

Adaptive Dynamic Range Improvement Method for Personal Printer Device

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Abstract

In recent years, we have seen remarkable progress in the production technology of inexpensive printers for personal use. Using such printers, it is now possible for us to print very high quality images. However, it is very difficult to output as printed images all of the objects or information contained in a scene that actually is sensed with the human eye. It is even possible for the human eye to sense details in an object or scene that are very bright and dark in the vision field. This is considered to be related to the fact that, in the human eye, the range on which the eye focuses fits well in a field of vision. That is, if we pay attention to a darker section, the pupil adjusts to that section, and other portions are blurred so to speak. Conversely, if we pay attention to a brighter section, the pupil adjusts to that section. With such an adjustment mechanism, we can sense details to a certain extent even when the differences in brightness of an object or scene are large. However, it is difficult to express the information about such subjects or scenery in an image when only a constant exposure can be established. In this regard, a method is proposed in which we don't lose the information sensed with the eyes when producing an output of an image. This is a method for expressing more information in an image by collapsing the balance of brightness intentionally and expanding local dynamic ranges. We have named the method the Adaptive Dynamic Range Improvement Algorithm (ADRIA).

ADRIA is an automatic image-processing algorithm that minimizes loss of information and sense of incongruity by collapsing the brightness balance in a printed image as a whole on a minimum level.

1. Introduction

In recent years, we have seen remarkable progress in the production technology for inexpensive printers for personal use. Using such printers, it is now possible for us to print very high quality images. But unlike the human eye, unique value for exposing condition is given in printed images.

As a result, there are cases that the information sensed with the human eye is lost because of insufficiency of dynamic range. Therefore, we propose a method that applies AHE (Adaptive Histogram Equalization), that is one of the algorithms for enhancing local contrast, to improve the local dynamic range. It is named Adaptive Dynamic Range Improvement Algorithm (ADRIA). In this paper, a description of the proposed method is given, and application results of the method are showcased for images taken with a digital camera that span a wide dynamic range.

2. Flow Chart of Proposed Method

Figure 1 shows the follow chart of proposed method.

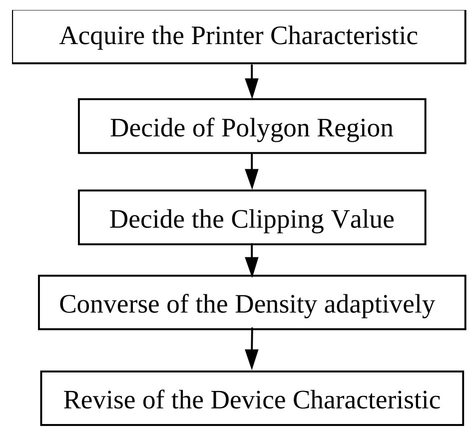
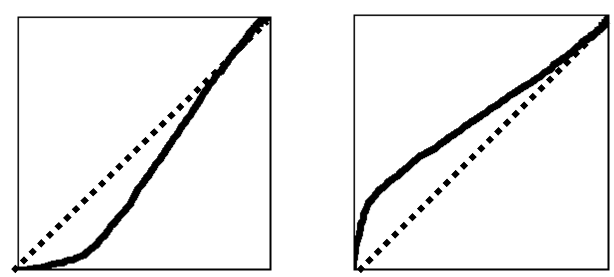


Figure 1. Flow chart of proposed method



(2a) Printer Characteristic *(2b) Inverse Conversion Curve*

Figure 2.

3. Measurement on the Printer Characteristic

In this method, the quantitative printer characteristics are measured first. We can measure the input-output characteristic of the printer by comparing the computer-produced input test pattern made and by scanning the printed output. (Figure 2).

4. Dynamic Range Improvement

In the case where the dynamic range of the original image is wide, the information of the original image is lost in the output image because it is impossible to print all of the information given the dynamic range of the printer. To avoid such a phenomenon, we can preserve precedently the necessary information by improving the dynamic range adaptively. We improved upon the Adaptive Histogram Equalization (AHE), which is one of contrast enhancement algorithms, and applied it to local dynamic range improvement.

4.1 Adaptive Histogram Equalization

The Adaptive Histogram Equalization (AHE) is a contrast enhancement algorithm. It is the algorithm to which HE (Histogram Equalization) as a general contrast enhancement algorithm is applied. We set the reference region to a suitable size around the attention pixel and make a density histogram from it. Then, we make an accumulation histogram from the density histogram. By using the density conversion curve, it is possible to enhance image contrast. In order to suppress excessive enhancement, we set up a threshold or clipping value and clipping off pixel values exceeding the value, which are distributed equally to every density. Last, an accumulation histogram is produced, which is used as the input-output curve for converting the density (Figure 3).

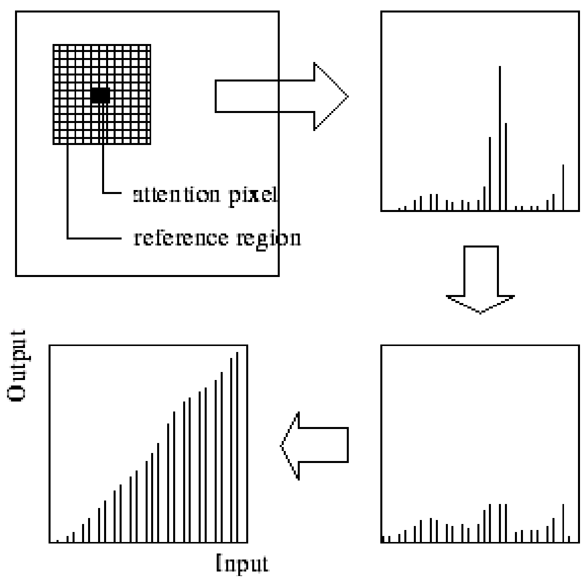


Figure 3. Adaptive Histogram Equalization

4.2 Proportional Distribution

In the above method, however, enormous processing time is needed because we need to generate a density histogram for all pixels in the image. As a result, we generally divide the image into square regions, and we use the same histogram in the same region. As a result, the processing time is shorter. Occasionally, however, the density at the boundary between regions is broken up, and block-noise occurs. In order to prevent block noise, a proportional distribution of the four blocks around the attention pixel is used (Figure 4). The output value using the proportional distribution explains the next equation.

$$g(x, y) = \{(J - j) / J\}\{(I - i)/I * g1 + I / I * g2\} + (j / J)\{(I - i) / I * g3 + I / I * g4\} \quad (1)$$

Where g1, g2, g3 and g4 are the converted values using the density conversion curve made from circumference 4 blocks.

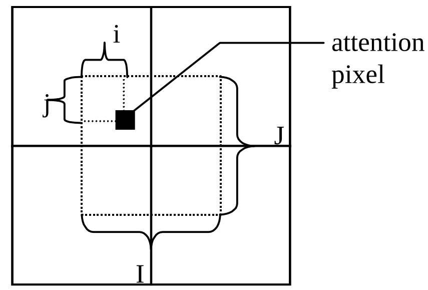


Figure 4. Proportional Distribution

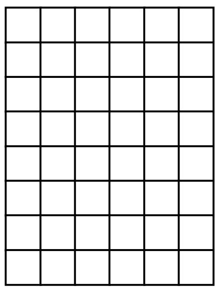
4.3 Automatic Decide of Polygon Region

In the method we propose to improve the local dynamic range by dividing the whole image into some regions, and adopting the most suitable parameter in each region.

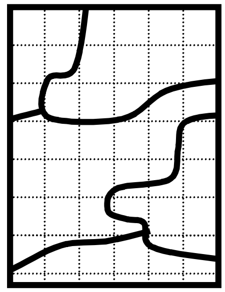
First, we divide the whole image into a small square block and integrate a block of the same region by using the LOG filter. And we make histograms in each region, and improve the local dynamic range by using them. In this instance, we use proportional distribution to prevent the density value from being non-continued at the boundaries of regions.

4.4 Automatic Decide the Clipping Value

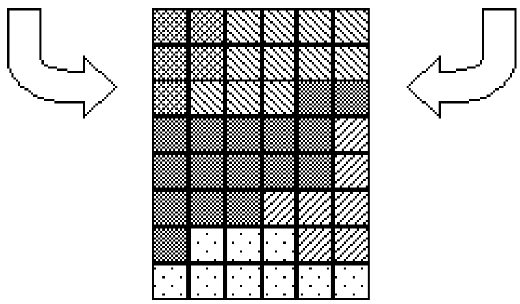
For each block, we use the same clipping value in the same region. The clipping value is the parameter that determines the degree of dynamic range improvement, and if it is larger, then the degree of the expanding dynamic range becomes larger. Conversely, if it is zero, the dynamic range doesn't change. Following this, the density average and dispersion of all pixels in a region are obtained, and the final clipping value is determined by comparing it with the printer characteristic shown in Figure 6. It can be considered that the incline of the line to tie up the two points shown in Figure 6 represents the width of the dynamic range in the region as based on the assumption that the density values in a region exist between ($m-\sigma$) and ($m+\sigma$). In other words, if the inclination of the line is large, the dynamic range is wide, and we can get more density steps for output than input. Due to this, it can be considered that the dynamic range in the region is wide. When the disappearance of information is less, a small clipping value is established. Conversely, we set clipping values to be large in cases where the inclination of the line is large.



(5a) Square Block

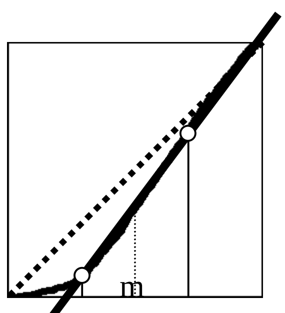


(5b) Log Filter



(5c) Polygon Regions

Figure 5. Division into Polygon Regions



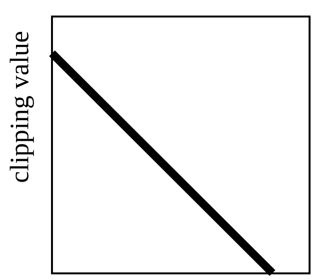


Figure 6. Decision the Clipping Value

5. Revision of the Density

Because the density is translated by the printer characteristic as shown in the printed image (Figure (2a)), there are density differences between the input image and the output image. Therefore, the density is adjusted by an inverse conversion as shown in Figure (2b) in order to reduce the differences.

6. Result

The following are processed images.

Figure 7 is the original image. Figure 8 is a printed image with no processing, and Figure 9 is an output image after processing using ADRIA.

Figure 10 is an image representing the regions, and Figure 11 is an image representing determined clipping values. In Figure 10, the boundaries of the regions are represented as a white line.

Figure 11 shows clipping values of each region, represented as density values. In a region where the density value is large (white), the clipping value is large. In a region where the density value is small (black), the clipping value is small.

The size of the original image was 480 x 640 pixels, and the time needed for processing was about 1.5 seconds (using a Pentium III running at 550 MHz).

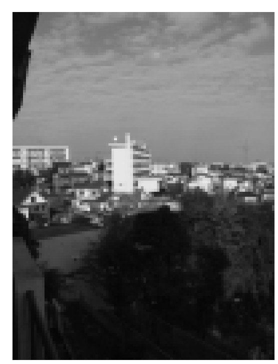


Figure 7. Original Image

Figure 8. Output Image without processing

Figure 9. Output Image with processing

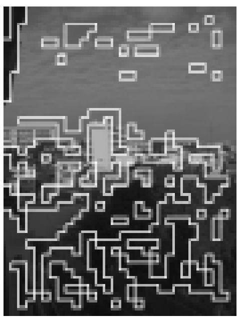


Figure 10. Image of regions

Figure 11. Image of clipping value

7. Conclusion

A method that doesn't lose information when printing images was proposed, even when the original image covers a wide dynamic range. We applied AHE, one of the algorithms for emphasizing local contrast, to improvement local dynamic range. In this instance, we divide the image into several polygon regions on the basis of information provided by the LOG filter and used proportional distribution in order to shorten processing time. The results are devoid of block-noise at the boundaries of regions. It was possible to obtain output images while considering the printer's characteristic by measuring the characteristic quantitatively and reflecting it into the determination of the clipping value.

It was possible to improve the dynamic range in each region by the proposed method. At the same time, it was possible to discern detailed information in the original image and preserve it as compared to an image produced without processing.

Reference

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Biography

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Born in 1975. Graduated from Factory of Science and Technology, Keio University in 1998. Now a graduate student and major in Imaging and Image Processing

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Born in 1943. Graduated from Postgraduate school of Keio University, Dept. of Electrical Engineering and received Degree of Doctor of engineering in 1973. Now, Professor and Vice-dean of the Factory of science and Technology, Keio University and President of Riso Laboratory Inc. Field of Specialization are Information Theory, Imaging Science and Technology, Optical Data Processing.