a whole image. The values on window are sorted by ascending, then it is count the median. the median value will replace the value on centre of window. Where the formula for median is, as follows:

\[ f(x,y) = \text{Median}\{g(x - i, y - j) | (i,j) \in w\} \]

Where \( f(x,y) \) is image which produced from image \( g(x,y) \) with \( w \) as window which is placed on image area and \( (i,j) \) element from window.
3.2 Harmonic Mean Filter
Harmonic mean filter is one of nonlinear filter. As you can see in the equation of harmonic mean filter, as follows:

\[ \hat{f}(x, y) = \frac{1}{\sum_{(s,t) \in S_{x,y}} g(s,t)} \]

Where \( m \times n \) is \( m \)-rows and \( n \)-columns of kernel harmonic mean filter, \( G(s,t) \) is pixel row and column that will be processed.

3.3 Contraharmonic Mean Filter
Contraharmonic mean filter is one of nonlinear filter. As you can see the equation from contraharmonic mean filter, as follows:

\[ \hat{f}(x, y) = \left( \sum_{(s,t) \in S_{x,y}} g(s,t)^{Q+1} \right)^{-1} \sum_{(s,t) \in S_{x,y}} g(s,t)^Q \]

Where \( G(s,t) \) is pixel row and column pixel which will be processed. \( Q \) is order from filter.

3.4 Adaptive Threshold
Adaptive threshold is threshold which used a local threshold value, counted adaptively based statistic neighbour pixel. This is based on reality that small part of image has same illumination, so that it is proper if threshold value counted based on small part of image and not based on whole pixel image.

One of adaptive threshold approaches mean of local intensity on image. Where The constant value involved. As you can see the equation, as follows:

\[ T = \frac{\sum_{(x,y) \in w} f(x,y)}{N_w} - C \]

Where \( w \) states as window on image, \( N_w \) states amount of pixels on window and \( C \) is constant. The second adaptive threshold approach is median of local intensity on image. as you can see the equation, as follows:

\[ T = \text{median}(f(x,y),(y,x) \in w) - C \]

Variable \( w \) states as window on image and variable \( C \) is constant.

3.5 Paramater of Measurement
3.5.1 \( MSE \) (Mean Square Error)
\( MSE \) is mean of squared fault value between original image with image result, it can be formulated as follows:

\[ MSE = \frac{1}{MN} \sum_{x=0}^{M-1} \sum_{y=0}^{N-1} (f(x,y) - g(x,y))^2 \]
Where \( f(x,y) \) is previous image before noise and \( g(x,y) \) is image which has been restored. The less MSE value, the more image restoration performance.

### 3.5.2 PSNR (Peak Signal to Noise Ratio)

PSNR is comparison value between maximum value of color on image result and disruption quantity which is stated in decibel (dB) unit. PSNR value can be formulated as follows:

\[
PSNR = 10 \log_{10} \left( \frac{(255)^2}{\sum_{x=0}^{M-1} \sum_{y=0}^{N-1} [f(x,y) - g(x,y)]^2} \right) \tag{7}
\]

### 3.5.3 SNR (Signal To Noise Ratio)

SNR(signal to noise ratio) is standard used to evaluate impact of noise from outside. Which compares the value of image result and noise power which are found on image. Mathematically, SNR is stated in decibel(dB) unit by using the formula as follows:

\[
SNR = 20 \log_{10} \left( \frac{a_{\max} - a_{\min}}{S_n} \right) \tag{8}
\]

Where is variable \( a_{\max} \) is maximum value of pixel from intensity, otherwise \( a_{\min} \) is minimum value of pixel from intensity on image. Variable \( S_n \) is standard deviation measurement to measure noise value on image.

### 4. Result And Discussion

The experiment on this research used inscription image which has dark brown patina. The data conducted are five data inscription images of dark brown patina. The first experiment conducted noise on inscription image by using window 3x3 and using median filter, harmonic mean filter, contra harmonic mean filter method. Can be noticed the result of several experiments noise reduction, as follows:

**Figure 2.** The result of noise decreasing on image inscription using method (a) median filter, (b) Harmonic mean filter and (c) Contra harmonic mean filter

Second experiment conducted is separated between background and object on inscription image using adaptive threshold. On Figure 3. Using image result from noise reduction, median filter and adaptive mean threshold by using value of \( w = 5 \ c = 0 \), \( w = 5 \ c = 5 \), \( w = 5 \ c = 15 \), and \( w = 10 \ c = 20 \). The separation of background and image objects that use the value \( w = 5 \ c = 5 \) successfully separated. However, for the value of \( w = 5 \ c = 0 \), \( w = 5 \ c = 15 \) and \( w = 10 \ c = 20 \) has not been succeeded, yet. \( c \) and \( w \) variable values influence the adaptive threshold on the separation of background and image objects. In the image that has done much noise reduction, the results were shown imperfect. This is due to the colour intensity values to the same object with the background to make the separation less than excellent.
We had been doing noise reduction on the image object using the Median filter, harmonic mean filter, and contra harmonic mean filter. Measurement results using MSE, PSNR and SNR Parameter.

5. Conclusion
Based on the result of experiment that had been done by researcher, could be concluded that median filter method is the best method for noise decreasing. It could be seen that the accurate value of \( MSE = 27.9264 \), \( PSNR = 10.0257 \) and \( SNR = 20.2873 \). Homogeneous colour on the inscription causes the failure of the direct use of threshold method. However, to separate between the background and the script object on inscription still couldn’t be tackled by using adaptive threshold method. It causes some noise on inscription becomes too hard to be deprived. On the future, the researcher propose other methods to separate between the background and the object on image. The methods proposed such as the
method of Otsu, sauvola, nickblack, NGF-ICA and other methods. This research could also be developed for classifying several features using the method of classifying such as SVM (Support vector machine), NN (Neural Network) and other classifying methods.

6. Reference

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