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Brightness Preserving Fuzzy Dynamic Histogram Equalization

Abdolhossein Sarrafzadeh, Fatemeh Rezazadeh, Jamshid Shanbehzadeh

***Abstract*—Image enhancement is a fundamental step of image processing and machine vision to improve the quality of an image for a specific application. Histogram equalization is an attractive and commonly-employed image enhancement algorithm which is used in certain circumstances because of its global nature. Brightness Preserving Dynamic Histogram Equalization (BPDHE) overcomes this problem by considering the local image histogram. However, this algorithm can result in false countering and ignoring of details. False countering is the result of dedicating wide intervals to intensities with high probability; ignoring details results from the wide distribution of regions with detailed information in small regions. This paper introduces a fuzzy version of BPDHE (i.e., BPFDHE) to overcome the aforementioned problems. The fuzzification is employed to provide a crisper version of an interval and of the number of pixels in that interval. This algorithm has been tested on 30 images under several different conditions. The results with BPFDHE, in terms of subjective quality, outperform histogram equalization and BPDHE.**

***Index Terms*— image enhancement, histogram equalization, false countering, ignoring detail**

I. Introduction

IMAGE enhancement (IE) is a fundamental step in most image-based applications and machine vision. An interesting and attractive IE algorithm is histogram equalization (HE). This algorithm tries to enhance an image by improving its contrast. This is achieved by equalizing the image histogram. However, the darkness or washed-out appearance of the enhanced image in specific situations is unacceptable. Several methods have been suggested to improve the performance of HE. The aim of all of these algorithms is to preserve the mean intensity of the image by local based histogram equalization rather than global equalization. The locality of the histogram can be based on one or several points. From this point of view, we can divide the algorithms into two groups, one point division or several points division. The first group partitions the image histogram into two parts by one point based on the mean, median or all the image intensities. The second group partitions the image histogram into several parts according to local histogram max, min or a tree based on the mean of image intensities.

There are three algorithms in the first group of histogram based enhancement techniques. The first one is Brightness-preserving Bi-Histogram Equalization (BBHE) [2]. This algorithm employs the mean of the histogram as the point of histogram partitioning. The second scheme is Dualistic Sub-Image Histogram Equalization (DSIHE) [3] which is similar to BBHE, but the partitioning point is based on the median of image intensities. The third one is Minimum Mean Brightness Error Bi-Histogram Equalization (MMBEBHE) [4] which is similar to BBHE, but the difference is that it divides the image histogram according to all the image intensities and we equalize it such that its result has the least mean difference with the input image.

There are three algorithms in the second group of histogram based enhancement techniques. The first is Recursive Mean-Separate Histogram Equalization (RMSHE) [5]. It divides the histogram of the input image into two parts on the basis of mean of image intensity, and we continue to divide the generated parts into two parts again. We continue histogram partitioning several times. Finally, each part is equalized separately. The number of histogram divisions is an unknown parameter which we can find by receiving to the minimum mean square error between the mean of the input image and the output image. This algorithm, despite its appropriate performance, suffers from a high computational cost in finding the number of histogram divisions and equalizations. This disadvantage has been solved by Multi Peak Histogram Equalization with Dynamic Brightness Preserving (MPHEDBP) [6], Dynamic Histogram Equalization (DHE) [7] and Brightness Preserving Dynamic Histogram Equalization (BPDHE) [8]. MPHEDBP and DHE employ local maximums and local minimums, respectively. The difference is the employment of the information about the number of pixels in each part by DHE. BPDHE is similar to DHE, but it uses a normalization step as well. BPDHE shows the best result when compared with all the above mentioned algorithms. However, it produces false contouring in the connected regions and ignores details. False countering is the result of dedicating wide intervals to intensities with high probability. Ignoring the details results from the wide distribution of regions with detailed information in small regions. In fact, the main source of these problems is crisp weighting to regions with high similarities in intensities or regions with a rapid change of intensities without any regard to human interpretation. This paper introduces a fuzzy approach for BPDHE to overcome the mentioned problems. The fuzzification is employed to improve the crisp

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A. Sarrafzadeh is an Associate Professor and Head of Department of Computing, Unitec Institute of Technology, New Zealand (email: hsarrafzadeh@unitec.ac.nz).

F. Rezazadeh is an M.Sc. student with the Department of Computer Engineering, Faculty of Engineering, Kharazmi University, Tehran, I.R. Iran (e-mail: author@lamar.colostate.edu).

Jamshid Shanbehzadeh is an Associate Professor with the Department of Computer Engineering, Faculty of Engineering, Kharazmi University (Tarbiat Moallem University of Tehran), Tehran, I.R. Iran (phone: +98 26 34550002; fax: +98 26 34569555; e-mail: jamshid@tmu.ac.ir).

definition in an interval and the number of pixels in that interval. This leads to fuzziness in weighting the regions of histogram to alleviate contouring in highly correlated areas and ignoring details in small regions and, consequently, arriving at a more human based interpretation in comparison with that of BPDHE.

The rest of this paper is organized as follows. The next section explains the algorithm. The third section explains the simulation results and the final section the conclusion and suggested further work.

II. Proposed Algorithm

The new image enhancement algorithm consists of five parts. Figure 1 illustrates these parts. The first part is image smoothing. The second part finds the local maxima. The third part fuzzifies the distance between the maximum points in the image histogram and the number of pixels in each interval. The fourth part equalizes each part separately, and the final part normalizes the output image. Next each part is explained briefly.

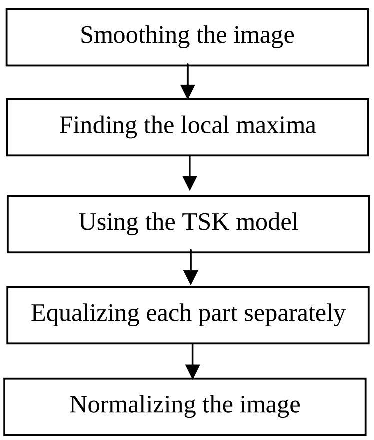

Fig 1. The steps of the new algorithm

The first step is the image smoothing. This paper employs a Gaussian function for smoothing. This function removes the redundant and noisy maximum and minimum peaks from the image histogram. This removal smoothes the image histogram's jagged points which are generated by high frequency components of the image. The jagged shape of the image histogram is caused mainly by noise. Figure 2 shows an image and its smoothed version and the associated histograms. These histograms illustrate the above mentioned points.

The second step finds the local maximum points of the histogram by tracing the histogram of the smoothed version of the image. A point on the histogram is a local maximum if its amplitude is more than its neighbors. Next the image histogram is partitioned according to the found maximum points. Each interval is the distance between two successive local maxima.

The third step fuzzifies a newly-generated factor from the multiplication of two factors the interval and the frequency of pixels in the interval. The third step, at first, finds the length of each interval and the frequency of intensities in that interval. The multiplication of these factors is fuzzified by a triangular shaped membership function. This membership function consists of three triangles where each one expresses three fuzzy terms: small, medium and large. These three terms come from the combination of length and the frequency of intensities. Thus, a small, medium or large interval will be changed into another interval according to the relative frequency of its members. Therefore, a small interval with a high number of members can be changed into a wide interval and vice versa. Thus, this method will give weight to each interval according to its effects on IE. This paper employs the TSK model for defuzzifying that was introduced in 1984 by T. Takag, M. Sugeno, and K. T. Kang [9].

Step four is HE. This step equalizes the histogram of each interval separately. The final section approximates the mean of the input image to the output one, by multiplying the intensity of each pixel to the ration of the mean intensity of the input and the output one.

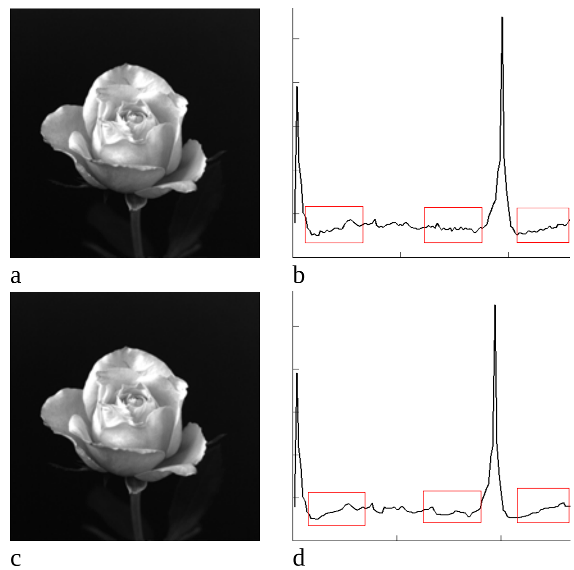

Fig 2. (a) Input image; (b) Histogram of input image; (c) Smoothed image; (d) Histogram of smoothed image

III. Simulation Results

This paper employs 30 images from the book Digital Image Processing [1] and free black and white images from a Google search to compare the results of BPDHE and our proposed algorithm. The images contain a variety of possible situations where HE could fail. The comparison is based on a subjective evaluation. Figure 3 shows the result for eight images. The first column is the original image; the second column shows the results of BPDHE; and the third column shows the results of the proposed algorithm. We can see two problems associated with BPDHE, that is, the contouring effect and losing information in the regions with detailed information. These problem areas are shown by circles and squares in the images. It is evident that there are no such problems using our proposed algorithm.

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IV. CONCLUSION

This paper presents a new histogram-based algorithm, BPFDHE for image enhancement. This algorithm was proposed to solve two problems with the BPDHE algorithm, namely, the contouring effect and the loss of information in regions with detailed information. We used a fuzzy approach to improve the crispness of the interval and the number of pixels in that interval. Experimental results show that BPFDHE can solve the problems mention above better than BPDHE. Further, similar to other HE-based algorithms, BPFDHE is easy to implement because of its simplicity.

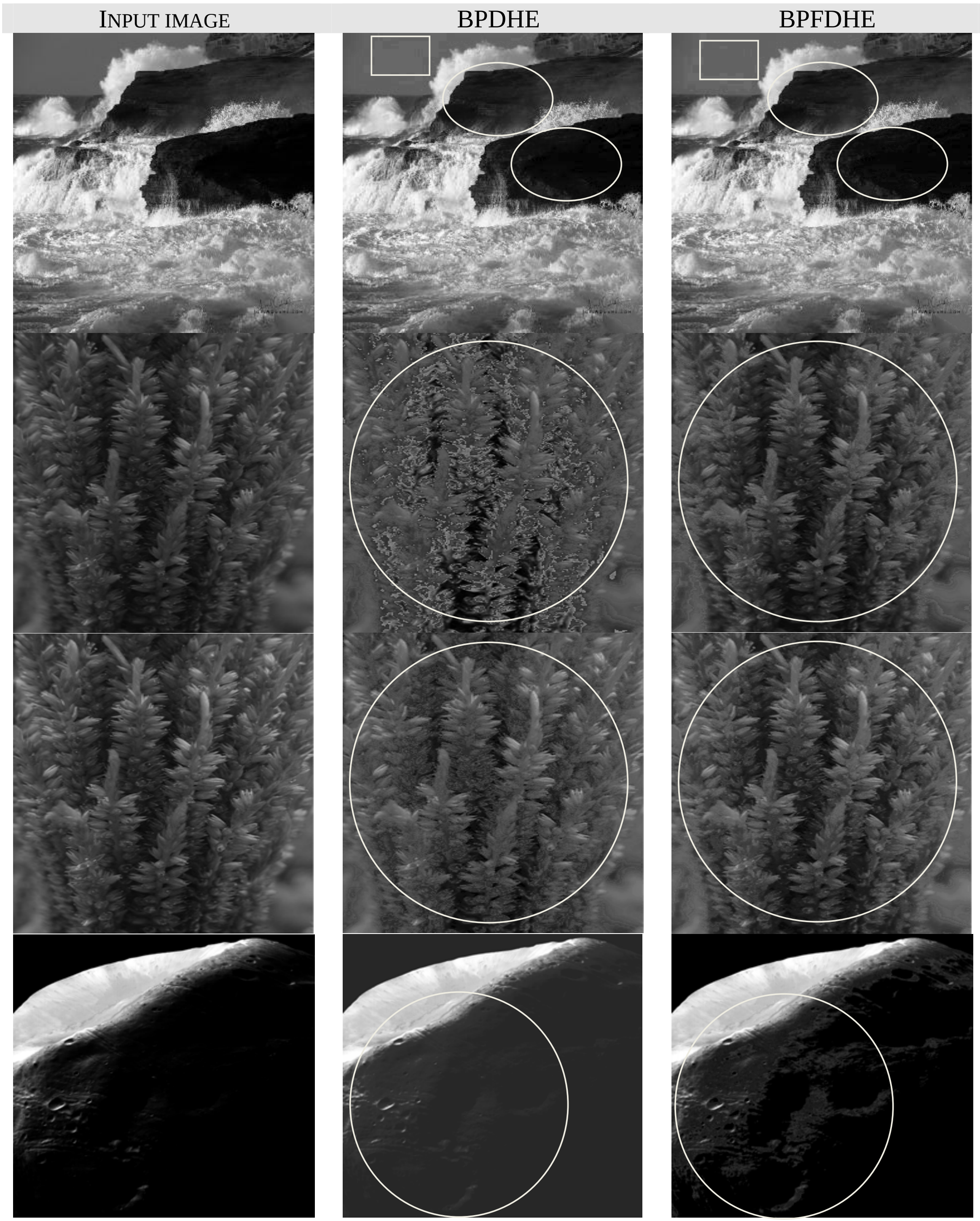

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Fig 3. Result of proposed algorithm. (a) Input image; (b) Result of BPDHE algorithm; (c) Result of proposed algorithm.

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