Review on Image Enhancement Methods of Old Manuscript with Damaged Background

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Abstract: Quite often old documents are subject to background damage. Examples of background damages are varying contrast, smudges, dirty background, ink through page, outdated paper and uneven background. The old Malay manuscripts which are a few hundred years of age, for example, are not legible even after preservation process by the library. Image processing offers a selection of approaches to counter these quality degradations and make the manuscripts readable. This paper provides a comprehensive review of the methods for enhancing old document images with damaged background. Three types of enhancement methods have been identified which are (a) image enhancement using binarization/ thresholding method, (b) image enhancement using a hybrid of binarization/thresholding and other methods, and (c) image enhancement using non-threshold based methods. Finally we found that the second method is becoming more popular and has a great potential for improvement in future.

Keywords: Image processing, Image enhancement, Damaged background, Binarization method, Thresholding method.

1. Introduction

Ancient manuscripts aging from hundreds to thousands of years are often in bad or damaged background. Several causing factors are ill age, environmental influence, ink quality worn and ancient. An example is the old Malay manuscripts which are normally written in the Jawi scripts. These documents, which were written in the period of 16th to 19th century, have still survived until today but the quality has been degraded. Besides the environmental issue, human negligence also contributes towards the destruction of the Malay manuscripts. In conjunction with this crucial issue, the manuscripts must be securely preserved and kept in soft or hard copies. With that, the ancient Jawi manuscripts are guaranteed of their life and quality and could be shared by interest parties and the future generations. A proactive measure has been taken by the National Library of Malaysia (PNM) to preserve the old manuscripts. Preservation process has been done through several levels of action. Among the actions are cleaning, testing the acid content, deacidification, drying, traditional repair, repair using the leaf casting machine, and binding. However, not all manuscripts which have gone through the preservation process are clear and readable. Sometimes, the documents have contrast problems such as the foregrounds are usually having damaged ink with different background color. Hence, to improve the validity of the manuscripts, the interested parties must deploy digital image processing approaches [1].

Based on the above problems, many researchers have discovered different methods to facilitate the readings and reproduction of manuscripts which possess damages in the antecedent images, such as [1]-[3], [6]-[11], [13], [15]-[19], [21]-[28], [31]. In general, some

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researchers initially repair the manuscript image from a clean background or free of noise character by using binarization or thresholding process, and then apply thresholding and stretching processes onto the grayscale image to obtain a noise free background ([2]-[7], [10]-[11], [16]-[18], [20]-[23], [25], [38], [39]). They developed a procedure to separate the letters from the background in the manuscripts.

Another research has attempted streak elimination in both sides of the document by using an edge detection method with a double threshold values in the foreground image [16]. On the other hand, other research separated the background and foreground by applying the clearing normalization algorithm and transformation histogram, and segmentation techniques such as the K-Means algorithm and the Maximum Likelihood algorithm [23].

In this paper, we classify the methods to enhance old manuscripts into three image enhancement methods, which are (a) Image enhancement method I – binarization/ thresholding method, (b) Image enhancement method II – a hybrid of binarization/thresholding and other methods, and (c) Image enhancement method III – non-threshold based methods. Figure 1 shows a flowchart of image enhancement steps for old manuscripts.

This paper is divided into five parts. Following this introduction is the image enhancement methods in Section 2. Difficulties in image enhancement for Malay manuscript are discussed in Section 3, and the benefits and limitations of image enhancement are given in Section 4. Section 5 gives the conclusions and suggestions for future work.

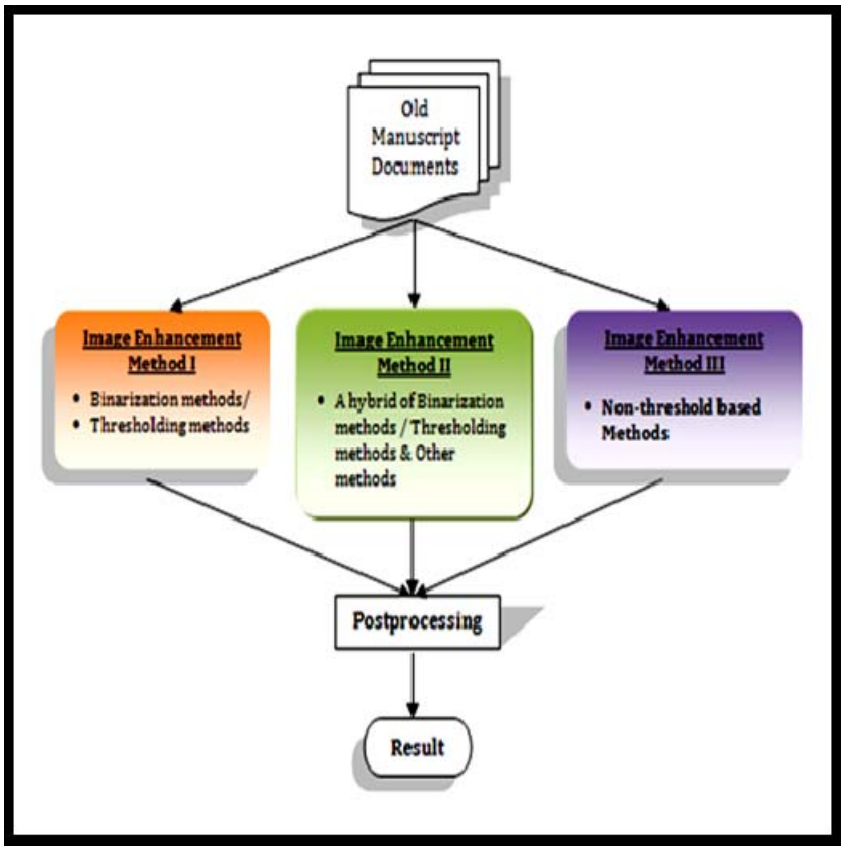


Figure 1. The flowchart of image enhancement methods for old manuscripts which have damaged background

2. Image Enhancement Methods

A. Image Enhancement Method I

A. 1. Binarization/Thresholding Method

1) Entropy-Based Method

There are a few useful methods to calculate background and foreground regions. A prominent method to segment the original image into binary image is called Entropy-based method [28].

Generally, this method is initiated by some threshold values in the range of two variables, namely *T1* (background) and *T2* (foreground). Some researchers proposed different parameter value arrangements for producing binary image which were also designed for document enhancement purposes [7], [12], [22]. The preserved gray level value is pixel at gray level below *T2* value and gray level value within *T1* value and *T2,* whereas the gray level values which are greater than *T1* value, are directly eliminated [28].

On the other hand, other research groups have discovered different approaches to encounter color documents [4], [34], [35]. Firstly, they transformed the color documents into gray scale before the binarization process, or directly binarized the color documents.

Beside that, another approach called Parameter Estimation Algorithm can also be used to automatically detect the best value for parameter setting (PS). This method executed results from a binary transformed image. It could estimate the different PS values based on any particular image analysis technique [2].

2) Locally Adaptive Thresholding

Using this method, every pixel within a locality is applied an adaptive threshold value based on the local image characteristic [28]. Firstly, the gray level value g(x,y) for every pixel (x,y) of a particular document image is calculated. The gray level is an intensity value within the range of [0, 255]. Then, the local adaptive threshold, t(x,y) for every pixel (x,y), is formulated as Eq. 1:

$$f(x,y)=\begin{cases}0 & \text{if } g(x,y) \le t(x,y)\\ 255 & \text{otherwise}\end{cases} \quad (1)$$

In addition, a local adaptive thresholding, such as Sauvola's binarization method, the threshold $t(x,y)$ is computed using the mean, $m(x,y)$ and standard deviation, $s(x,y)$ of the pixel intensities in a $w \times$ window which is centered around the (x,y) pixel [3], [12]. The formula is as follows (Eq. 2):

$$t(x,y)=m(x,y)\left[1+k\left(\frac{s(x,y)}{R}-1\right)\right] \quad (2)$$

where R is the maximum value of the standard deviation (R = 128 for gray scale document), and k is a parameter consists of positive values in between 0.2 and 0.5. The local mean $m(x,y)$ and standard deviation $s(x,y)$ are adapted threshold value pertaining to the contrast of pixels of the local neighborhood. If there is a contrast in some particular region of the image, then $s(x,y) = R$ is selected and it would produce $t(x,y) = m(x,y)$.

B. Image Enhancement Method II

B. 1. Hybrid of Binarization/Thresholding Method and Other Methods

Perantonis *et al.* [18] proposed a scheme for image binarization and improvement, which contains different measures. Firstly, a low-pass Wiener filter was used as thepre-processing

procedure. Secondly, the Niblack's approach was used for a rough estimation of the foreground regions [36]. Thirdly, the interpolating neighboring background intensities are used a background surface calculation process then the combination of the calculated background surface and the original image are applied as a thresholding process. Finally, a post-processing step is performed to improve the quality of text regions and preserve the stroke connectivity.

The majority of characters and its ligatures are calculated based on the existence of closed cavity regions by proposing a novel segmentation-free, fast and efficient technique. It assists the recognition procedure by tracing and recognizing the most frequently appearing characters or character ligatures [18]. He also tried out Sauvola's approach for the adaptive thresholding process. After executing the preprocessing task, they estimated the foreground by using the rough estimation approach. It processes the image in order to extract the binary image where black or white pixel corresponds to the rough estimated foreground regions.

Document analyses such as to identify dates, locations, and writers with different writing styles are conducted by [22]. They used a multi-stage algorithm. At the first step, a variable is initially set as a character. After transforming the image into gray scale, the threshold process is executed subsequently. Next step, the evolution process is applied for connected component labeling on that particular image. It could separate characters from the damaged background. Let SD_i becomes the seed image of CC_i using m_i as a local threshold, we have:

$$SD_i = \begin{cases} 1, & if\ CC_i \leq = m_i \\ 0, & \text{otherwise} \end{cases} \quad (3)$$

Apart from that, an extension of Otsu automatic threshold method is introduced to separate character from a damaged manuscript background [19]. They discovered this method in order to solve several conventional threshold value techniques: such as handling overlapping characters. They had to scale down the image and apply a recursive labeling method for word extraction process.

Initially, they approximated the background of a gray scale image using one of the two models such as piece-wise linear or nonlinear models. With the purpose of overcoming unevenness of document, background are designed by using background approximations. Then, the background normalization algorithm is applied to the component channel images of a color palm leaf image. They also proposed two local adaptive normalization algorithms for extracting enhanced gray scale images from color palm leaf images. They partitioned an image into *m* by *n* smaller regions whereby each region approximated a flat surface of the background using piece-wise linear model. In each such region, a second linear function in the form of Eq. 4 is applied:

$$A_x + B_y - z + D = 0 \quad (4)$$

For image normalization phase, any pixel at location *(x,y)* with pixel value z_{orig}, the normalized pixel value is computed by a linear translation as below (Eq. 5),

$$z_{new} = z_{orig} + z_{back} + C \quad (5)$$

where, $z_{back} = Ax + By + D$ for the linear approximation case and $z_{back} = Value(x,y)$ for the nonlinear approximation and *Value(x,y)* is a value taken from the nonlinear approximation at *(x,y)*. *C* is a constant fixed to some number closed to the white color value of 255, and for a global shifting, the suggested value is 220. After that, adjustment is made by stretching. For any pixel at *(x, y)* the enhanced pixel value is derived by Eq. 6.

$$z_{new} = \frac{z_{original}}{z_{back}} + C \tag{6}$$

To ensure a white background, C is set to 255 (usually) to as the gray level can never exceed 255. They proposed for extraction of pre-specified letters using a segmentation-free approach based on the well-known erosion operator [1], composed of several stages in the extraction process: structuring element generation, character extraction, character validation and structuring element adaptation.

Wang *et al.* [15] suggested that by applying a directional wavelet transform in double side mapping, it is able to distinguish the reverse side strokes and the foreground much better than the conventional wavelet transform. The restored images are transformed into binary using Niblack's approach to improve the final appearance [36].

On the other hand, other research has identified script at word level in a bilingual document containing Roman and Tamil scripts [24]. After pre-processing the binary image, they applied skew detection and correction processes. They achieved an accuracy rate of 86-98%. Moreover, they also implemented segmentation process at line and sentence levels. Gabor filter, well-known as a Gaussian modulated sinusoid is used while in the feature extraction process. With orientation θ, and centered at frequency F, a complex 2-D Gabor function is given as below (Eq. 7) :

$$h(x, y) = \frac{1}{2\pi\sigma_x\sigma_y} \exp\left\{-\frac{1}{2}\left[\frac{x^2}{\sigma_x^2} + \frac{y^2}{\sigma_y^2}\right]\right\} \exp\left\{j2\pi F\left[\begin{matrix} x\cos\theta \\ + y\sin\theta \end{matrix}\right]\right\}, \tag{7}$$

In the x and y directions, the spatial spreads of the Gaussian are given by:

$$\sigma_x = \sqrt{\ln 2}\,(2^{\Omega_F} + 1) / (\sqrt{2\pi}\,F\,(2^{\Omega_F} - 1)) \tag{8}$$

$$\sigma_y = \sqrt{\ln 2}\,/ (\sqrt{2\pi}\,F \tan(\Omega_\theta / 2)) \tag{9}$$

where Ω_F and Ω_θ are the frequency and the angular bandwidth, respectively. The necessary parameters to model the human visual system were provided by changing the frequency and scaling of the Gabor function.

An alternative method to separate foreground from a background in colored image of Arabic historical manuscript is to use a normalization algorithm of the lighting intensity and classification using K-means [23]. The normalization algorithm of the lighting intensity solves the irregular and low-contrast image background problem. This technique can transform colored image into binary image based on histogram point average.

Subsequently, recursive estimation is calculated with regards to gray scale pixels. It would also alter the window size of that particular image. In order to estimate pixel strength of value in foreground, two rules are used as below (Eq. 10 and 11),

Linear normalization by translation

$$Y_{new} = (Y_{original} - Y_{Back}) + C \tag{10}$$

Linear normalization by stretching

$$Y_{new} = (Y_{original} / Y_{Back}) * C \tag{11}$$

The foreground and background segmentation process are executed using K-means algorithm which computes the necessary statistical features vectors for the classification. The parameters obtained by the K-means algorithm are further refined using the maximum likelihood algorithm in order to improve the final segmentation.

C. Image Enhancement Method III

C. 1. Non-Threshold Based Methods

Fuzzy logic method has been applied to old document recognition in [9]. The research investigated document damages such as distance between letter and tuner for thin and thick character styles. The Gabor Filter and Fuzzy Logic were used for feature extraction and classification techniques respectively. They claimed that Gabor filter is useful to extract local information of district environment in an image. Besides this information, the aspect ratio for each unknown character is also calculated. Lastly, the equality of classified character is derived as below (Eq. 12), where the equality rule is given as:

$$S_{ij}(C) = \frac{\sum_{x,y} W_{ij}(x,y) a_{ij}(x,y) C_{ij}(x,y)}{\sum_{x,y} W_{ij}(x,y)}, \tag{12}$$

and the rule for the aspect factor as:

$$r_j(C) = \min\left(\frac{ar(c)}{ar_j}, \frac{ar_j}{ar(c)}\right) \tag{13}$$

where $r_j(C)$ is the aspect ratio factor which to compare aspects of the image on the character C and the average aspect ratio of the group ar_j of letter j. A recommendation called Backup method or the Stroke Model, has been designed by [16] with the intention of solving the overlapping text in a document image. The stroke model could show the location of a thick edge that is the most visible image of any posts in the document. The Canny edge detection is applied to highlight edges and magnitude of an image. The white colored edges are indicated as a larger magnitude. Since the handwritten styles involve skewness from below left to upper right, therefore the overlapping text could be easily detected and separated those characters from the background.

Another interesting method called word spotting algorithm is introduced by [25]. Normally, old manuscripts are spoiled due to mutually overlap letters, shadowy background color, ill paper with fly in the ointment, etc. In spite of those damages, this algorithm could still trace the position of each unclear letter. They also introduced the Zones of Interest (ZOIs) Algorithm to fit superlatives and to solve the above matters.

They compared ZOIs with Naive matching, Elastic naive matching and Cohesive elastic matching and the results are shown in Table 1. In conclusion, Cohesive elastic has successfully obtained the highest accuracy rate with the most minimum runtime compared to Naïve and Elastic Naive.

Table 1. Matching Method Performance [25]

Matching Method	Naive	Elastic naive	Cohesive elastic
Runtime on full validation DB	60 min	880 min	20 min
P = R	0.8	0.85	0.99
P(R = 1)	0.02	0.2	0.99
Complexity	O*(NP)*	O*(NPK)*	O*(MK)*

Furthermore, Sulem & Sigelle [26] used Dynamic Bayesian Networks (DBNs) method for the character recognition phase. By using DBNs method, destroying character could be improve the to become more readable and clear. In general, DBNs architecture consists of coupling two Hidden Markov Models (HMMs). The HMMs involved interactions between rows and columns of the observations throughout the state/observation transitions or state transitions. The HMMs involved the interactions between rows and columns in the observations that through state/observation transitions or state transitions. The experimental results are divided into two off-line recognition tasks as stated in Table II. In conclusion, the combination of HMMs could boost up the performance of character recognition rate.

Table 2. Recognition Rates (%) For Standard And Degraded Old Printed Characters [26]

Model	Standard (test-s)	Degraded (test-d)
Vertical-HMM	98.3	93.8
Horizontal-HMM	93.7	88.1
Vertical-AR	97.9	94.5
Horizontal-AR	96.2	91.2
ST_CPL	98.7	95.5
GNI_CPL	98.6	94
AR_CPL	98.8	96
Combination of HMM scores	98.4	95.4
Combination of AR_HMM scores	98.7	95.5
SVM	98.4	94.9

3. Difficulties In Malay Manuscript Image Enhancement

Based on the image enhancement research work on Hikayat Hang Tuah, we are facing a number of difficulties to separate its foreground (text) and background, namely:

- Overlapping between text as foreground and background manuscript image,
- The overlapping text has caused the associate image producing the same color, and hence parts of the characters cannot be seen and read clearly.
- The angles of the skewness on the manuscript characters are undetectable; either right skewed or left skewed. This problem might be due to the non-optical or different handwriting styles in the manuscript.
- It is difficult to recognize the associated characters in the image manuscript. Therefore, an efficient method is required to overcome this problem.

Not all the pages of the Hikayat Hang Tuah have the same level of difficulties and damages. Some damages may appear more on the top lines compared to the bottom lines of the page. Besides that, the background color is observed to be thicker than the foreground as illustrated in Figure 2. Hence, in the early work, we will concentrate only on the images of the old manuscript which have lower level of difficulties as depicted in Figure 2(b). Figure 3 gives a closer view of medium and bad quality images extracted from the manuscript and their

corresponding grayscale histograms. More examples of the collections of the Hikayat Hang Tuah manuscripts are shown in Figure 4.

Figure 2. A sample page of Hikayat Hang Tuah with different level of difficulties: (a) Level of difficulties to detect characters is higher, (b) Level of difficulties to detect characters is lesser.

4. Advantages of Image Enhancement Methods

As per discussion in previous sections (also referring to Figure 2), the best image enhancement method is the second method namely image enhancement method using a hybrid of binarization/thresholding method and other methods. This method can solve damaged images in a more complete way by using image enhancement methods. The process is being firstly initialized with a pre-processing task.

The second method, in the pre processing phase, it begins by changing the whole color image into grayscale, so as to ease the subsequent processes. Then, the gray scale image is transformed into a binary image using the thresholding process. We suggest that the first image cleaning process execution is extended to the second cleaning process by applying other additional methods. As a result, the double image cleaning process could produce more acceptable and accurate image.

Another interesting point regarding the above matter is that it could also detect damaged characters in the image and separate them into another copy of image. The copy of the image could be refiltered with other methods in order to gain a better image preview. Also, researchers rarely improve damaged characters in a more detailed way such as a double cleaning process. Many old manuscripts suffer illness due to inappropriate paper quality and unclear handwriting. Therefore, it is an obligation to establish new or adaptive methods in the context of digital image processing, to ease and encourage more people to read the invaluable old manuscripts.

In the third method, normally mathematical techniques such as linear function, minimal sum distance or morphological techniques are actively applied and modified by most researchers [1], [23], [25]. Since those techniques involved a series of training and testing activities, a lot of mathematical functions were used to improve the accuracy of the recognition

especially for damaged characters. By combining various practical machine learning approaches, the third method also looks very promising in terms of research purposes and commercial values.

Finally, some examples of the image results obtained by previous researchers using those three groups of image enhancement method are shown in Figures 5, 6 and 7.

5. Conclusions

The image enhancement methods are discussed in detailed in this paper. The various techniques for image enhancement on old manuscripts were classified into three types of methods. Based on previous research results, the methods have proven to improve several distinctive obstructions in the old manuscripts. The benefits and drawbacks of the methods are also being explained in detailed. This study concluded that method II, namely a hybrid of binarization/thresholding method and other methods, can produce promising results compared to the other methods.

We obtained a collection of the manuscripts of the Hikayat Hang Tuah from PNM [41] and transformed them into a collection of image database. Those manuscripts have gone through the preservation process. Up to now, those manuscripts are still in poor state and few actions were taken to establish methods to make the manuscripts more readable. Having a database of old manuscript images would definitely assist researchers in reading and understanding the gist of the manuscript without any damaging effect to the original manuscript at PNM.

The processing of medium quality images of the manuscripts such as the one in Figure 3 (a) will be the main focus of the current work. Extending the methods to handle more challenging pages like Figure 3 (b) and the complex ones in Figure 4 is the recommended further work.

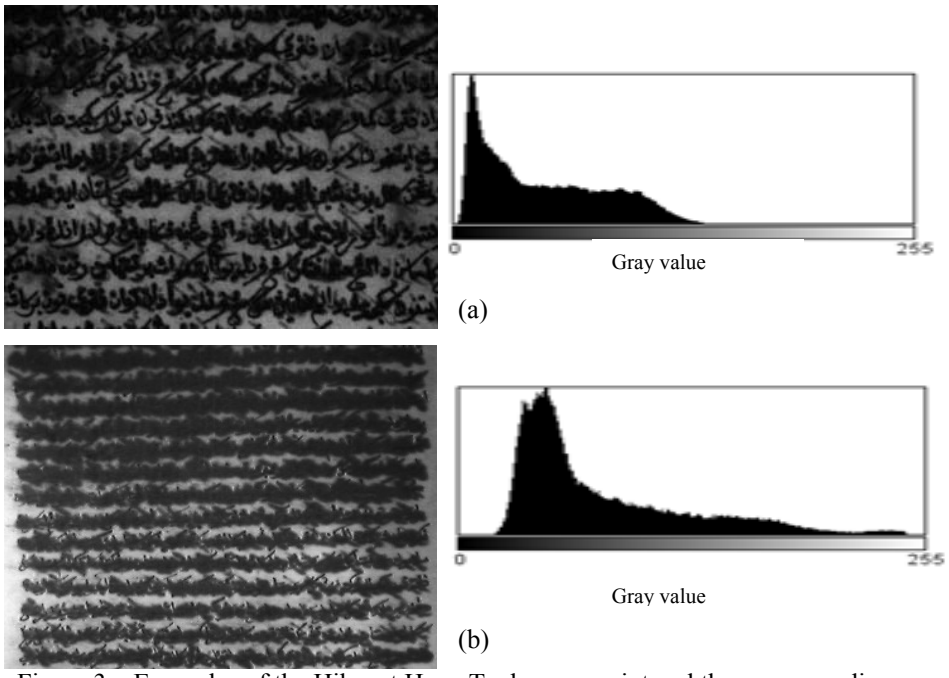
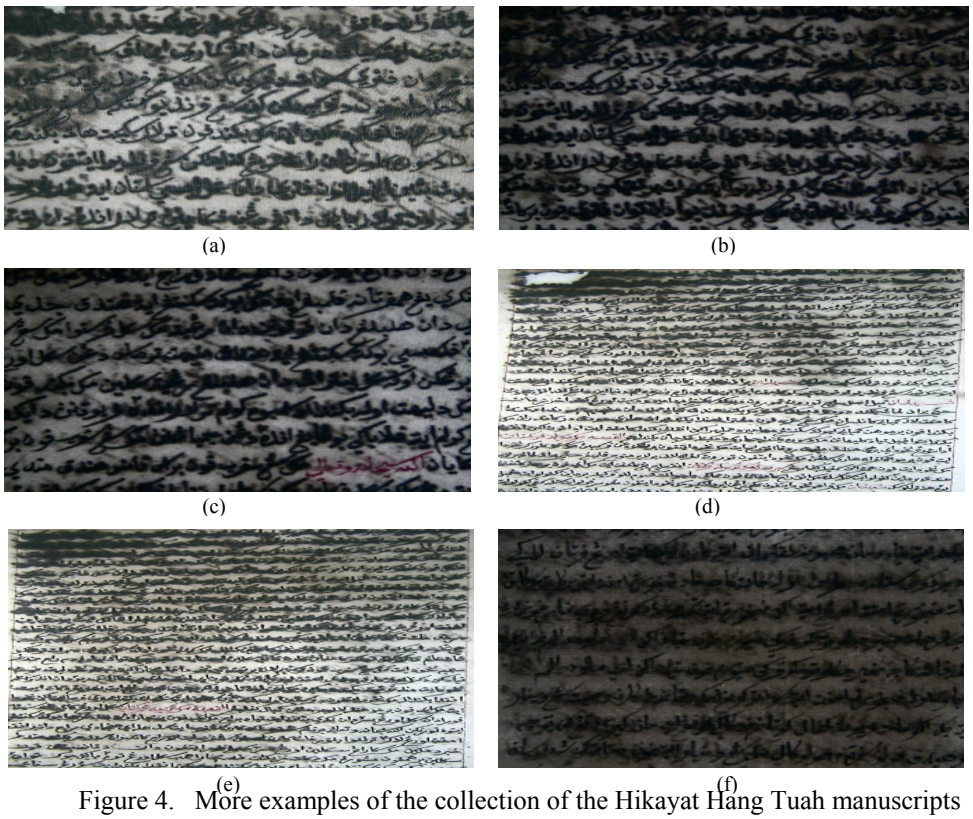
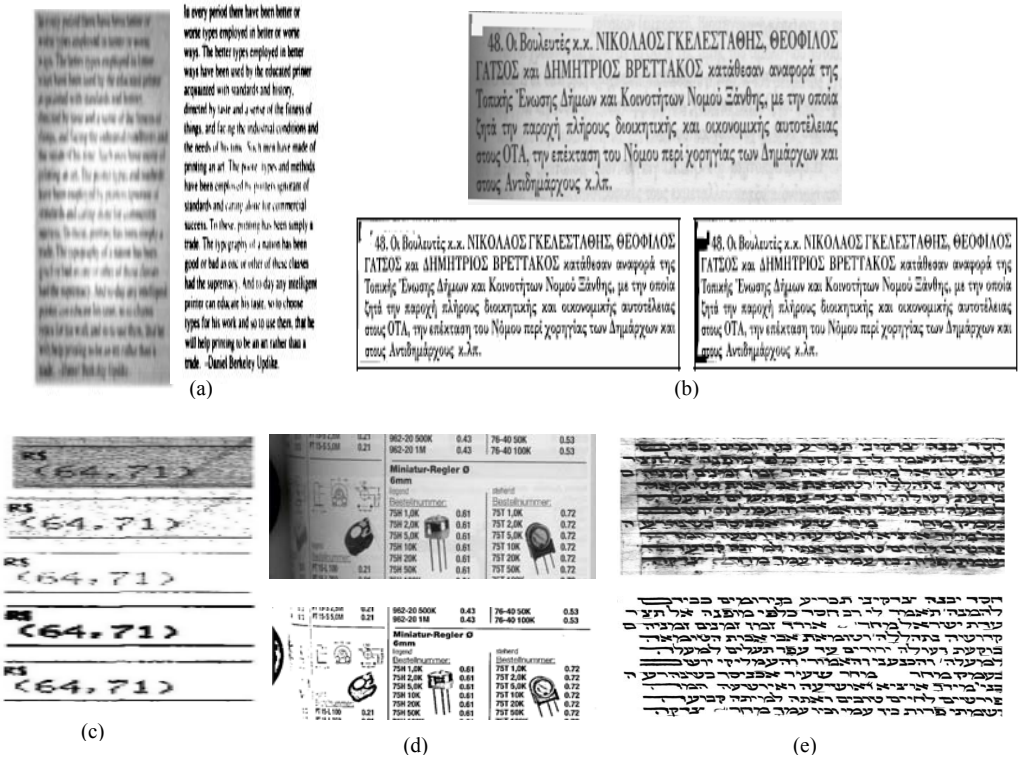


Figure 3. Examples of the Hikayat Hang Tuah manuscript and the corresponding grayscale histograms for (a) medium quality image, and (b) bad quality image



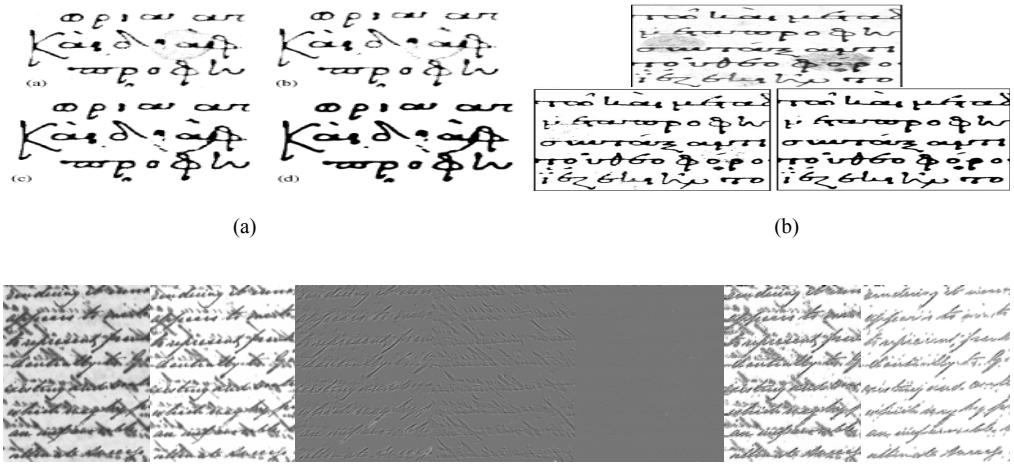
(a) (b) (c) (d) (e) (f)

Figure 4. More examples of the collection of the Hikayat Hang Tuah manuscripts



(a) (b) (c) (d) (e)

Figure 5. Examples of image results using Image Enhancement Method I (a) proposed by [3], (b) proposed by [4], (c) proposed by [7], (d) proposed by [1], and (e) proposed by [6]



(a) (b)

(c)

Figure 6. Examples of image results using Image Enhancement Method II (a) proposed by [17], (b) proposed by [11], [18], [21], and (c) proposed by [15]

(a) (b)

(c)

Figure 7. Examples of image results using Image Enhancement Method III: (a) proposed by [12], (b) proposed by [23], and (c) proposed by [16]

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