# A Unified Framework for Degraded Thai Historical Document Image Restoration

Krisda Khankasikam
Nakhon Sawan Rajabhat University, Nakhon Sawan, Thailand
Email: KrisdaK@gmail.com

***Abstract*— Binarization method is the key process to restore degraded historical document image. In this paper, the framework for degraded Thai historical document image restoration is proposed. The proposed framework consists of three stage including image filtering stage, local-based thresholding stage, and cluster analysis stage. Image filtering stage aims to eliminate some noises by using Wiener filter. Local-based thresholding stage aims to calculate the optimal threshold of a local block by using Niblack's methods. Cluster analysis stage aims to improve the quality of binary image by using Kim's method. The experiments are implemented by using Matlab and conducted on real degraded Thai historical document image dataset which is provided by Nation Library of Thailand. The experimental results are evaluated by using three widely used indices including precision, recall and f-index. The experimental results show that the proposed framework outperforms four classical binarization methods.**

***Index Terms*—binarization; binary image; document images restoration; degraded Thai historical documents**

## I. Introduction

The historical documents are valuable resources for human race history. The problem of historical document image restoration suffers from degradation condition which is the crucial task in historical document analysis and understanding. The document image binarization is an old issue but challenging problem for the document restoration and understanding. The binarization is the key process to restore degraded historical document image. Numerous binarization methods have been developed such as model-based feature [1], recursive segmentation in the PCA space [2], fuzzy classification [3-5], entropy-based binarization [6-8], noise attributes-based binarization [9], locally adaptive method [10-15], edge information [16-19], gradient information [20-22], water flow model [23-24], innovative hybrid methods [25-29], combined SVM with Otsu's method [30], combined multi-scale grid with the common binarization method [31], neural network [32], connected operator [33], dynamic windows [34], multi-scale framework [35], Markov model [36-37], etc. One of the popular binarization methods is the thresholding-based methods since the most of pixel in digital image can be segmented into two classes including text and various type of degradation of the background. Sezgin and Sankur [38] classified the thresholding-based methods into six categories including histogram shape-based method, clustering-based methods, entropy-based method, object attribute-based method, spatial binarization methods and locally adaptive methods. These methods have their own advantage and disadvantage and some methods overlap category boundaries. Based on the aforementioned methods, the locally adaptive methods have been gaining more attention. The threshold values of locally adaptive methods are spatially varied and determined based on the local property of the image. These methods have been successfully applied in many restoration of degraded document image. However, the expensive computational cost and the needs of large computational power make it infeasible in real system implementation.

Generally, the characteristic of degraded Thai historical documents is not similar to foreign historical documents. The segmentation of text from degraded background depends on the degradation condition, which is not clarified and fluctuates according to the context of document images. The degraded Thai historical document images represent a brownish background. The degradation of the background depends on the quality of paper and document age. Variations in background color usually affect the quality of the binary image. A combined framework is required to reduce the effect of the degradation condition.

The objective of this research is to illustrate that the degraded Thai historical document image restoration can be efficiently solved by using a framework that encompasses different methods within its structure. The advantage of combined method is the combined effect between its components where the strength of one method can compensate the weakness of another one. The proposed framework has the benefit of encompassing image filtering, local-based thresholding and cluster analysis method within its structure. The rest of this paper is organized as follows. In section II, the proposed framework is described, followed by a description of the experiment in Section III. Finally, the paper is concluded in the last section.

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## II. THE PROPOSED FRAMEWORK

This section presents the proposed framework for restoration of degraded Thai historical document image. The proposed framework consists of three stages including image filtering, local-based thresholding and cluster analysis method. Image filtering stage aims to eliminate some noise by using Wiener filter. Local-based thresholding stage aims to calculate the optimal threshold of a local block by using Niblack's methods. Cluster analysis stage aims to improve the quality of binary image by using Kim's method. The overview of the proposed framework is shown in Fig 1. The description of the proposed framework is fully described following.

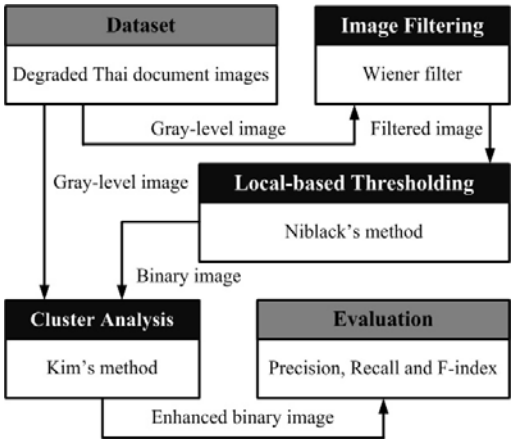


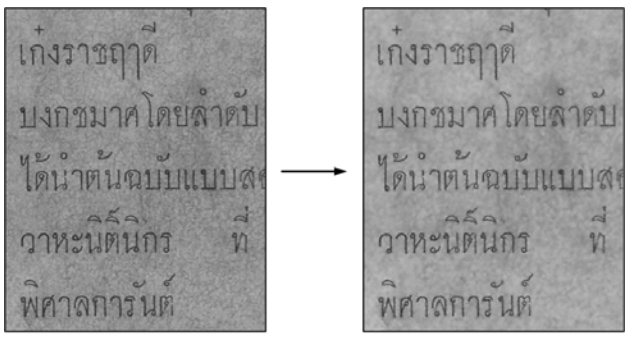

Figure 1. The proposed framework overview.

### A. Image Filtering

The Wiener filter [39] is commonly used as a practicable method in filtering theory for image restoration. The gray-level original image $I_O(x,y)$ is transformed to the filtered gray-level image $I_W(x,y)$ by using the following formula:

$$I_W(x,y) = \mu + \left(\frac{\sigma}{\sigma+\nu}\right) * (I_O(x,y) - \mu) . \quad (1)$$

Where μ is the local mean, σ is the variance of 5·5 neighborhoods around each pixel (x,y) and v is the average of all estimated variances for each pixel in the neighborhood. Fig 2 shows the result of applying a 5·5 Wiener filter to document image.



**Original image $I_O(x,y)$** **Filtered image $I_W(x,y)$**

Figure 2. Sample result of image filtering stage

### B. Local-based Thresholdingq

In this stage, Niblack's method [11] is adopted as a widely used locally adaptive thresholding in binarization task. Niblack's method calculate threshold by using the statistic property of local block including local mean and local standard deviation. The threshold T(x,y) of a pixel at (x, y) is calculated by using following formula:

$$T(x,y) = \mu(x,y) + (k * \sigma(x,y)) . \quad (2)$$

Where μ(x,y) and σ(x,y) are the average and standard deviation of gray-level values of the pixels in the block at (x, y). The size of the block must be small enough to reflect local details, but large enough to suppress noise. Fig 3 shows the result of applying a 10·10 local block to filtered image $I_W(x,y)$.

**Filtered image $I_W(x,y)$** **Binary image $I_N(x,y)$**

Figure 3. Sample result of Local-based thresholding stage

### C. Cluster Analysis Method

The existing binary image enhancement usually used the information of binary image. In this research, the cluster analysis method of Kim [40] is adopted. The Kim's method aims to improve the quality of binary image by removing ghost objects (as shown in Fig 4). It uses not only the cluster information in its binary image but also the gray-level value in its original image. As aforementioned description in introduction section, binarization methods can be considered as segmentation all the pixels in digital image into two classes. If the resulted binary image is a reliable of clustering result of its gray-level original image, most of the pixels with similar gray values may be segmented into the same cluster. If the cluster of an interested pixel is not equal to the major cluster of the similar surrounding pixel, the cluster of the interested pixel is corrected by reversing value. Fig 4 shows the result of cluster analysis method stage.

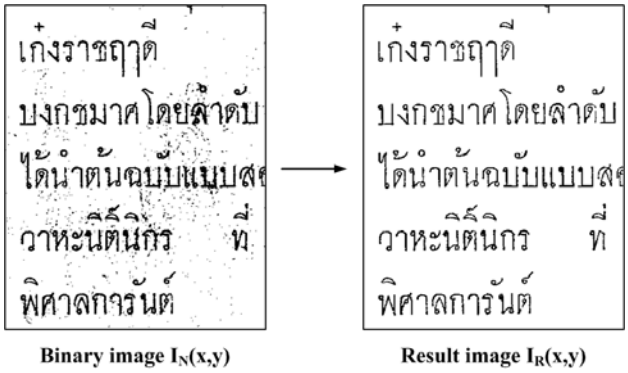



Figure 4. Sample result of cluster analysis method stage

The description of the experiment with 30 degraded Thai historical document images and results evaluation will be described in the next section.

## III. The Experiment

In this section, the degraded Thai document image dataset which is provided by Nation Library of Thailand (NLT) is prepared to the experiment. The proposed framework is evaluated by using three popular indices including precision, recall and f-index.

### A. Dataset

The typical approach for testing the binarization method is to create an ideal binary image by expert for comparing with the experimental results. Unfortunately, the Thai standard dataset for binarization method evaluation are not yet available. In order to observe the characteristic of the proposed framework, the degraded Thai document image dataset, provided by expert of NLT, is adopted. Some samples of images in dataset are shown in Fig 5.

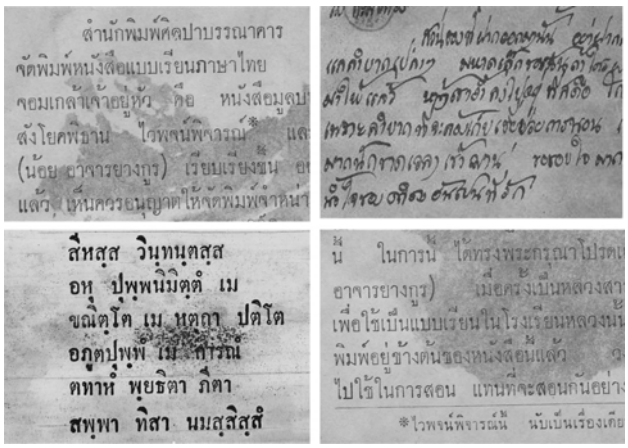


Figure 5. Samples images in dataset

### B. Evaluation

In order to calculate the value of precision, recall and f-index, the skeletonized and estimated ground truth images must be established. In this research, the skeletonized and estimated ground truth images are manually established by expert of NLT. The skeletonized ground truth refers to the binary image which character are approximately drawn a one pixel wide in the middle of the character as shown in Fig 6. The estimated ground truth refers to the actual binary image which are manually eliminated all noises and degraded factors. The examples of skeletonized and estimated ground truth are shown in Fig 6.


Figure 6. Sample skeletonized and estimated ground truth image

To evaluate the efficiency of the proposed framework, the three widely used indices for binarization method evaluation in term of precision, recall and f-index are adopted. Let $I_{SG}(x,y)$, $I_{EG}(x,y)$ and $I_R(x,y)$ are the value of binary image (0 or 1) of skeletonized ground truth image, estimated ground truth image and evaluated binary image at point (x,y), respectively.

Precision refers to the percentage of the estimated ground truth pixel which is detected in the binary image of the proposed framework. The precision index can be calculated by using the following formula:

$$precision = \frac{\sum_{x=1,y=1}^{x=width,y=height} I_{EG}(x,y)\cdot I_R(x,y)}{\sum_{x=1,y=1}^{x=width,y=height} I_R(x,y)}. \quad (3)$$

Recall refers to the percentage of the skeletonized ground truth pixel which is detected in the binary image of the proposed framework. The recall index can be calculated by using the following formula:

$$recall = \frac{\sum_{x=1,y=1}^{x=width,y=height} I_{SG}(x,y)\cdot I_R(x,y)}{\sum_{x=1,y=1}^{x=width,y=height} I_{SG}(x,y)}. \quad (4)$$

F-index refers to the compromise value of precision and recall which can be calculated by using the following formula:

$$f-index = \frac{2\cdot precision\cdot recall}{precision + recall}. \quad (5)$$

The values of these three indices vary from 0 to 100.

### C. Experimental Results

In this stage, the proposed framework results are compared with the results of four classical binarization methods including Otsu's, Kittler's, Bernsen's and Sauvola's methods. Based on visual observation, the

proposed framework outperforms four classical methods as shown in Fig 7.


Figure 7. Sample results of binarization methods

Based on numerically evaluation, the proposed framework also outperforms four classical methods in term of f-index as shown in Table I.

TABLE I.
BENCHMARK VALUES OF THE PROPOSED FRAMEWORK AND COMPARISON METHODS

| Binarization | Precision | Recall | F-Index |
|---|---|---|---|
| **Otsu's Method** | 76.65 | 93.55 | 84.26 |
| **Kittler's Method** | 78.38 | 91.45 | 84.41 |
| **Bernsen's Method** | 85.11 | 89.89 | 87.43 |
| **Sauvola's Method** | 84.54 | 92.64 | 88.40 |
| **Proposed Framework** | 88.17 | 90.37 | 89.26 |

Among these indices, precision is a measure that directly indicates binarization efficiency. However, recall and f-index do not exactly express binarization performance but they are useful for indirectly measuring the performance.

## IV. CONCLUSION

In this paper, the framework for degraded Thai historical document image restoration is proposed. The proposed framework performs the level of precision, recall and f-index at 88.17%, 90.37% and 89.26%, respectively. Furthermore, the experiments on larger number of degraded Thai document images are needed to determine the performance of the proposed framework. However, these preliminary results are very encouraging.

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**Krisda Khankasikam** was born in Thailand, on September 8, 1980. He received the Bachelor of Engineering degree in Computer Engineering from Naresuan University, Phitsanulok, Thailand, in 2002, the Master of Engineering degree in Computer Engineering from King Mongkut's University of Technology Thonburi, Bangkok, Thailand, in 2005 and the Doctor of Philosophy degree in Knowledge Management from Chiang Mai University, Chiang Mai, Thailand, in 2010.

He is an Assistance Professor in Computer Science, Department of Applied Science, Faculty of Science and Technology, Nakhon Sawan Rajabhat University, Thailand. His research interests are image processing, pattern recognition and knowledge management.

Dr. Krisda is a senior member of international association of computer science and information technology (IACSIT), Singapore, and a member of the science and engineering institute (SCIEI), China.