Backlight Image Enhancement Technique based on Multi-range Stretching in Color Histograms

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Abstract—This paper proposes a novel contrast enhancement method which determines the stretching ranges based on the distribution densities of segmented sub-histogram of a backlight image. In order to enhance the contrast of image effectively, the histogram is segmented into sub-histograms based on the density in each brightness region. Then the stretching range of each sub-histogram is determined by analyzing its distribution density. The higher density region is extended wider than the lower density region in the histogram of RGB colors. This method solves the over stretching problem, by stretching based on density rate of each area in the three RGB-histograms. Consequently, the object appeared dark due to backlight is now seen clearer and more visually natural image is extracted. To evaluate the performance of the proposed algorithm, the experiments have been carried out on complex contrast images and its work has been confirmed by comparing with the conventional methods.

Keywords-divide; histogram; stretching algorithm; improvement of contrast

I. INTRODUCTION

Contrast is defined as the distribution of brightness of pixels in an image. So dark image and bright image have the histograms where the pixels are concentrated in specific ranges of brightness. In such images, it is very difficult to see the details in the image since most pixels are similarly bright or dark. Backlight image is a good example. It can be divided by two areas: one is too bright and the other one is too dark so the objects in the image cannot be segmented clearly. We say that these images have low contrast.

To find the details of the objects located in such low contrast area, many contrast enhancement algorithms have been introduced. Contrast enhancement can be achieved by stretching the ranges where the pixels are concentrated to redistribute the intensity values. The typical techniques of contrast enhancement are histogram equalization and specification. Histogram equalization and specification redistribute the contrast distribution to averagely improve the brightness of an input image. Histogram specification inverse-equalizes the histogram and makes an image lighter or darker during this process. The ultimate purpose of histogram equalization is the production of histogram with average distribution in all ranges. Existing stretching algorithms can improve the images with low contrast, since they extend histogram to maximize image's contrast distribution.[1][2] However, if the image's brightness is evenly spread throughout histogram, the outcome can be disappointing since some part where the image quality was good enough can become less clear than the original one. In general, such disadvantage appears in the global contrast enhancement methods. In order to improve these faults, the local contrast enhancement has been proposed. However, because a local contrast enhancement algorithm processes each block individually, blocking effect is observed.[3] For solving such problem, several techniques have been proposed. Firstly, BBHE (Brightness preserving Bi-Histogram Equalization) proposed by Kim[4] separates the input histogram into two parts based on its mean brightness. RSIHE (Recursive Sub-Image Histogram Equalization), proposed by Sim[5] separates the input histogram into several parts based on accumulate of histogram's brightness. These methods are not much effective in preventing over-equalization. It is due to the low flexibility in deciding the number of regions to separate. LRS (Local Region Stretching), proposed by Srinivasan[6], is based on local contrast enhancement using stretching algorithm that separates the input image and then stretches and merges in one area to another. LRS has some disadvantages in that the boundary lines are included and contrast enhancement of a certain part is declined.

In this paper, a new local contrast enhancement based on stretching algorithm is proposed. Each area of high density in the RGB histograms is segmented and then the distribution of each area is analyzed and compared with others. Based on this analysis, how much to stretch the individual ranges is determined. Finally, each region is stretched with the calculated stretching range. The stretching range of high density area is wide. Likely, the stretching range of low density area is narrow. So the high contrast area is more contrast effective than the low contrast area. Since three histograms of RGB color components have been used to determine the stretching factors, the resulting image looks more natural than those of other methods.

The rest of this paper is consisted as follows: In section II, the conventional contrast enhancement approaches and their problems are discussed. In section III, the proposed algorithm is introduced. In section IV, the outstanding performance of the proposed algorithm is proved by the experiments and compared with the conventional algorithms. Section V presents the conclusion.

II. Conventional Approaches

For contrast enhancement, the conventional global stretching methods stretch wider the brightness range in which the distribution is concentrated in the histogram, using Eq. (1).

$$DN_{st} = \frac{DN - DN_{\min}}{DN_{\max} - DN_{\min}} \times Cr \tag{1}$$

They expect to obtain a clearer image than the original one by evenly distributing the pixels over full brightness ranges. But because they make use of the histogram as a whole, this approach may not obtain the expected result in all cases. A solution to this problem is End-In Search stretching. It uses two of thresholds as weight of light and dark area and stretch specific parts on histogram as Eq(2).

$$output = \begin{cases} 0 & x \le low \\ 255 \times \dfrac{x - low}{high - low} & low \le x \le high \\ 255 & high \le x \end{cases} \tag{2}$$

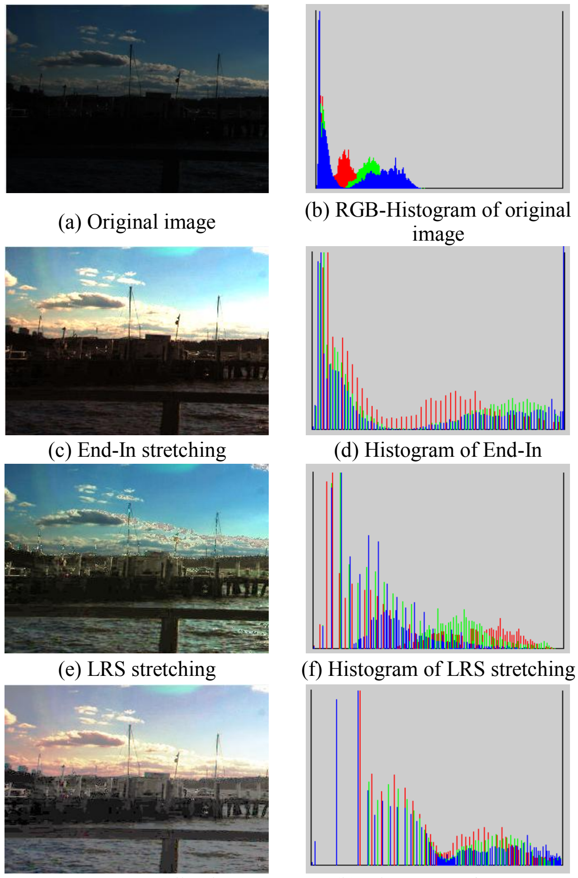
End-In Search stretching best applies to the case where histogram of brightness is concentrated on a certain area. But this method has defect. The algorithm shows good results in the bright and dark area but not in-between area. Fig. 1(c) is an example of End-In stretching. The histogram is consisted of three histograms of individual RGB colors. The result image in Fig. 1(c) shows a clearer image than the original one. But End-In stretching's threshold is a random value so it may not be appropriate for other images. In other words, since End-In stretching method decides the threshold with concerning only the darkest and the brightest areas and ignoring center area on histogram, it cannot generate the same performance for other cases.

Another solution, LRS, is a sub-area stretching method that partially extends certain area on image as shown in Fig. 1(e). Since it considers local areas separately, it is called a block stretching method. As a result, the output image contains boundary lines around the blocks. RSIHE, the other contrast enhancement method, repeatedly applying BBHE (Brightness preserving Bi-Histogram Equalization) method that divides two areas based on the mean brightness of input image using Eq. (3) ~ Eq. (5). [7][8]

$$x_B = \int_0^1 r P_r(r) d_r \tag{3}$$

$$\int_0^{x_D} P_r(r) dr = 0.5 \tag{4}$$

$$P_z(Z) = \begin{cases} \dfrac{1}{xB} \displaystyle\int_0^{xB} P_r(r) dr, & 0 \le Z < xB \\ \dfrac{1}{1 - xB} \displaystyle\int_{xB}^{1} P_r(r) dr, & xB \le Z < 1 \end{cases} \tag{5}$$



(a) Original image (b) RGB-Histogram of original image
(c) End-In stretching (d) Histogram of End-In
(e) LRS stretching (f) Histogram of LRS stretching
(g) RSIHE equalization (h) Histogram of RSIHE

Fig. 1 Original fog image and resulting images obtained by using the conventional stretching algorithms.

The histogram of the result image shows a more equalized distribution in terms of number of pixels but a less equalized distribution in terms of brightness, as shown in Fig. 1(h). As the result, the resulting image given in Fig. 1(g) shows a clearer image where all objects are shown clearly but it does not show the natural colors included in the original image. RSIHE still has the problems of how to determine the best repeat count and of image distortion due to over-equalization.

III. Stretching Algorithm Based on Distribution Densities of Histograms

The proposed stretching algorithm has the flow chart given in Fig. (2). At first, the three RGB histograms are obtained from the original image. The mean value of each histogram is calculated, and then smooth histogram is created by using density function of neighboring pixels. And next accumulation graph is created. With the accumulation graph, weigh its value to find a peak and valley point then divide the area using them. After each area's density is analyzed, the distribution-rate of

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each area is calculated with the used of divided areas. The proposed stretching method uses the calculated distribution-rate for decision length of stretching area. At last, it stretches within calculated ranges of RGB histograms. The stretched areas are merged in restoration process for contrast enhancement.

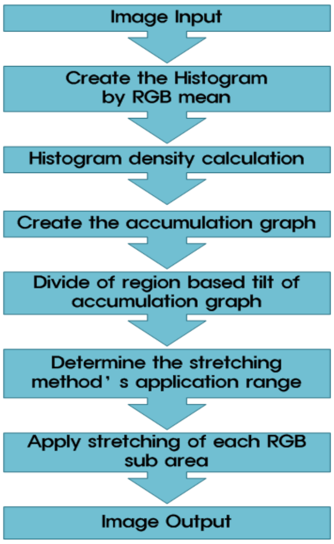


Fig. 2. Block diagram of the proposed algorithm

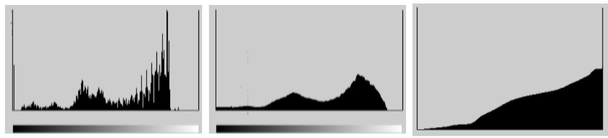
A. *Creation and division of the Histogram*

Because it processes RGB images, consider how the histogram is created. Therefore the average histogram has to be produce by using RGB color information. The average histogram is determined by each of RGB-distribution's mean value on the histogram. This paper proposes the partition technique. Before stretching process, it searches peak and valley point then divide area as a means of division area. In order to divide the histogram, an arithmetical calculation uses the brightness density. If histogram's distribution is generally smooth, searching of peak and valley point is easy. When smooth, the accumulation graph's angle is gradually increasing then decreasing. These changes of angle help to find the peak and valley point. But generally, histograms represent drastic change on histogram as Fig. 3(a).

$$D_n = \sum_{i=n-\frac{w}{2}}^{n+\frac{w}{2}} f(x_i) \qquad (6)$$

Eq (6) can divide into low and high distribution areas by using information of neighboring brightness values as neighborhood window size on rapidly changing whole histogram. D_n is the mean density function obtained by referring to the surrounding density. w is the window size and n is the normalized intensity. Therefore, the image's brightness is normalized, of which presents the value of $\frac{w}{2\times255}$~1-$\frac{w}{2\times255}$. $f(x_i)$ is the function that shows the i th brightness frequency. At this point, w allows the maximum value so that the histogram can have a smooth curve. The rapidly changing histogram becomes stable by neighboring brightness as Fig. 3(a) and (b). It will have more than one peak and valley point. In other hand, this has several Gaussian shapes. And then cumulative graph is created by this smoothed histogram. If $f(n)$ is considered as density function that includes n th brightness, the accumulation value can be calculated with each brightness as Eq (7).

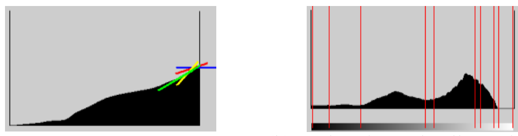
$$f(n) = \sum_{i=0}^{n} F(i) \qquad (7)$$



(a) histogram of original image (b) mean histogram (c) accumulation graph of Histogram

Fig. 3. Use the neighboring brightness density function to create accumulation graph

Fig. 4(c) shows the accumulation graph that uses the image's mean-histogram with neighboring brightness as Fig. 4(b). The peak point is found by tilt of accumulation graph. At first, the mean-brightness rate is determined whether the image is light or not. If the image is light, the accumulation graph's angle is created from the start point of 255. When making an angle, an increasing then some point that begins to dwindle can be found. This site reaches peak-point and back down to valley-point. Also find the candidate point for the best peak and valley point. Candidate points are shown with two red lines on the right side of histogram as Fig. (4).



(a) Angle of accumulation graph (b) Peak Point and valley point on mean histogram

Fig. 4. Search a peak point with accumulation graph.

The peak points of high distribution are eliminated to divide areas of histogram. The valley points are recalled based on candidate points as calculated above. The candidate areas of valley points are final points, of which are determined by comparing the distribution rate and length from each point. Fig. (5) is the outcome obtained by divided histogram with eliminated points that are considered unnecessary. At last, perform sub-stretching method with divided histogram region.

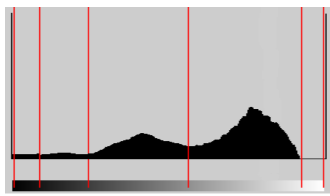


Fig. 5. Divided of Histogram

B. *Calculation of range and application of stretching*

When the histogram is divided as stated above, stretching region can be calculated for stretching operation. Divided areas of histogram have to be calculated with different rate because sub-area of histogram vary according to each images.

$$S_i = \sum_{n}^{n+1} P_n , \quad n = 0 \sim 255 \tag{8}$$

$$P(i) = \frac{S_i}{PT} (i = 1 \sim n) \tag{9}$$

S_i is the number of pixels that have brightness in specified area. And it includes bright area from n th boundary to n+1 th boundary. $P(i)$ is the rate that divides i th area on the histogram and TP is the image's total pixels as Eq (9). As a result, $P(i)$ simplifies the calculation of the stretching range. r_i is the interval for how much to stretched. H_r is the global histogram range(0~255). Also n is the total number area divided in the histogram.

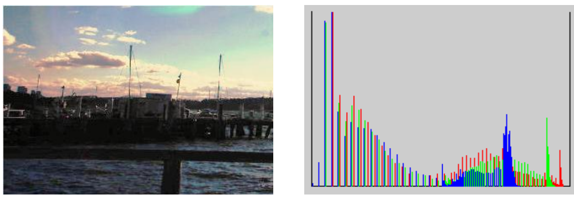
$$r_i = \frac{P(i)}{H_r} (i = 0 \sim n) \tag{10}$$

$$\sum_{i=0}^{n} r_i = H_r \tag{11}$$

At last, when stretching interval is calculated about each area, each area is stretched by calculated interval as Eq(12). St_i is the i th stretching area and $R_{(i)}$, $R_{(i+1)}$ are the i th and i +1 point lint. And D_k is brightness distribution. St_i uses the distance between $R_{(i)}$ and $R_{(i+1)}$ and calculates to extend the brightness distribution distance.

$$St_i = r_i \times \frac{D_k}{R_{(i+1)} - R_{(i)}} (i = 0 \sim n) \tag{12}$$

Fig. 6(a) is the outcome of the image achieved with the proposed method. The original image is Fig. 1(a). After analysis of Fig. 6(b), each area is stretched with one another in terms of its density. Because of the dense distribution in the left area of histogram, Fig. 1(a) is the original dark image. Therefore, because left area of histogram has the high density, this area is stretched more widely than other areas. Consequently, the dark image becomes brighter and enhanced.



(a) Proposed method (b) Histogram of result image

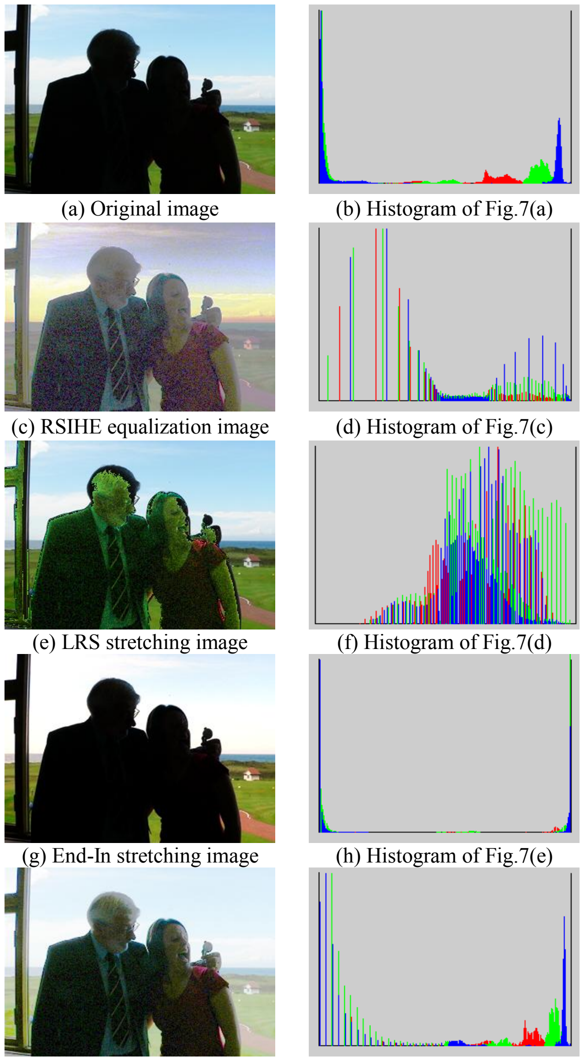
Fig. 6. resulting image using proposed method and related histogram

IV. Using the Template

Studied as above, the proposed method has been tested and analyzed with 300 images. The different methods are studied in comparison to others. Fig. 7, Fig.8, and Fig. 9 are the result images that are compared with the proposed method and previous methods. Due to the brightness of the background, the dark and light are have high distributions; the object in Fig. 7(a) is dark. RSIHE equalization is applied in Fig. 7(c). Although contrast seems to be enhanced, the quality of the image is visually low because of over-equalization. Having such results it says, RSIHE is not effective for the image that shows the stark difference of contrast of object and back ground.

However, because LRS is applied to the person area as main area and background as remainder area of image, the problem of boundary lines is appeared. Therefore LRS algorithm isn't absolutely effect as shown in Fig. 7(e).

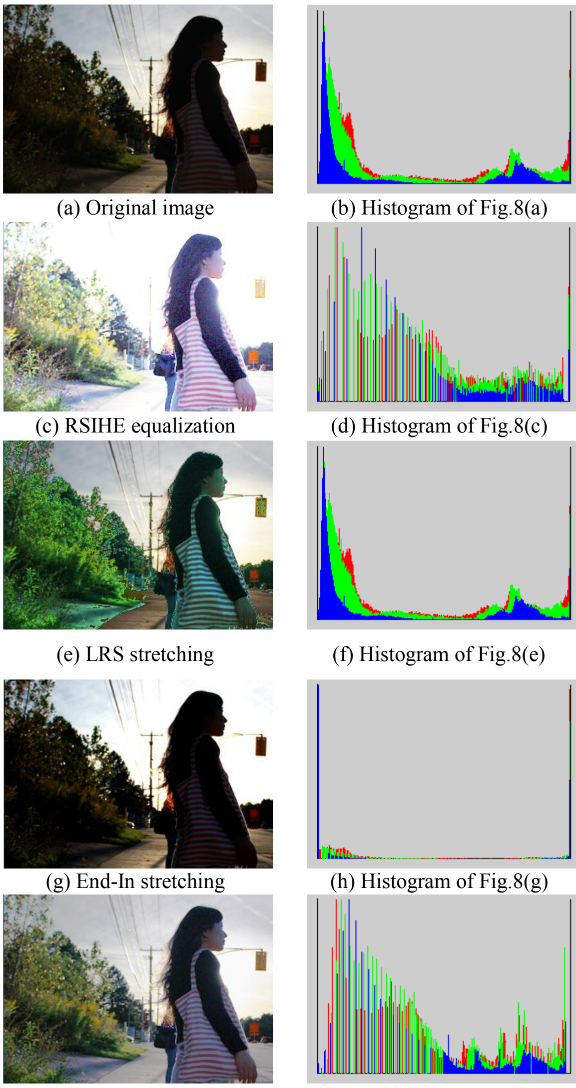
Additionally, result of End-In stretching algorithm gives dark region on the image(person area) still shown as Fig. 7(g). As a result, previous methods are excessive applied on the backlight image, which is background area is brighter than main object of whole image by bright lights as Fig. 7(a). The study proves that the proposed method prevents over-stretching, because applied stretching range is decided by density of histogram as Fig. 7(i). Also in visually, the result image is natural and clear as Fig. 7(c) but it is less noise as Fig. 7(i).



(a) Original image (b) Histogram of Fig.7(a)
(c) RSIHE equalization image (d) Histogram of Fig.7(c)
(e) LRS stretching image (f) Histogram of Fig.7(d)
(g) End-In stretching image (h) Histogram of Fig.7(e)
(i) Proposed stretching method image (j) Histogram of Fig.7(f)

Fig. 7. Result images and each histograms used exist method and Sub-stretching method

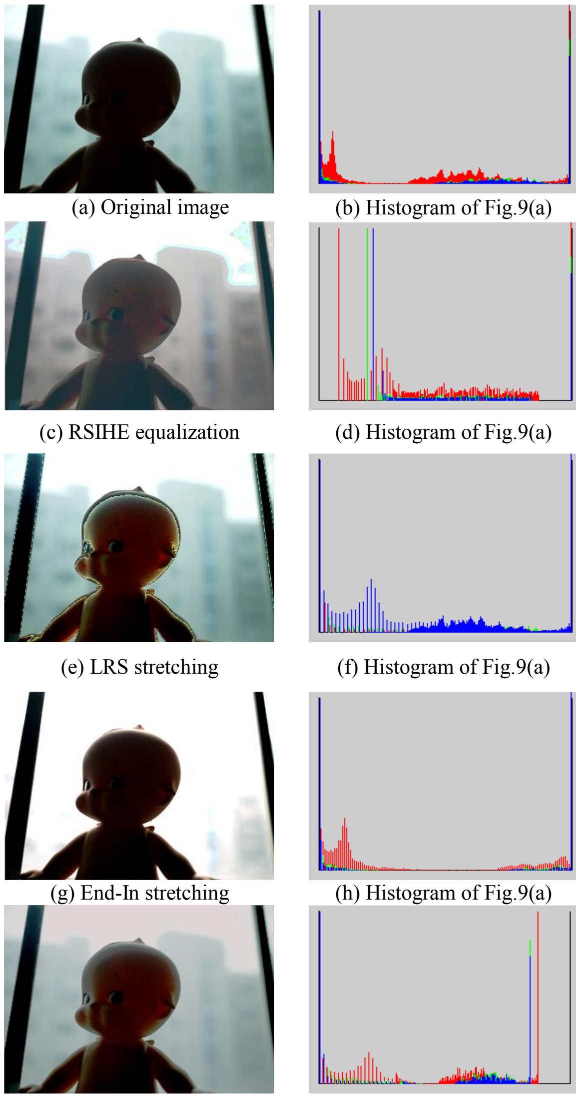
Woman is of Fig. 8(a) is generally dark due to backlight. Fig. 8(c) is obtained after applying RSIHE. The region of the object is now contrast-enhanced. But the head region reveals some noises because the sky area is over-equalized. The image by LRS shows boundary noise because it utilizes stretching of sub-area on image as Fig. 8(e). The End-In stretching method uses the weight but it is a global-stretching and it is hard the decision of weight's amount. Also End-In stretching method is maladjusted to center area of histogram. So that it cannot enhance contrast as Fig. 8(g). At last, the proposed method has contrast enhancement with only few noises with the help of the adaptive decision for stretching range as Fig. 8(i). It may be seen that the woman's dress and bag are clear.



(a) Original image (b) Histogram of Fig.8(a)
(c) RSIHE equalization (d) Histogram of Fig.8(c)
(e) LRS stretching (f) Histogram of Fig.8(e)
(g) End-In stretching (h) Histogram of Fig.8(g)
(i) Proposed stretching method (j) Histogram of Fig.8(i)

Fig. 8. Result images and each histograms used exist method and Sub-stretching method

The image with dark doll and light background shows color histogram and the result image as Fig. 9. RSIHE method brightens the image but it contains boundary edge due to over-equalization shown as Fig. 9(c). LRS stretching shows light image but doll and window area give out white boundary noise. The image derived from the End-In stretching method has been improved. However, the buildings in background are most disappeared because of over-brightness as Fig 9(g).



(a) Original image (b) Histogram of Fig.9(a)
(c) RSIHE equalization (d) Histogram of Fig.9(a)
(e) LRS stretching (f) Histogram of Fig.9(a)
(g) End-In stretching (h) Histogram of Fig.9(a)
(i) Proposed stretching method (j) Histogram of Fig.9(a)

Fig. 9. Result images and each histograms used exist method and Sub-stretching method

At last, the proposed method enhances contrast of the image shown as Fig. 9(i). Also result became clear and natural and background area isn't harmed by appropriate stretching.

In this experiment, the detection process of the boundary edge gives less noise than the previous methods. But yet, it gives more noise than the original image. Although the distribution in the dramatically changed histogram is flexibly by using mean distribution value, defects still remain. To improve both defects and contrast enhancement, variable histogram's patterns are analyzed and needed the more accurate division of histogram.

V. Conclusion

In paper, proposed method is image processing which lay emphasis on visual contrast enhancement. Divide histogram by high density degree of histogram, and then distribution rate of divided each area is calculated. When stretching method is operated, calculated distribution rate decide application range of histogram. At last, divided histogram areas are stretched about decided range, and then it can create enhanced image. Proposed method can solve these problems of previous methods by experiment. In other words, because histogram's areas are stretched exclusively from calculated ranges, this algorithm can prevent over-stretching and decrease the distortion as blocking effect and staircase phenomenon on the backlight-image. Also in bright image, it prevent that histogram is unduly stretched to place of dark and help the visual contrast enhancement by consideration of detail brightness part. In addition, for the complexity of time and space, more study needs to be done.

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