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Image Thresholding for Malay Ancient Manuscript (Terengganu Inscribed Stone)

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***Abstract*—**Image Thresholding is aimed to convert image format to another color scale for the purpose of feature extraction process or other processes in image processing domain. In this project, image thresholding is used to convert image into binary scale. Lots of methods have been proposed around the globe while some researchers regard this matter as a non-trivial problem. Quite often old documents are subject to background damage. Examples of background damages are varying contrast, smudges, dirty background, and ink through page, outdated paper and uneven background. The purpose of this project is to investigate thresholding methods used in ancient manuscript fields. Four methods of thresholding for enhancing the image used in this project are Global Thresholding including Huang, Kapur, Otsu and Yen. Research problems at the moment are to get the algorithm can remove noise and successfully distinguish foreground and background well. Thus, this study will examine the algorithms used by researchers, especially in ancient manuscripts to get an appropriate algorithm used in Terengganu Inscribed Stone. The image of Terengganu Inscribed Stone has been segmented into four side based on every side of Terengganu Inscribed Stone itself. Then, the segmented images are processed using the four methods. The threshold values, histogram analysis along with determining the PSNR and MAE are used as an evaluation technique to compare all four methods. Based on the evaluation process, Yen methods gives better result compared to others. So, for Terengganu Inscribed Stone, Yen method is better to be used for thresholding processed.

Keywords—Image Thresholding, Global Thresholding, Malay Ancient manuscript, Terengganu Inscribed Stone

1. INTRODUCTION

The intention of this paper is to find the better image enhancement methods for Malay ancients' manuscript: Terengganu Inscribed Stone. The aging of ancient manuscripts centuries resulted in the situation on the background become obsolete or damaged. Among the factors that cause the quality of ancient manuscripts are low, due to aging, environmental influences, and the quality of ink used. Old Malay manuscripts written in a period of 16th to the 19th century, has remained until today but the quality has been degraded. Apart from environmental issues, human negligence also contributes to the destruction of Malay manuscripts. The main objective of this paper are to make a comparison between Huang, Kapur, Otsu and Yen methods for image thresholding for which one is the better method for the selected manuscript. Scope contemplated and applicable in this study only touched on aspects of image enhancement for Terengganu inscribed stone is thresholding methods instead of the memory space of time. The result of this study is the comparison of thresholding's methods applied.

The paper is organized as follows. Section 2 in this paper give a review of the literature and research in this field and it concerns with the main fundamental concept to understand the idea of image thresholding. In Section 3, the review on thresholding in image processing including the thresholding methods will be explained. Next in Section 4, the methodology used in this paper will be discussed, then in Section 5, the results and findings are elaborated. Finally, the discussion and conclusion are provided in Section 6.

2. LITERATURE REVIEW

The main research in this paper are tries to understand the image processing and enhancement for historical document images or ancient manuscript. The images used at this point are an image of Terengganu Inscribed Stone. At this point forward, the previous research on historical document and ancient manuscript will be elaborated. The main objective of this research in this paper are to find the better thresholding methods and do the comparative analysis.

3.2 Progress in Ancient Manuscript Studies

A growing interest in the analysis of document image pre-history created many challenges for researchers. The decayed state of historical documents (e.g., bleed-throughput, ink stains, torn pages, etc.) to motivate researchers to enhance the binarization and appropriate algorithms for these challenges. Binarization is usually the first stage in the processing system and image analysis. In the context of differences ancient documents and processing also plays an important role in image analysis to eliminate background noise and improve the readability of the document.

[1] in his research shows the processes in the pre-processing performed by researchers in the Jawi script. This process is based on the process undertaken by [2]. Generally phases that have been used by the pioneers of the Jawi script has committed process of images converted to a scale representation of color, noise removal, skew and slant correction and thinning of the frame (skeleton). However, the process used by not all of them are used by researchers to perform pre-processing as shown in Table 1.

Table 1: Pre-processing for Jawi pattern recognition

Researcher	Format Conversion	Noise Removal	Skew and slant correction	Thinning
Khairuddin Omar	Yes	Yes	Yes	No
Mazani Manaf	Yes	Yes	No	Yes
Mohammad Roslim	No	No	No	Yes
Mohammad Faidzul	Yes	Yes	No	No

3.3 Types of Ancient Manuscript

2.3.1 Malay Ancient Manuscript

Malay manuscript is the intellectual heritage of the past which are recognized as national heritage documents. Malay manuscripts here defined as work hand-written, produced around the 14th century until the early 20th century. Malay manuscripts preserved in the knowledge reflect the wealth of knowledge and glory of Malay civilization. Malay manuscripts are the epitome of Malay scholar scholar-ship in ancient times. Manuscript writing and production activities in various subjects are to pass on their knowledge of science and something for the next generation of Malays. Among the areas of Malay manuscripts writing that are often highlighted as an area that consists of religious knowledge fluently, fiqh, Sufism, character and history while in the local Malay traditions such as stories, culture and medicine.

According to [3], often the aging of ancient manuscripts centuries resulted in the situation on the background become obsolete or damaged. Among the factors that cause the quality of ancient manuscripts are low, due to aging, environmental influences, and the quality of ink used. Old Malay manuscripts written in a period of 16th to the 19th century, has remained until today but the quality has been degraded. Apart from environmental issues, human negligence also contributes to the destruction of Malay manuscripts.

In conjunction with this crucial issue, the manuscripts must be securely preserved and kept in soft or hard copies. With it, guaranteed traditional Jawi manuscripts and their quality of life and can be shared with the parties and the interests of future generations.

2.3.2 Palm Leaf Manuscript

Image processing offers a choice of approaches to ad-dress this quality degradations and make a readable manuscript. Therefore, to increase the efficacy of the manuscript, interested parties need to use digital image processing approach [4]. As stated in the researches [5], and [6], palm leaf documents correlated to sculpture and construction, arithmetic, astrophysics, prophecy, medication and dating back numerous hundreds of ages are still accessible for reference today thanks to the many enduring efforts for the conservation of ancient documents by libraries and universities around world. Palm leaf manuscripts usually lasted several centuries but by the time of the writing of palm leaves and lowers it becomes illegible useful in any form. Image pro-cessing techniques can help improve the image of the manuscript to enable the recovery of written text of these documents degraded.

In the researched by [7] concluded that there is no single binarization technique suitable for all images. For this reason, how to choose the best binarization technique for users is a major issue and at this time, there is no automatic selection of optimal binarization technique. They use image data set is based on ancient palm leaf manuscripts acquired from Palm Leaf Manuscript Preservation Project in the Northeast Region, Mahasarakham University in 2005. Later in 2010, [6] proposed a new two-stage scheme for enhancement and binarization of palm-leaf manuscripts are severely degraded. The proposed scheme reduces the need for pre-processing technique for calculating the complex, such as filtering, histogram normalization. The proposed scheme shows superior performance of the two techniques are very effective in many palm-leaf manuscripts are degraded. Such a scheme proposes a simple and fast way to improve and maintain large corpus invaluable palm-leaf manuscripts, digitally.

In 2014, [8], come out with a new clustering based method for extracting the foreground data from palm leaf manuscript images. In comparison with existing thresholding approaches, the proposed method achieves better accuracy in palm leaf manuscript image binarization. The measurement of ground truth image is introduced to compare the efficacy of different methods.

2.3.3 Terengganu Inscribed Stone

Previously, the research on Terengganu Inscribed Stone can be found in paper by [9], [10] and [11]. In 2008, [9] reported that the earliest inscriptions in writing Jawi script, so far discovered, is the inscription Terengganu. It was written on stone pillars. The content for Terengganu inscription is on the propagation Hudud Law of Islam in the Sultanate of Terengganu. The inscription has been interpreted scientifically by Prof. Dr. Syed Muhammad Al-Attas, Professor of Islamic Studies from Universiti Kebangsaan Malaysia. He has written and published a book on this subject entitled "Date is correct in Terengganu inscription" in 1971. In the book he concluded that the date of the inscription is on February 22, 1303 AD. Professor Dr. Syed Muhammad Naquib Al-Attas has given public lectures related inscriptions Terengganu in 1971, in the Main Lecture Hall, at Universiti Kebangsaan Malaysia, Lembah Pantai, Kuala Lumpur.

Sanusi et al in the research paper [11], has proposed an Arabic calligraphy classification and identification using Triangle Model of ancient Malay manuscripts and inscribed stone. Manuscripts which have been the selected are Hikayat Merong Mahawangsa and unknown manuscripts from the National Library of Malaysia. The inscription that has been selected is Terengganu Inscribed Stones. Sanusi et al has used method of selection 128. By such, the purpose of study was conducted is to review the Terengganu stone compose in context of image enhancement.

3. THRESHOLDING IN IMAGE PROCESSING

A Set of technique that allows digital images to be modified in order to improve or extract information from it is known as digital image processing. Image segmentation is the process of distribution of digital images into various segments (set of pixels, also known as super pixels). The goal of segmentation is to facilitate and / or change the representation of the image into something more meaningful and easier to analyze. In many image processing applications, the gray level of the pixels belonging to the object that is quite different from the gray level of the pixels belonging to the background.

Segmentation involves the process of separating the image into regions (or contour) corresponding to the object. Its easiest for pixels in the area that can be shared is the intensity. So, the natural way for the region segmentation by thresholding process, the separation of light and dark areas. Thresholding process of creating a binary image of the gray level with all pixels below some threshold value to zero and all pixels to a threshold value of one. Thresholded process into a simple but effective tool for separating objects from the background. Several thresholding techniques have been proposed before by using global and local techniques. Global method using a threshold value for the entire image, while local thresholding method to apply different thresholds to different areas of the image. Value determined by the pixel neighbourhood that is being used for thresholding.

Thresholded process is a technique used when scanning the gray scale image and save as Black & White. A gray scale image will have a 16 bit per pixel (representing 65,536 shades of gray) and black & white image will have 1 bit per pixel (representing either black or white). When converting from grayscale to black & white (eg scan images in black & white mode), each pixel has a different shade of gray should be changed in either black or white. This separation point is called the threshold value. By changing the threshold value of the output image quality will change.

3.1 Thresholding Methods

Image thresholding, a method which extracts objects in an image from the background, is one of the most common operations in image processing and, as such, it has been extensively researched by computer vision experts. In [12], thresholding method is categorized based on information derived from data through local spatial approaches and methods, methods based on entropy, attribute-based method object, group-based method and the method based on histogram form.

3.1.1 Huang Methods

[13] has been developed based on fuzzy entropy thresholding method, which utilizes a pixel image histogram, therefore it is not necessary to address each pixel individually. This method creates an ambiguity index by measuring the distance between the image of gray-level and binary version. The image I is represented as the array μ_f (I), where $0 \leq \mu_f (I) \leq 1$ represents the fuzzy measure of belonging to the foreground. Given the fuzzy membership value for each image pixel, an index of fuzziness for the whole image can be obtained via the Shannon entropy, which is used as a cost function. The optimum threshold is calculated by minimizing the index of fuzziness defined in terms of class (foreground and back-ground) medians or means and membership functions;

$$J_T = -\frac{1}{ln2} \sum_{z=0}^{255} \left[\mu_f(g) \ln\left(\mu_f(g)\right) + \left(1-\mu_f(g)\right) \ln\left(1-\mu_f(g)\right)\right] \quad (1)$$

3.1.2 Kapur Methods

In this method [14], the fore-ground and background classes are considered as two different sources. When the sum of the two class entropies is a maximum the image is said to be optimally threshold. Let P_1, P_2, … P_n be the probability distribution of gray-levels. Derivation from this distribution are two probability distribution, one defined for discrete values 1 to s and the other for values s + 1 to n. The two distribution are:

$$A = \frac{P_1}{P_s}, \frac{P_2}{P_s}, \dots, \frac{P_s}{P_s} \quad B = \frac{P_{s+1}}{1-P_s}, \frac{P_{s+2}}{1-P_s}, \dots, \frac{P_n}{1-P_s} \quad (2)$$

The entropies associated with each distribution are as follow:

$$H(A) = -\sum_{i=1}^{s} \frac{P_i}{P_s} \ln \frac{P_i}{P_s} \quad (3)$$

$$H(A) = \frac{1}{P_s} \left[\sum_{i=1}^{s} P_i \ln P_1 - P_s \ln P_s\right] \quad (4)$$

$$H(A) = \ln P_s + \frac{H_s}{P_s} \quad (5)$$

Similarly,

$$H(B) = -\sum_{i=1+s}^{n} \frac{P_i}{1-P_s} \ln \frac{P_i}{1-P_s} \quad (6)$$

$$H(B) = \frac{1}{1-P_s} \left[\sum_{i=1+s}^{n} P_i \ln P_1 - (1-P_s) \ln(1-P_s)\right] \quad (7)$$

$$H(B) = \ln(1-P_s) + \frac{H_n - H_s}{1-P_s} \quad (8)$$

Then the optimal threshold *T** is defined as the gray level which maximizes *H(A) +H(B)*, that is;

$$T^* = Arg\ max\ \{H(A) + H(B)\} \quad (9)$$

3.1.3 Otsu Methods

An early histogram-based global segmentation algorithm, Otsu's method are widely used. Nobuyuki Otsu in his research back to 1979 come out with a nonparametric and unsupervised method of automatic threshold selection for picture segmentation. The optimum threshold is chosen due to the discriminant criterion, namely, to maximize the reliability of foreign revenue in gray level classes. This is a very simple procedure, in which he utilizes only the zeroth- and first order moments of the cumulative histogram of gray-level. It is straightforward to extend the method for multi-threshold problem. Otsu's method is used to automatically perform clustering-based image thresholding [15] or, the reduction of a gray-level image to a binary image. The algorithm assumes that the image to be threshold contains two classes of pixels or bi-modal histogram (e.g. foreground and background) then calculates the optimum threshold separating those two classes so that their combined spread (intra-class variance) is minimal [16].

Otsu method is based on a very simple idea that is to find the threshold that minimizes the weighted within-class variance, defined as a weighted sum of variances of the two classes.

$$\sigma_w^2(t) = w_1(t)\,\sigma_1^2(t) + w_2(t)\,\sigma_2^2(t) \quad (12)$$

Weights w_i are the probabilities of the two classes separated by a threshold t and σ_i^2 variances of these classes. This can be demonstrated to be the same as maximizing the between-class variance.

$$\sigma_b^2(t) = \sigma^2 - \sigma_w^2(t) = w_1(t)\,w_2(t)\,[\mu_1(t) - \mu_2(t)]^2 \quad (13)$$

Where μ_i represent the class means. The next step is to calculate the 'Within-Class Variance'. This is simply the sum of the two variances multiplied by their associated weights.

$$Within\ Class\ Variance;\ \sigma_w^2 = W_b\sigma_b^2 + W_f\sigma_f^2 \quad (14)$$

3.1.4 Yen Methods

Following J.N. Kapur, P.K. Sahoo, (1985) idea, Yen, Chang, and Chang (1995) come out with thresholding method known as Entropy–Yen. It define the entropic correlation as

$$TC(T) = C_b(T) + C_f(T) \quad (10)$$

$$= -\log\left\{\sum_{g=0}^{T}\left[\frac{p(g)}{P(T)}\right]^2\right\} - \log\left\{\sum_{g=T+1}^{G}\left[\frac{p(g)}{1-P(T)}\right]^2\right\} \quad (11)$$

3.2 Earlier Research Problems

The method used by [1] in his study on Malay manuscripts using a threshold value of 128 is not suitable to applied to manuscript images regarding to that manuscript images are undergoing with degradation due to time and environmental factors [17], [18]. Accordingly, the use of threshold methods or binarization available at present may be tried to remove noises found in Ancient manuscripts especially for Terengganu Inscribed Stone.

This paper examined in detail the thresholding method chosen to enhance the image quality of Terengganu Inscribed Stone. Some of the methods discussed such as Huang, Kapur, Yen and Otsu method. The method dynamically chooses the discriminant threshold based on the foreground and background of image. So, the threshold value is more precise for images from various sources of Jawi ancient manuscripts. The purpose of this process is to remove noise. Next, the study will recommend thresholding technique suitable for Terengganu Inscribed Stone to over-come the letters blurred due to time and environmental degradation.

4. METHODOLOGY

The methodology of the study discusses the conceptual framework, the task framework and the experimental framework. Each framework has a sub-section for details on the implementation found in these frameworks.

4.1 Research Framework

Conceptual framework has been divided into two parts, Investigation and Implementation Phase. The two phases are illustrated in Figure 1.

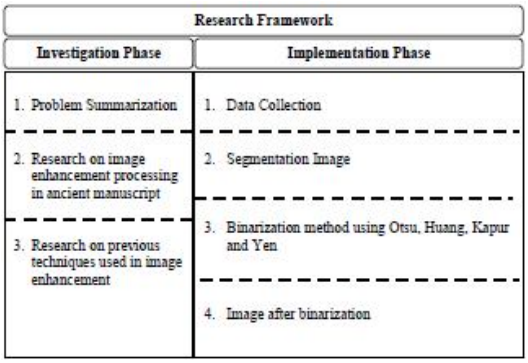


Figure 1: Research Framework

4.2 Task Framework

Figure 2 show the task framework. The task framework proposed method is based on research done by (Yahya et al., 2009).

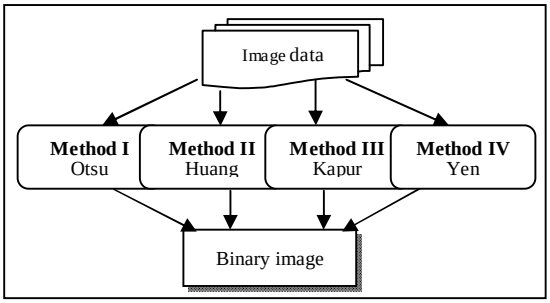


Figure 2: Task Framework

In this research, classification of methods to enhance old manuscripts divided into four image enhancement methods, which are (a) Image thresholding method I – Otsu's Method, (b) Image thresholding method II – Huang's Method, (c) Image thresholding method III – Kapur's Methods, and (d) Image thresholding method IV – Yen's Method. At the end, the best practice methods for thresholding techniques can be obtained. For this paper, the images used are from Terengganu Inscribed Stone. The sample of image used is in Figure 3 below.

Figure 3: Terengganu Inscribed Stone

4.3 Research Tools

In this study, some research tools are used to support the research. Equipment needed summarized in Table 2.

Table 2: Programming languages and tools that used in this research

Steps	Datasets	Programming Language	Tools
Data Collection	Image of Terengganu Inscribed Stone	Java	ImageJ
Segmentation		-	-
Binarization		Java	ImageJ

5. RESULTS AND FINDINGS

In order to assess and compare the performance of different thresholding techniques, a set of experiments has been conducted and their results are explained and dis-cussed in this section.

5.1 Data Collection

The image used is from Terengganu Inscribed Stone. So the image was taken from Terengganu State Museum web-site. There are four main images that represent four sides for Terengganu Inscribed Stone used in this project including side A until side D as shown in Figure 4.

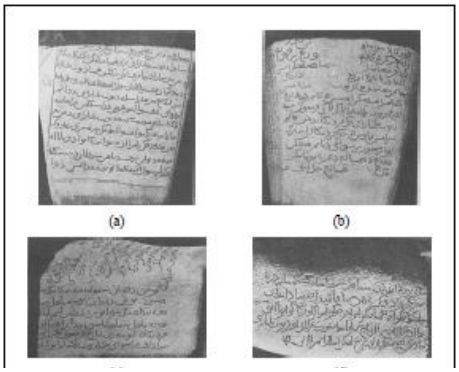


Figure 4: Four sided image of Terengganu Inscribed Stone

5.2 Image Segmentation

The segmentation of the images from Terengganu In-scribed Stone is not the focus of study. Thus, the segmentation to single characters are done manually as proposed by Mohammad Faidzul (2010) and Mohd Sanusi (2013). Segmentation by thresholding distinguishes between back-ground and foreground objects by partitioning the pixels into two or more categories according to the pixel intensity. For this purposes of project, the image has been segmented into four sides of the Terengganu Inscribed Stone.

5.3 Image Binarization

Binarization is performed in the pre-processing stage for document analysis and it aims to segment the foreground text from the document background. Many algorithms have been proposed for the document binarization task. In this paper, the methods used for binarization purposes used are Huang, and Yen as thresholding methods. Thresholding is the simplest method of image segmentation. From a grayscale image, thresholding can be used to create binary images. The processes involved are illustrated in Figure 5.

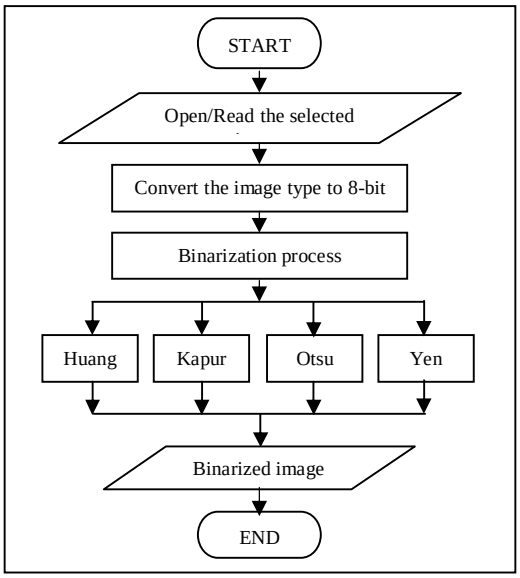


Figure 5: Process flow in binarization images

ImageJ is used as a tool in this project for the purpose to convert images into binary using Huang and Yen methods. ImageJ is a powerful image analysis program that was created by National Institutes of Health (NIH). ImageJ is a freeware application available at http://imagej.nih.gov/ij/download.html. It is in the public domain, runs on a variety of operating systems such as Macintosh, Windows, and Linux and is updated frequently. An image processing package of ImageJ called Fiji, which comes with added functionality and includes many useful plug-ins by default, has gained popularity; http://fiji.sc/wiki/index.php/Fiji .

Table 3: Threshold value for Huang, Kapur, Otsu and Yen methods

Image	Threshold value for methods			
	Huang	Kapur	Otsu	Yen
Side A	149	165	153	174
Side B	131	144	139	146
Side C	114	130	127	131
Side D	143	152	145	155

5.4 Histogram Analysis

As a preliminary step to a more in-depth thresholding analysis, the histograms of the image set were extracted. Image histograms are a useful tool to help discover some properties from images, and even directly obtain thresholds from them. A morphological analysis of histograms can help predict which thresholding method may offer the best performance for a particular image by reasoning about some assumptions of the thresholding method itself. Figure 6 shows the gray-level images and their associated histograms.

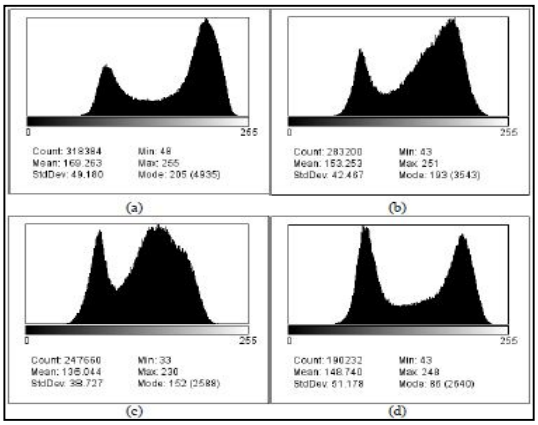
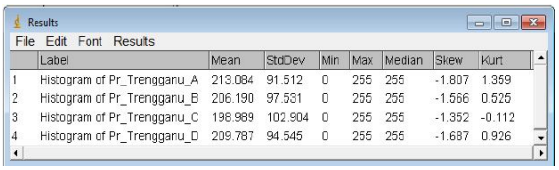


Figure 6: Images histogram for the sample images

Image histogram describes the frequency of the intensity values that occur in an image. Histograms don't encode information about the spatial arrangement of pixels in the image. Figure 7 sums up this metrics for the gray-level input images in the experiment.



	Label	Mean	StdDev	Min	Max	Median	Skew	Kurt
1	Histogram of Pr_Trengganu_A	213.084	91.512	0	255	255	-1.807	1.359
2	Histogram of Pr_Trengganu_B	206.190	97.531	0	255	255	-1.566	0.525
3	Histogram of Pr_Trengganu_C	198.989	102.904	0	255	255	-1.352	-0.112
4	Histogram of Pr_Trengganu_D	209.787	94.545	0	255	255	-1.687	0.926

Figure 7: Histogram statistical properties for a subset of images in the test set

The mean of a data set, and in particular of an image histogram, is the arithmetic average of the values in the set, obtained by summing all values and dividing by the number of them. The mean is, thus, a measure of the centre of the distribution. In the case of images Pr_Trengganu_A refer to side A and Pr_Trengganu_D refer to side D from Terengganu Inscribed Stone, with the highest mean value of the test set as Figure 8, it is indicative that predominant white gray levels exist. Therefore, most pixels in the image have gray-level values close to white.

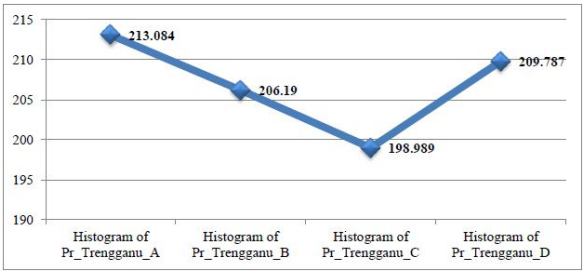


Figure 8: Graphic of mean values of the image set histograms

The standard deviation is the squared root of the variance. The variance and the standard deviation are both measures of the spread of the distribution around the mean.

Skew is a measure of histogram asymmetry; it measures the balance between the positive and negative tails of a distribution. In contrast, images with a negative skewness indicate that the bulk of values lie to the right of the mean and those with sparse dark regions, so the image is lighter. All side of Terengganu Inscribed Stone with a negative skewness indicate that the bulk of values lie to the right of the mean. Therefore, most pixels in the image have gray-level values close to white.

5.5 Canny Edge Detector

The Canny edge detector is an edge detection operator that uses a multi-stage algorithm to detect a wide range of edges in images. Canny is one of the most commonly used optimal edge detector. It was developed by John F. Canny in 1986. John F. Canny developed this algorithm which is widely considered as a standard edge detection method. For the purposes of this project, the threshold selection methods used are Huang, and Yen based technique for detecting edges efficiently.

Table 4 indicates the evaluation value for Signal-to-Noise Ratio given in dB (SNR), Peak Signal-to-Noise Ratio given in dB (PSNR), Root Mean Square Error (RMSE), and Mean Absolute Error (MAE) of grayscale images or series of grayscale images for the selection of threshold methods using Canny Edge Detector.

Table 4: SNR, PSNR, RMSE and MAE value

Original Image	Threshold Methods	SNR[dB]	PSNR[dB]	RMSE	MAE
Side A	Huang	0.366925	3.854947	163.6036	146.8287
	Kapur	0.436578	3.924599	162.2969	145.1587
	Otsu	0.379263	3.867285	163.3714	146.5309
	Yen	0.503707	3.991728	161.0474	143.5743
Side B	Huang	0.308243	5.125994	139.11502	119.7128
	Kapur	0.408790	5.226542	137.51391	117.9759
	Otsu	0.368074	5.185825	138.16004	118.6744
	Yen	0.428489	5.246240	137.20240	117.6403
Side C	Huang	0.101497	6.562446	107.575448	84.396838
	Kapur	0.218678	6.679628	106.133888	83.188702
	Otsu	0.189752	6.650702	106.487934	83.483909
	Yen	0.225667	6.686617	106.048531	83.117677
Side D	Huang	0.434900	6.825657	113.023523	76.299455
	Kapur	0.487449	6.878206	112.341802	75.696960
	Otsu	0.452184	6.842940	112.798848	76.100488
	Yen	0.506957	6.897714	112.089770	75.475141

The plugin used to calculate the SNR, PSNR, RMSE and MAE written in Java and embedded into ImageJ. The plugin compares a reference image r(x,y) with a test t(x,y). The two images should have the same size [nx, ny]. The plugin is also able to compare a reference with a stack or a test images or with a sequence a test images. Figure 9 shows the flow chart for calculation of SNR, PSNR, RMSE and MAE based on the results from Canny Edge Detection for all images with different threshold methods.

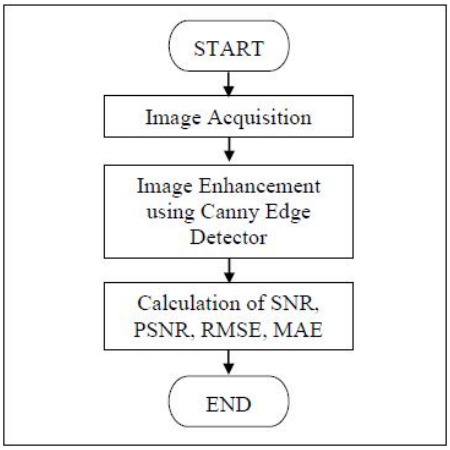


Figure 9: Flow chart for calculation of SNR, PSNR, RMSE & MAE

The SNR is a measure used that compares the level of a desired signal to the level of background noise. It is defined as the ratio of signal power to the noise power, often ex-pressed in decibels (dB). The PSNR often expressed in decibels (dB) is most commonly used to measure the quality of reconstruction of lossy for image compression. The signal in this case is the original data, and the noise is the error introduced by compression.

The RMSE is a frequently used measure of the difference between values predicted by a model and the values actually observed from the environment that is being modelled. These individual differences are also called residuals, and the RMSE serves to aggregate them into a single measure of predictive power.

The MAE and the RMSE can be used together to diagnose the variation in the errors in a set of forecasts. The RMSE will always be larger or equal to the MAE; the greater difference between them, the greater the variance in the individual errors in the sample. If the RMSE=MAE, then all the errors are of the same magnitude. Both the MAE and RMSE can range from 0 to ∞. They are negatively-oriented scores: Lower values are better.

The image enhancement methods are discussed in de-tailed in this paper. The various techniques for image enhancement on Terengganu Inscribed Stone were classified into two types of methods including Huang and Yen. All two methods are in the same categories of thresholding that is global thresholding methods. Based on results, the methods have proven to improve several distinctive obstructions in the Terengganu Inscribed Stone image.

From the works done for this project, it can be concluded that Yen method can produce promising results compared to the other methods. Therefore, the thresholding process may preserve possible features / values that can be eliminated within the thresholding process. It also can get rid of the noise resulting from degradation due to the age of Terengganu Inscribed Stone.

6. DISCUSSION

There are variant of evaluations methods that have been used for identifying which thresholding methods that can perform better to enhance the Terengganu Inscribed Stone image. For purpose of this project, some of the evaluations methods used such as from the images results from histogram analysis, the various thresholding methods itself and Canny Edge Detector.

Evaluation results showed that in image thresholding for Terengganu Inscribed Stones that there is not a single method that outperforms the rest in every case. Certain kinds of histograms, however, help decide an appropriate thresholding method that offers good results for that type of images.

6.1 Evaluation and Testing

The methods used for binarization purposes used are Huang, Kapur, Otsu and Yen as thresholding methods. Thresholding is the simplest method of image segmentation. From a grayscale image, thresholding can be used to create binary images. Based on the results from the binarization process mentioned earlier, the thresholds value obtained for each methods are shown in Figure 10.

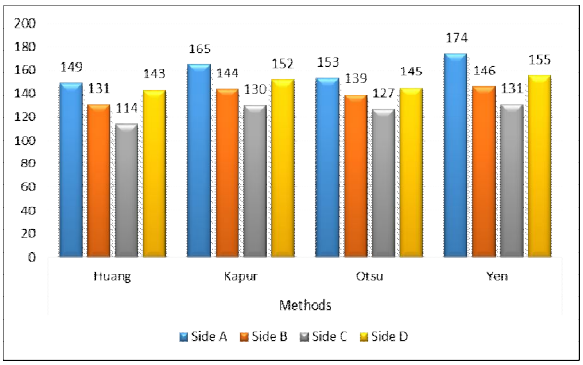


Figure 10: Comparison of threshold value

Figure 10 shows the graphical representation of different levels of the threshold values of the different techniques for four side of Terengganu Inscribed Stone. Based on the graph, Side A from Terengganu Inscribed Stone requires the highest threshold value using all four global thresholding methods in this project (Huang and Yen) while Side C requires the lowest threshold value. This may be due to the original image, which was old due to degradation.

Based on the histogram analysis done as explained in Section V, it can be concluded that image from Side A and Side D from Terengganu Inscribed Stone indicates that predominant white gray levels exist. All side of Terengganu Inscribed Stone with a negative skewness indicate that the bulk of values lie to the right of the mean. Therefore, most pixels in the image have gray-level values close to white.

Using Canny Edge Detector to detect wide range of edges in images, the Peak Signal to Noise Ratio (PSNR) and the Root Mean Square Area (RMSE) can be obtained between the thresholds selected method for this project, the comparison of difference methods are shown as Figure 11 and Figure 12.

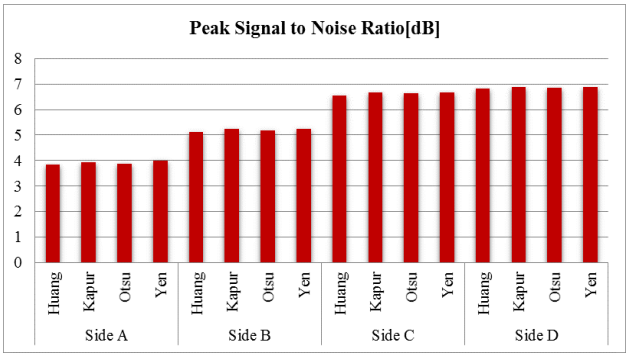


Figure 11: Comparison of PSNR

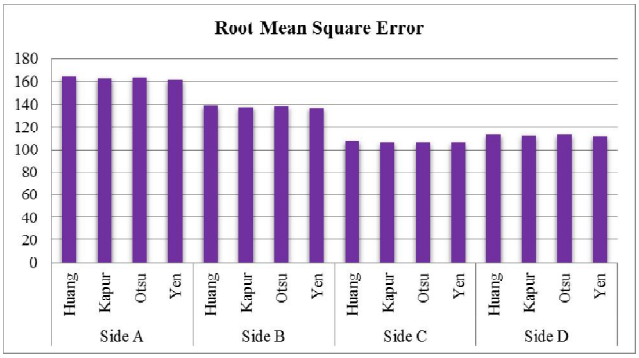


Figure 12: Comparison of RMSE

High value of PSNR indicates the high quality of image while lower value of RMSE indicates higher the quality of image. Based on the results shown in Figure 13, Yen method get both the highest value for PSNR for Side D with 6.897714 and lowest value for RMSE for Side C with 106.0485 from Terengganu Inscribed Stone after applying canny Edge Detection. From that, Yen methods have the better performance between other methods for each side of image from Terengganu Inscribed Stone.

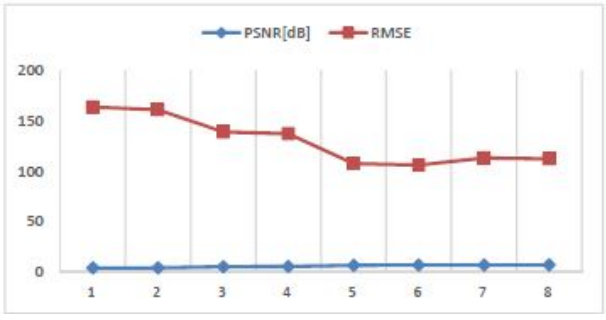


Figure 13: Comparison of RMSE and PSNR

Evaluation results showed that in image thresholding for Terengganu Inscribed Stone, there is not a single method that outperforms the rest in every case. Certain kinds of histograms, however, help decide an appropriate thresholding method that offers good results for that type of images.

6.2 Futher Research

Further research could be directed towards the following:

- The expansion of methods applied for thresholding process for the image of Terengganu inscribed Stone. The methods could be widening using local thresholding methods.
- The expansion of Malay Ancient Manuscript images as test data apart from image of Terengganu Inscribed Stone.

7. CONCLUSION

The research described in this project is concerned with digital image processing focussing in image enhancement for Malay Ancient Manuscript for Terengganu Inscribed Stone. The main objective of this research is to find the better thresholding methods and do the comparative analysis.

Based on results, the methods have proven to improve several distinctive obstructions in the Terengganu Inscribed Stone image. From the works done for this project, it can be concluded that Yen method can produce promising results compared to the other methods. The evaluation performed to identify which thresholding methods are better for enhancing image of Terengganu Inscribed Stone.

For purpose of this project, some of the evaluations methods used such as from the images results from histogram analysis, the various thresholding methods itself and Canny Edge Detector. Using Canny Edge Detector to detect wide range of edges in images, the Peak Signal to Noise Ratio (PSNR) and the Root Mean Square Area (RMSE) can be obtained between the thresholds selected method.

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