Implementation and Analysis of Image Contrast Enhancement using Gaussian Mixture Model

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Abstract— In this paper, we propose a new global contrast enhancement algorithm using the histogram color and depth images. On the basis of the histogram-modification framework, the color and depth image histograms are first partitioned into sub-intervals using the Gaussian mixture model. The positions partitioning the color histogram are then adjusted such that spatially neighboring pixels with the similar intensity and depth values can be grouped into the same sub-interval. By estimating the mapping curve of the contrast enhancement for each sub-interval, the global image contrast can be improved without over-enhancing the local image contrast. Experimental results demonstrate the effectiveness of the proposed algorithm. The current major project in contrast enhancement is to partition the input histogram into multiple sub histograms before final equalization of each sub-histogram is performed. This paper presents a novel contrast enhancement method based on Gaussian mixture modeling of image histograms, which provides a sound theoretical underpinning of the partitioning process .By estimating the mapping curve of the contrast enhancement for each sub-interval, the global image contrast can be improved without over-enhancing the local image contrast.

Index words — Contrast enhancement, depth image, histogram modification, histogram partitioning.

I. INTRODUCTION

IMAGE contrast enhancement techniques have been extensively studied in the past decades. Among various contrast enhancement approaches, histogram modification based methods have received the greatest attention owing to their simplicity and effectiveness [1]. In particular, since global histogram equalization (GHE) tends to over-enhance the image details, the approaches of dividing an image histogram into several sub-intervals and modifying each sub-interval separately have been considered as an alternative to GHE [2], [3]. The effectiveness of these sub-histogram based methods is highly dependent on how the image histogram is divided.

II. PROPOSED ALGORITHM

We use a pair of color and depth images as input, as shown in Fig. 1. The proposed algorithm modifies the histogram of the color image using the histogram of the depth image as side information. When representing the histogram of the color image, we transform the color space from the RGB space to the hue-saturation intensity (HSI) space and use only the intensity channel.

Fig. 1. (a) The color image Teddy and (b) its depth image obtained by [10].
Histogram modification is appropriately activated to the acuteness channel, and the resultant blush angle is acquired by transforming the blush amplitude aback to the RGB space. Figs. 2(a) and (b) appearance the histograms of the blush and abyss images with their estimated GMMs. The cogent circle credibility [2] (marked by the dejected dots in Figs. 2(a) and (b)) are again acclimated to bisect the histogram into sub-intervals. Note that we accept the GMM based histogram administration adjustment due to its capability in the adverse accessory [2], [11], but added histogram administration algorithms [3], [12] can aswell be formed with the proposed algorithm. Let and represent the blush angel and the abyss image, respectively. The histograms of and are assumed to be divided into N and M sub-intervals, respectively, and the intersection points between the i-th and (i+1)-th sub-intervals

\[ S_1(k) = \{(i, j) | \frac{e(i, j)}{e_{i-1}} \leq \{c(i, j) \}, k = 1, \ldots, N, \]

\[ S_{ii+1}(k) = \{(i, j) | \frac{m_{i-1}}{m_i} \leq d(i, j) < m_k \}, k = 1, \ldots, M. \]

(1)

where \((i, j)\) represents a pixel coordinate, and \(S_1(K)\) and \(S_{ii+1}(K)\) are the sets of pixels in the -th layer of and , respectively, and are the start and end positions corresponding to the first and last sub-intervals, respectively, and are defined similarly. Here, the pixels with the same color belong to the same layer. It should be noted that the adopted GMM technique [2] automatically determines the number of GMMs, and thus and are different for each color and depth image pair. In histogram partitioning-based contrast enhancement algorithms, the mapping function for each layer is estimated exclusively such that image details in each layer can be effectively enhanced [2], [3].

However, histogram partitioning using only the intensity channel can assign different labels to the neighboring pixels that have similar intensity and depth values. For example, the background region inside the dotted circle has similar intensity and depth values as can be seen in Fig. 1, but different labels are cluttered in the region. Thus, the contrast enhancement on this background region using the conventional method [2] can yield unnatural images. To this end, we propose an algorithm that adjusts the histogram partitioning such that a same label is enforced for the pixels with the similar intensity and depth values. Specifically, we modify the layer intersection positions of the color histogram as

\[ (3) \]

The first term in (3) is used to prevent an excessive change of the intersection positions, whereas the second term is used to measure the spatial dissimilarity between the layer labeling obtained using the current estimate and the depth partitioning result \(m^*\), respectively. Note that we do not absolutely accomplish that the spatially adjoining pixels with the agnate blush and abyss ethics are aggregate calm back such an absolute administration requires a complicated pixel-level optimization. Instead, the blush band labeling is guided to be spatially overlapped with the abyss band labeling such that the adjoining pixels with the agnate blush and abyss ethics are acceptable to be alloyed together. Our absolute administration appropriately yields a simple layer-level optimization. By analytic (2), adapted histogram sub-intervals are obtained. Due to the non-differentiability of (4), we accept the abiogenetic algorithm (GA), which is an able apparatus for analytic nonlinear and/or non arched functions. Although the all-around optimum is not guaranteed, we empirically begin that the GA performs able-bodied if the antecedent blush band labeling is use as the antecedent appraisal of . The absorbed readers are referred to [13] for the data about accomplishing and constant settings of the GA.

Regarding the GA, only the difference compared to [13] is our use of (3) as a fitness function. In (3), controls the amount of interval changes. If , the original intervals remain, and thus the proposed method reduces to [2]. Otherwise, if increases, the dissimilarity term becomes dominant. The size of overlapping between and is maximized when and become equivalent. However, it needs to be noted that the order of pixel values should be maintained when a color image is divided into multiple layers [2], [3]. Therefore, in practice, we can only make to be largely overlapped with Finally, using the modified histogram sub-intervals, a mapping curve of the color intensity is obtained using the method described in [2]. Note that our contribution is the modification method of the histogram sub-intervals, and thus a development of a new mapping-curve generation algorithm is out of focus in this letter.

III. EXPERIMENTAL RESULTS

In order to evaluate the performance of the proposed algorithm, the Middlebury stereo test images [14] were used in our experiment. The depth images were obtained using the stereo matching algorithm [10] as shown in Fig. 3. The pixel values of the color images were then divided by 4 to simulate low-contrast input images. Using the same histogram partitioning and mapping curve generation methods in [2], the effectiveness of the proposed algorithm can be evaluated by comparing the results obtained with and without modifying the histogram sub-intervals, respectively. Fig.3 shows the experimental results obtained using the conventional [2] and proposed algorithms. Both algorithms successfully enhanced the global contrast of the input images shown in Fig. 3. However, the conventional method produced artifacts at some image regions as shown in Figs. 5(g), (i), and (k). This is because the image regions with the similar intensity and depth values were decomposed into

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different groups as shown in Figs. 6(a), (c), and (e). By using the proposed algorithm, such regions were merged into the same layer as shown.

![Different groups as shown](image)

Fig: Experimental results corresponding to the input images in Fig. 3. (a)-(c) the resultant image obtained by [2], (d)-(f) the resultant image obtained by the proposed algorithm, (g), (i), (k): the magnified subregions corresponding to (a)-c), respectively, (h), (j), (l) the magnified subregions corresponding to (d)-(f), respectively.

It should be noted that the depth image was used only for providing additional layer labeling information. Our layer-level optimization was not significantly dependent on pixel-level depth errors, and the use of the conventional stereo matching algorithm [10] was found to be effective. In our naive MATLAB implementation on a PC with 3Ghz CPU, 4 GB RAM, and Windows 7, it took about one minute to obtain a contrast enhanced color image. About 20% of time was required for solving (2), and the other procedures including the GMM and mapping curve generation were more computationally demanding. It is expected that an efficient GPU implementation could significantly reduce the overall computational complexity.

**Image + vision plus output:**

![Image output](image)

**IV. CONCLUSIONS**

In this letter, we proposed a new histogram-based image contrast enhancement algorithm using the histograms of color and depth images. The histograms of the color and depth images are first partitioned into sub-intervals using the Gaussian mixture model. The abstracted histograms are again adjusted to access the band labeling after-effects of the blush and abyss angels. The sub-intervals of the blush histogram are adapted such that the pixels with the analogous acuteness and abyss ethics can accord to the aforementioned layer. Therefore, while a all-around angel adverse is stretched, a bounded angel adverse is as well consistently bigger after the over-enhancement. We plan to extend our layer-based algorithm to a segment-based algorithm by using a joint color-depth segmentation method.

**REFERENCES**


Author’s

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