Brightness Preservation and Image Enhancement Based on Maximum Entropy Distribution*

Ji Hyun Yoo, Seong Yong Ohm, and Min Gyo Chung**

Department of Computer Science, Seoul Women's University,
Seoul, 139-774, Republic of Korea
{jhyu,osy,mchung}@swu.ac.kr

Abstract. Histogram equalization or histogram specification is a widely-used method for image enhancement. In 2005, Wang and Ye used histogram specification to propose an image enhancement method based on variational calculus. However, their method often produces over-enhanced or unnatural images, especially when the input histogram has some high peaks around the middle of the intensity interval. Extending Wang and Ye's approach, this paper proposes a new image enhancement method called MEDHS (Maximum Entropy Distribution based Histogram Specification), which uses the Gaussian distribution to maximize the entropy and preserve the mean brightness. Specifically, the mean of the Gaussian distribution is equal to the brightness mean of the input image, and the variance of the Gaussian distribution is chosen to maximize the entropy of the output image. Experimental results show that compared to the existing methods, our method preserves the mean brightness more accurately and generates more natural looking images.

Keywords: Image contrast enhancement, mean brightness preservation, histogram specification, histogram equalization, maximum entropy, Gaussian distribution.

1 Introduction

Histogram equalization (HE) is a well-known method for image enhancement in digital image processing. It improves the visual appearance of an original image by flattening the histogram of the image [1]. However, HE method drastically changes the mean brightness of the input image (mean-shift problem), which is an undesirable property in consumer electronics products where preserving the input brightness is essential to avoid unnecessary visual deterioration.

Some variants of HE method have been published to overcome the mean-shift problem. Kim [2] proposed BBHE (Brightness preserving Bi-Histogram Equalization), which first segments an input histogram into two sub-histograms based on the brightness mean of the input image and then executes HE on each

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** Corresponding author.

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sub-histogram independently. Subsequently, DSIHE (Dualistic Sub-Image Histogram Equalization) was introduced by Wan et al. [3]. DSIHE is conceptually similar to BBHE, but for histogram decomposition it uses the median of the input image's brightness instead of the mean brightness.

Following the aforementioned basic ideas, Chen and Ramli [4] developed RMSHE (Recursive Mean Separate Histogram Equalization), and Sim et al. [5] proposed RSIHE (Recursive Sub-Image Histogram Equalization). In fact, RMSHE and RSIHE are recursive versions of BBHE and DSIHE, respectively. RMSHE performs the mean-based histogram decomposition recursively and then equalizes the resulting sub-histograms individually. RSIHE acts similarly to RMSHE except that the medians are used for successive histogram decomposition. Meanwhile, Wang and Ye [6] turned their attention to the variational calculus, and developed a histogram specification-based method, called BPHEME (Brightness Preserving Histogram Equalization with Maximum Entropy). They showed by the calculus of variations that the target histogram should take the form of the exponential distribution, which maximizes the differential entropy and preserves the mean brightness as well.

The previous methods in the literature resolve the mean-shift problem to some extent, but tend to over-enhance or amplify background noises, thereby producing unnatural images with non-existing artifacts. To overcome such drawbacks of the existing algorithms, this paper extends the basic concept of Wang and Ye's method, and proposes a new image enhancement method named MEDHS (Maximum Entropy Distribution based Histogram Specification), which uses the Gaussian distribution as the desirable distribution and maximizes the entropy of the output image. Wang and Ye's method considers only the brightness mean in deriving the objective histogram. However, we will take into account both the mean and the variance of image brightness, since the brightness variance is one of important factors to have an influence on the contrast of images. Given a mean μ and a variance σ^2 alike, the maximum entropy principle states that the probability distribution to maximize the differential entropy is the Gaussian distribution with the mean μ and the variance σ^2 [8]. The Gaussian distribution was also used in [7], but no theoretical justification for using it was provided.

The rest of this paper is organized as follows. Section 2 describes in detail our proposed method. In Section 3, we show the experimental results followed by some discussions. Finally a short concluding remark is given in Section 4.

2 MEDHS (Maximum Entropy Distribution based Histogram Specification)

This section gives a detailed description of the proposed method MEDHS. MEDHS is designed to find the ideal target histogram or PDF (Probability Density Function) that maximizes the differential entropy under the constraints on the mean brightness and the brightness variance. MEDHS consists of the following three major processes: a) *find the maximum entropy distribution*, b) *normalize the distribution*, and c) *perform histogram specification*. The first process is responsible for solving the maximum