Using Adaptive Threshold to Enhance Scanned Images

Algorithm Engineering 2022 Project Paper

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ABSTRACT

Scanned images may have noise due to uneven or poor lighting conditions. In this paper, different image enhancing methods are compared to enhance the scanned image degradation caused by poor lighting conditions. The adaptive threshold method is found to have achieved the best result. In addition, the OpenMp is used to reduce the overall computing time.

KEYWORDS

enhance scanned image, noise reduction, adaptive mean filter, contrast enhancement, histogram equalization

1 INTRODUCTION

1.1 Background

Turn paper documents into scanned image is a fundamental process in digital transformation. There are many benefits of having a digital version of document, such as increased accessibility to people both online and offline, and increased compatibility to data analyzing programs.

Information on enhanced images is less contaminated by noise. Via scanned image enhancement, the content on the image is clearer to human eyes. It is also easier to extract information by computer.

Image enhancing techniques fall into the category of Image processing. It is a method aiming at useful information extraction. The typical workflow in an image processing system is as follows:

Acquisition → Image preprocessing → Segmentation (for example, thresholding) → Feature extraction → Classification → Assertion.

But scanned documents can often have noise. The source of the noise may be uneven or too dark light when scanning, or poor quality paper, or signal interference in the scanning process. The purpose of this paper is to find the best and fastest way to enhance the scanned images.

1.2 Related Work

One of the methods to enhance background quality of gray scale images employs thresholding and binarization techniques. [1] Thresholding techniques can be divided into two major groups. The methods in the first group apply global algorithms referencing global image features for appropriate thresholds to divide image pixels into object class or background class. The second group uses local image information to calculate thresholds, similar to the locally adaptive thresholding method that uses neighborhood features such as the mean and standard deviation of pixels.[3]

1.3 Contributions

This paper compares different methods of image enhancement and presents an executable, portable, and fast method for image enhancement.

1.4 Outline

This paper starts with introducing several image processing algorithms that can enhance contrast of scanned images and reduce noise. These methods are then experimented separately to to have their effectiveness in enhancing the scanned images evaluated. Then the most effective methods are accelerated. The purpose is to get the most effective and fastest method to enhance the scanned images.

2 THE ALGORITHM

2.1 Power-Law (Gamma) Transformations

The gamma correction algorithm improve the low contrast images. Gamma correction is, in the simplest cases, defined by the following power-law expression:

$$V_{out} = AV_{in}^{\gamma} \tag{1}$$

where the non-negative real input value V_{in} is raised to the power γ and multiplied by the constant A to get the output value V_{out}. Sometimes, a higher gamma makes the displayed image look better to viewers than the original because of an increase in contrast.[2]

2.2 Mean filter

To eliminate pixel values which are unrepresentative of their surroundings. We can use mean filter. The idea of mean filtering is to replace each pixel value in an image with the average of its neighbors, including itself. Mean filtering is usually implemented by convolutional operations. It is based around a kernel, which represents the shape and size of the neighborhood to be sampled when calculating the mean. Often a square kernel is used. In general, the arithmetic mean filters are well suited for random noise like Gaussian or uniform noise.[2]

2.3 Histogram linearisation

A significant mass of the histogram in a small interval of the range of intensity values means sub-optimal contrast. We can enhance the contrast with method of histogram equalization. This method usually increases the global contrast of images. Through this adjustment, the intensities can be better distributed on the histogram utilizing the full range of intensities evenly. This allows for areas of lower local contrast to gain a higher contrast. With histogram linearisation, the quantisation characteristic is optimally adapted to the brightness values occurring in an image, i.e. areas with rare grey values are "moved closer together" in the histogram, areas with frequent grey values are stretched.

In order to linearise the histogram of an image, first cumulative the histogram:

$$h_c(I) = \sum_{i=0}^{I} h(i). \tag{2}$$

which gives the frequency of intensities below this gray value for each gray value I . Each pixel in the image with gray value I is then assigned a new gray value $I' = h_c(I)$ scaling the values of h_c to the range of gray values.

2.4 Binary thresholds

A thresholding operation can be applied to separate objects from the background in text analysis(OCR) and medical image segmentation. Usually, the thresholding methods binarize an initial image, two segments are formed, ideally separate the background and the searched objects. The assignment to the two segments (0 and 1) is made on the basis of a comparison of the gray value g of the pixel under consideration with the previously defined threshold value t . The resulting image can thus be calculated with very little computational effort, since only one simple comparison operation needs to be performed per pixel. The corresponding calculation rule of the image T_{global} is:

$$T_{\text{global}}(g) = \begin{cases} 0 & \text{falls } g < t \\ 1 & \text{falls } g \geq t \end{cases} \tag{3}$$

In the global thresholding method, a threshold value is selected globally for the entire image. The method is the easiest to calculate, but also very susceptible to brightness changes in the image.

2.5 Adaptive mean filter

In the previous method, one global value is used as a threshold. But this might not be good in all cases, e.g. if an image has different lighting conditions in different areas. In restauration, noise removal wants to consider the local image properties to optimally reduce noise such filter are called adaptive filter. Adaptive filters change their properties depending on the local image statistics in a neighbourhood S_{xy} around the current pixel at x, y. In that case, adaptive filter can help. Here, the algorithm determines the threshold for a pixel based on a small region around it. Different thresholds is used for different regions of the same image which gives better results for images with varying illumination. Here we apply an adaptive mean C filter, the threshold value T(x,y) is a mean of the **filter mask size × filter mask size** neighborhood of (x,y) minus C, where C is a constant.

This method follows the following steps:

(1) Convert original image to grayscale,the Gray conversation RGB image is defined as follows: [4]

$$(.) = 0.2989 \times r + O.5870 \times g + 0.1140 \times b \tag{4}$$

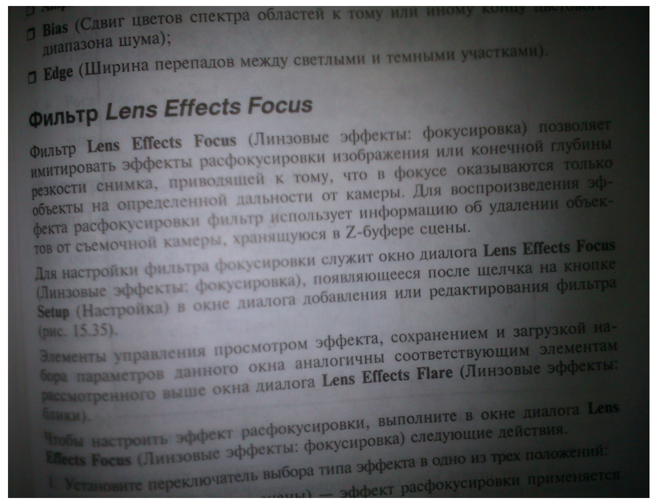
where r,g,b, are red, green and blue colors of the RGB image (.) correspondingly.

(2) Determine the parameters **filter mask size** and constant C, and **max value** in the result.
(3) Build the filter mask
(4) Zero padding the original image to ensure that the image does not get smaller after the convolution operation.
(5) Do the convolution operation with the filter mask and the image.
(6) • if : grayscale value of current pixel > T : result value in current pixel is **max value**
    • else : result value in current pixel is **0**

    where T is threshold, i.e. the result of the convolution operation minus **C**

3 EXPERIMENTS

Figure 1 is the example of original scanned image that should be enhanced.



Bias (Сдвиг цветов спектра областей к тому или иному концу цветового диапазона шума);

Edge (Ширина перепадов между светлыми и темными участками).

Фильтр *Lens Effects Focus*

Фильтр **Lens Effects Focus** (Линзовые эффекты: фокусировка) позволяет имитировать эффекты расфокусировки изображения или конечной глубины резкости снимка, приводящей к тому, что в фокусе оказываются только объекты на определенной дальности от камеры. Для воспроизведения эффекта расфокусировки фильтр использует информацию об удалении объектов от съемочной камеры, хранящуюся в Z-буфере сцены.

Для настройки фильтра фокусировки служит окно диалога **Lens Effects Focus** (Линзовые эффекты: фокусировка), появляющееся после щелчка на кнопке **Setup** (Настройка) в окне диалога добавления или редактирования фильтра (рис. 15.35).

Элементы управления просмотром эффекта, сохранением и загрузкой набора параметров данного окна аналогичны соответствующим элементам рассмотренного выше окна диалога **Lens Effects Flare** (Линзовые эффекты: блики).

Чтобы настроить эффект расфокусировки, выполните в окне диалога **Lens Effects Focus** (Линзовые эффекты: фокусировка) следующие действия.

1. Установите переключатель выбора типа эффекта в одно из трех положений:

— эффект расфокусировки применяется

Figure 1: original scanned image

3.1 Power-Law (Gamma) Transformations

In Figure 2 gamma correction is applied with different value of γ on the scanned image.

This method brightens or darkens all pixel points at the same time, it does not effectively enhance the scanned image.

3.2 Mean filter

Figure 3 shows the effect of a mean filter. After convolving the image with a mean filter the image does not change a lot, this method is not applicable for our case.

3.3 Histogram linearisation

Figure 4 shows the cumulative histogram before and after histogram linearisation.

After histogram linearisation, the image (Figure 5 right) seems brighter. The disadvantage is that the text in the center is not visible due to overexposure and the edges of the picture are even darker.

3.4 Binary thresholds

In the processed image from previous methods, the text is blended into the background. Blurred boundry between the text and the

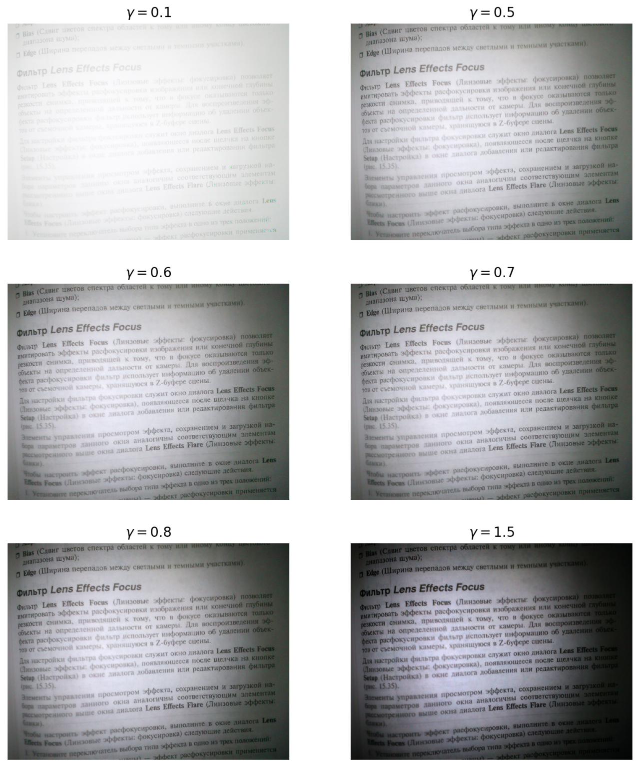


Figure 2: gamma correction on the scanned image with different γ. We can see when $\gamma = 0.1$ the shadows around the edges almost disappear, but the whole image looks brighter too, the text is not clear. When a larger gamma is selected, the text looks clearer, but the shadows around the edges are getting darker.

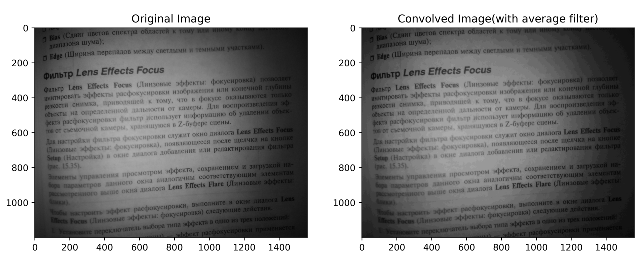


Figure 3: original scanned image compared with mean filter processed image

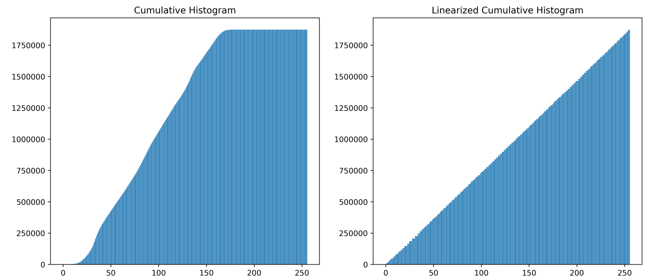


Figure 4: the cumulative histogram before and after histogram linearisation. We can notice that before histogram linearisation(left), the grayscale distribution of the images is not uniform. The overall picture looks greyish.

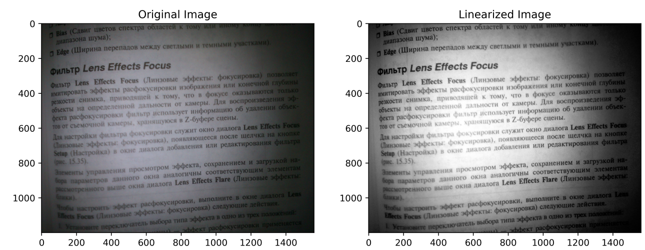


Figure 5: original scanned image compared with histogram linearisation processed image

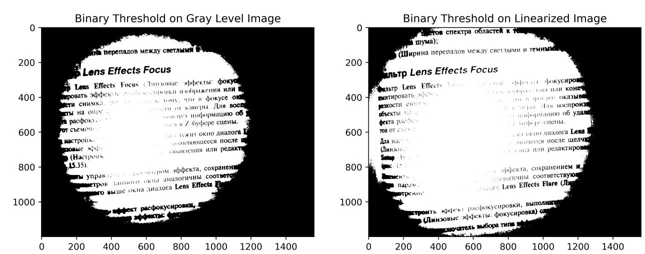


Figure 6: Binary thresholds method applied on original image and linearized image. Although we have partial information loss in the brightest region in the center and darkest regions around the text, there is a larger range of visible text after histogram equalization(right).

noise is often observed. Therefore the Binary thresholds method is examined.

Figure 6 shows the effect of binary thresholds applied on the original image and on the linearized image.

Due to the stronger lighting in the center and inadequate linghing in the preiphery. So the text color in the center may same as the background color at the edges. That caused the text in center is not visible but a rounded black shadow is founded at the edges.

Therefore we should split the image into smaller blocks and use a binary threshold segmentation in each block so that the different lighting at the edges and the center can be considered separately.

3.5 Adaptive mean filter

The threshold method is used with a neighborhood size of 11 and constant C of 2. From Figure 7, we can notice a significant improvement in this method compared to the previous algorithms. Because in this algorithm the intensity is maximum greyscale when the current pixel value is greater than the neighborhood pixel intensity average minus C, and zero in all other cases. So there is no intermediate gray scale. The text and background are nicely separated. Only the background has notable noise.

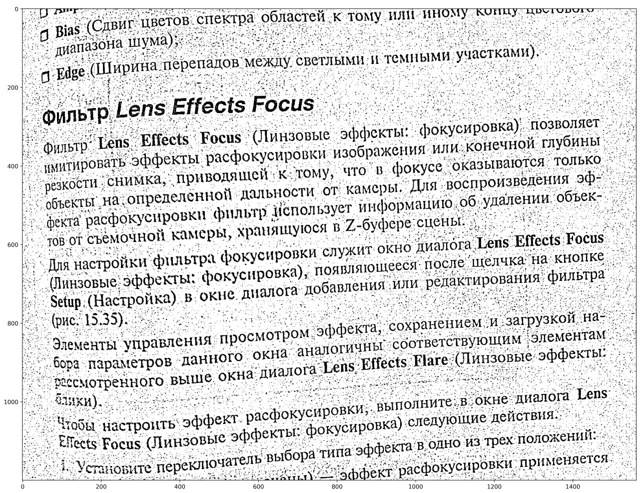


Figure 7: adaptive mean C filter (filter mask size = 11, C = 2)

By adjusting the parameters, we found that this approach can emphasize the scanned images very successfully. Figure 8 shows the effect of adaptive mean C method with **filter mask size** = 55, constant C = 8.

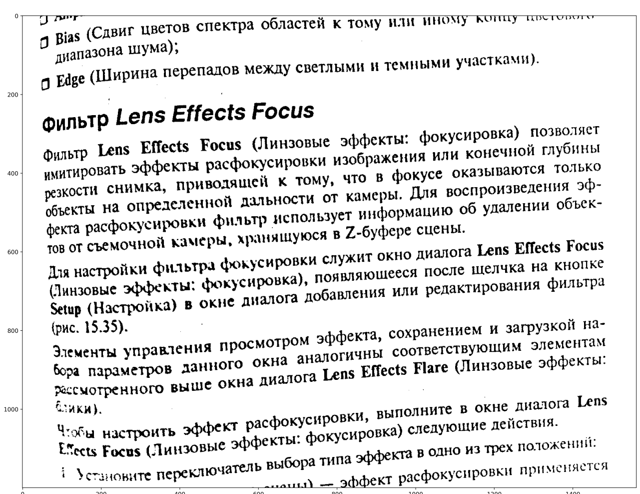


Figure 8: adaptive mean C filter (filter mask size = 55, C = 8)

Figure 9 shows the test of this method on other scanned images. It can be seen that this method can enhance the scanned images with uneven illumination very well.

Next step, OpenMP is applied when generate the zero padding images, and then convolutional calculations to speedup the adaptive mean C function.

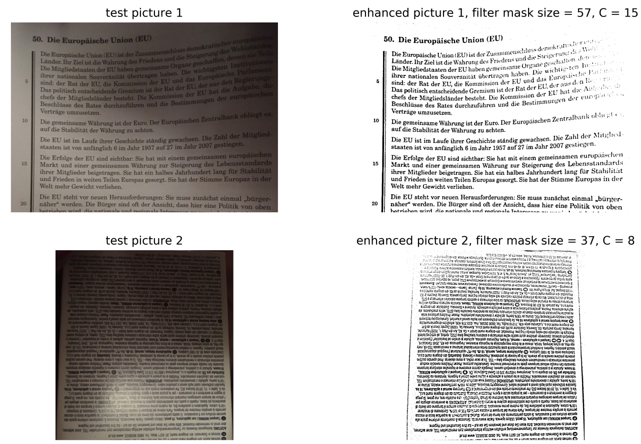


Figure 9: test adaptive mean C filter with more scanned images

4 CONCLUSIONS

4.1 Best solution

From the analysis and the experiments, **adaptive mean filter** has the best enhancement effect. The binary threshold can also enhance the image, but it is not effective for images under the uneven lighting condition.

4.2 About speed up

Table 1 shows the comparison of the running time of different method.

Table 1: Comparison of the running time of different method. As can be seen the normal Python function is over 60 times slower than the normal (unaccelerated) C++ function. The OpenMP accelerated C++ function is 9 times faster than the unaccelerated one. But the OpenMP accelerated C++ function is still slower than the OpenCV function in Python.

Language	Method	Running time (s)
C++	OpenMP	**0.053**
C++	–	0.783
Python	OpenCV	0.036
Python	–	52.7

REFERENCES

[1] Atena Farahmand, Abdolhossein Sarrafzadeh, and Jamshid Shanbezadeh. 2013. Noise Removal and Binarization of Scanned Document Images. https://www.researchgate.net/publication/290530622_Document_Image_Noises_and_Removal_Methods

[2] Richard E. Woods Rafael C. Gonzalez. 2009. *Digital Image Processing.* Pearson Education.

[3] J. Sauvola and M. Pietikainen. 2000. *Adaptive document image binarization," Pattern Recognition.* Vol. 33 Issue 2, pp. 225-236.

[4] J. R. Mohanty Suresh Chandra Satapathy, Vikrant Bhateja and Siba K. Udgata. 2019. *Smart Intelligent Computing and Applications: Proceedings of the Third.* Springer.