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Edge Detection in Digital Images Using Multiple Filtering Process and Bi-Histogram Equalization

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ABSTRACT:

Edge detection plays an important role in image processing. The performance of an edge detection algorithm can be affected by serious noise & intensity inhomogeneity. In this paper, a procedure of edge detection for a high dynamic range image with damaged edge information is proposed. This procedure is based on a scheme of multiple filtering processes which does not include any segmentation of the image. The first step is to perform bi-histogram equalization to improve the signal contrast in a discriminative manner. To this end, the histogram of the input image is analyzed and the irregularity of image intensity, if there is any, is identified and removed by using a contrast enhanced bi-histogram equalization technique. The second step is a gradient modulation filtering process. An image acquired under complex condition may need multiple processes.

Three different filtering processes are designed to generate three gradient maps, in each of which gradients are calculated and modulated by using a specific filter. The enhanced gradients, i.e. those modulated correctly, are identified in each of the three gradient maps by using a selection algorithm. They are taken to generate a complete edge map. This procedure allows varieties of edge gradient enhancements applied in the same image by employing a set of simple filters without segmentation. The comparision of subjective and objective analysis in the simulation results show that the proposed method is applicable and effective to detect edges of low quality HDR images.

INTRODUCTION:

Edge detection plays a important role in image processing. Detecting edges from a low-quality image where gradient signals are degraded is a challenging task. The signal degradation is usually caused by restricted conditions of image signal acquisition. In many image filtering tasks, the images which are to be processed are usually captured or acquired under non-ideal conditions, some of the images can lead to complex signal degradation in the image. One of the best examples is high dynamic range (HDR) images captured by an ordinary camera with some signal details damaged. A complex filtering process can be used to detect the edges with the various intensity variances. One of such examples is found in [1]. Capturing a high-dynamic-range scene with a range-limited camera, which is very often the case, results in over-and under exposed regions in the image. However, for the reduction of the computation complexity, a multiple-process structure can be considered.

Each of the processes is to be made to enhance the edge signals under one condition [2]. Simple gradient based edge detection methods might not be effective to extract edge signals. In multi-stage edge detection algorithms, low pass filtering was widely used, before the gradient calculation, to reduce effectively the noise level and intensity inhomogeneity, but it might also lead to a permanent loss of important edge information. Canny edge detection algorithm [3] and its variations are widely used to extract edges under various conditions. They can be effective in finding edge pixels in some noised environment, but may be less efficient for detecting very low contrast edges.

Hence there is a need to develop edge detection algorithms tackling effectively varieties of low quality images.In this paper, a method for edge detection of HDR images is proposed. It aims at extracting the edges effectively from images with the low contrast captured under non-ideal conditions. This method comprises two steps, first step is image processing by Bi-histogram equalization and secondly, multiple filtering process involving simple gradient detection operators is applied.

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METHODS ADAPTED:
II. ESCRIPTION OF THE EDGE DETECTION METHOD:

To help bring about the detection of gradient signal of low-quality HDR image, a stage of pre-processing of image is often used to improve the signal quality. As mentioned previously, low-pass filtering can help to remove some noise, but also erase low-contrast gradients that might correspond to edges. Hence one would place a process of contrast enhancement preceding that of the gradient modulation filtering process. This section is dedicated to the description of the two parts of the proposed edge detection method, namely the bi- histogram equalization for preserving the mean brightness of a given image while the contrast is enhanced and filtering involving multiple gradient modulations to remove the signal deformations in an image.

A.Bi-Histogram Equalization:

Histogram is a graphical representation of tonal distribution of an image which shows the occurrence of each intensity value in the image. Histogram equalization is used for contrast enhancement in several types of applications due to its simple function and effectiveness. Examples include medical image processing and radar signal processing. One drawback of the histogram equalization can be found on the fact that the brightness of an image can be changed after the histogram equalization, which is mainly due to the flattening property of the histogram equalization. Here we are using a bi-histogram equalization technique, ultimate goal of which is to preserve the mean brightness of a given image while the contrast of the image is enhanced.

As the images to be processed may involve different kinds of signal degradation, and the intensity condition varies from region to region, it is necessary to consider the local signal level while performing the contrast enhancement. In the first stage, the original image(X) is simply divided into two sub-images as Xl and Xu. The local contrast enhancement technique is used here in bi-histogram equalization. The bi-histogram equalization decomposes an input image into two sub-images based on the mean of the input image. One of the sub-images is the set of samples less than or equal to the mean denoted as Xl whereas the other one is the set of samples greater than the mean denoted as Xu.

Then the bi-histogram equalization equalizes the sub-images independently based on their respective histograms with the constraint that the samples in the formal set are mapped into the range from the minimum gray level to the input mean and the samples in the latter set are mapped into the range from the mean to the maximum gray level. In other words, one of the sub-images is equalized over the range up to the mean and the other sub-image is equalized over the range from the mean based on the respective histograms. Therefore, the output of the equalized sub-images are bounded by each other around the input mean, which has an effect of preserving mean brightness. To address the problems of eliminating the amplification of noise contrast while improving the local signal contrast a technique of bi-histogram equalization is applied. The information of the pixel signal level of an image is well reflected to its histogram. Homogeneous areas generate the high peaks in the histogram and forms great slopes in its graphical representation. It is thus reasonable to say that the slope of the mapping function is proportional to the height of the histogram at that intensity and limiting the height of the histogram can lead to a suppression of some of the undesirable local high contrast[4]. So here we are utilizing the independent histogram equalizations separately over two sub- images obtained by decomposing the input image based on its mean with a constraint that the resulting equalized sub-images are bounded by each other around the input mean.

The first procedure, known as the pre-processing step, the bi-histogram equalization for preserving the mean brightness while enhancing the contrast can be executed as follows:

•Denote by Xm, the mean of the image X.
•Based on the mean the input image is decomposed into two sub-images Xl and Xu.
•Next, define the respective probability density functions of the sub-images Xl and Xu.
•Then calculate the respective cumulative density function for {X}l and {X}u.
•Similar to the case of histogram equalization where a cumulative density function is used
as a transform function, define the transform functions exploiting the cumulative density
functions.
•Based on these transform functions, the decomposed sub-images are equalized independently and the composition of the resulting equalized sub-images constitutes the output of the Bi-Histogram Equalization.

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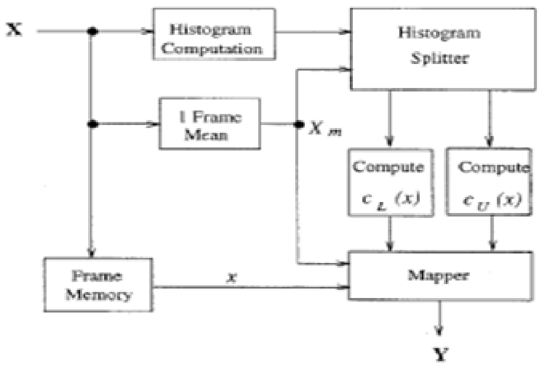

Figure 1: Bi-Histogram Equalization process.

In the next section the multiple filtering process including the gradient modulations is described.

B.Multiple filtering process including Gradient modulations:

A procedure is designed here, for an edge detection to be applied to an HDR image. Due to the nonlinear characteristics of image sensor, the edge signals in different locations may be attenuated in a complex manner related to the intensity variation. In this case, the gradients produced by the edges and those by the noise may not be easily distinguished, and a fixed threshold or filtering process with fixed parameters is not suitable. To extract all the edge signals, a group of filtering processes need to be designed, and each of them is to match one of the intensity conditions. A group of filtered images (FIs) are generated by the filtering processes. In this procedure, each of the filtered image (FIs) is a gradient magnitude image with enhanced gradients in certain regions. Like most of the edge detection techniques the gradient signal at each pixel position is binarized with a threshold value to get the final edge map. Since multiple gradients are produced in this procedure at each pixel, we need a selection process to sort the gradient data for the binarization.

Design of filtering process (Gradient Modulation):

In a HDR image the signal can vary over a very wide range, which greatly exceeds the range of linear operation of most of the image sensors. Instead of using multiple exposures to acquiring all the detail information in different ranges [5], the proposed procedure is designed to extract the information from an image acquired range-limited devices.

To enhance the edge gradients, in the regions under different intensity conditions different degrees of signal attenuation are needed to be investigated. As mentioned previously, while acquiring the image the signal attenuation is due to the nonlinear characteristics of the sensors. In the bright illumination, signal gradient decreases while the intensity is increasing and in the weak illumination the signal gradient increases with the intensity. Thus, the gain applied to find the gradient in the gradient process should be different in the two cases.

In this method, the intensity range of an image is divided into three sub-ranges, corresponding to dark, median and bright regions for simplicity of the procedure. The filtering process is nothing but a modulated gradient calculation process. Let the gradient magnitude at a given pixel position is denoted as G, and it is obtained by applying a set of gradient kernels, such as the SOBEL operator. However, the parameter of the filtering process should be different from region to region and needs to be related to the local intensity conditions.

•In a dark region, the under exposure makes edge gradients weaker in a weaker background. If GD denotes the result of the filtering process in this region, it is defined as the division of gradient magnitude to the sum of the square roots of the original pixel signals in the neighborhood;

•In a bright region, due to the device saturation, the signals are more attenuated if the background level is higher. Therefore, the filtering result GB in this case is given by the multiplication of the gradient magnitude and the sum of the square roots of the original pixel signals in the neighborhood;

•There must be regions, called median regions, in which signals are acquired under the illumination condition between the two cases discussed above. Let GM be the result of the filtering process in this case, we have the gradient modulation as output.

The gradient values are modulated by different filtering processes. In general, which kind of regions, dark, median or bright, the pixel is located in, determines which of the three different filters is the matched one. We should remember here that in the stage of the filtering process, we do not need to identify which pixels should be processed by its matched filtering process, as every pixel is filtered three times without discrimination.

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But each of the three filters produces the gradients in a discriminative manner according to the original pixel signals in the neighborhood. The next section describes the details of the selection algorithm, to differentiate in each of the three normalized filtered image, the pixels in the matched regions from those in the unmatched ones.

Design of Selection Process:

The at each pixel position, three filtering processes result in, three different modulated gradient signals. The selection algorithm is needed to identify the one that is generated by the most appropriate filtering process among the three. The results of this selection are then used to determine the threshold of the selected regions to produce the final results. As each of the filtering processes is designed to enhance the edge gradients in certain regions, different filters have different signal-dependent parameters. The actual gains of the processes are different from one another. Thus, the results generated from these processes need to be normalized with a signal-and-process-dependent parameter in order to implement the selection process. In this design, the pixels of each FI are normalized by the maximum pixelvalue of the FI. The normalized filtered images (FIs) are called NFIs.

Let the normalized GD, GB and GM be GND, GNB and GNM respectively. At a given pixel position (i, j) in each of the NFIs, the normalized values of the processes.As the pixel signals are generated by the three different filtering processes, three threshold values are applied for the binarization. Each of them is determined by the average value of the selected pixel signals from the same NFI, and is then applied to these pixels in the binarization. The completed edge map is then generated.The proposed procedure of the edge detection including the multiple filtering process and the selection algorithm described in the figure is as follows:

•The original HDR image is preprocessed with a Gaussian smooth filtering for removing the unwanted noise;

•Three filtered images (FIs) are generated by using a set of classical Sobel operators with the different modulation;

•The pixels in each filtered image (FI) are normalized to generate the normalized FI images NFID, NFIM and NFIB;

•At every pixel, the local result is compared to the other two, from the other NFIs respectively;

•For each NFI, if the local one is the maximum among the three, it will be kept at this position; otherwise, the pixel value at this position will be replaced by zero. The outputs of this stage are the images SID, SIM and SIB, with SIs standing for the selected images.

•In each of the selected images (SIs), the threshold value is determined by the average value of all the non-zero pixels and applied to this SI to perform binarization. After a thinning process, three edge maps EMD, EMM and EMB are then generated and merged.

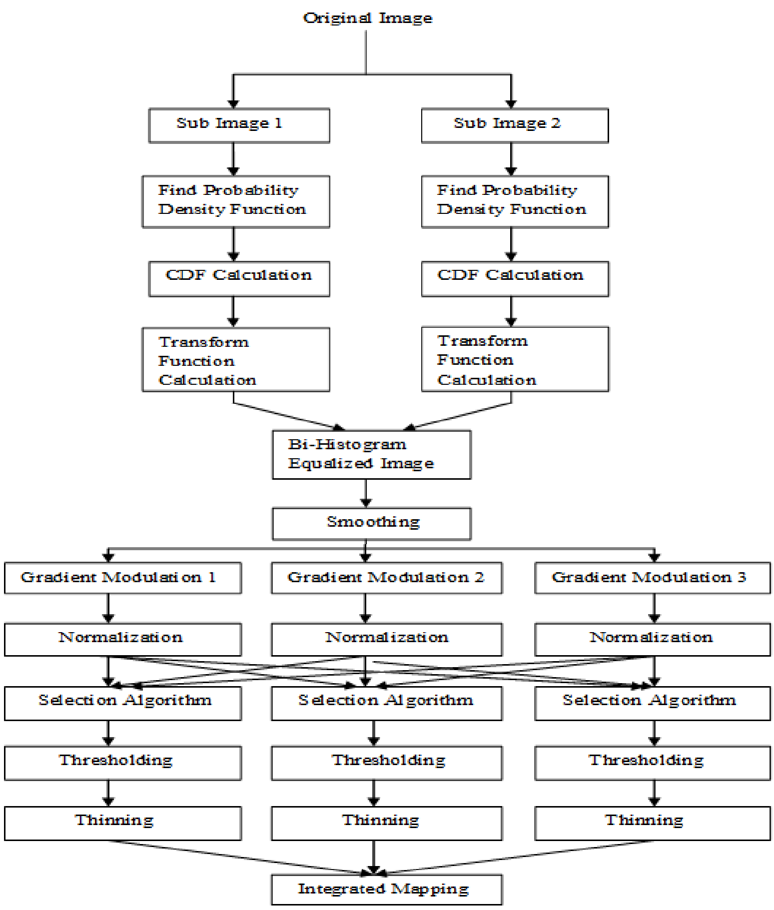

Figure 2: The block diagram of the proposed procedure implementing the edge detection method.

Experimental Details:

The proposed procedure shown in Figure 2 has been simulated to evaluate the feasibility and the effectiveness of the proposed edge detection method.

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The simulation consists of subjective and objective measurements. Several images of different patterns have been used to test the suitability of the method under different conditions. For example, medical images, digital images and low-contrast images. The SOBEL operators are used to calculate the gradients and the data. The results of the simulation are compared to those generated by the sobel and canny method as it is considered as highly effective to detect difficult edges. As the original images are obtained by a single exposure, some regions suffer under-exposure and some other regions suffer over-exposure. The results of one of the cases are shown in Fig.4. The three edge maps are obtained by applying the different methods, namely simple SOBEL, Canny and the proposed procedure, respectively. It is easily observed that by using the proposed method, much more edges can be detected correctly. The simulation results of the other HDR images have confirmed the same.

For the objective measurement, Pratt's Figure of Merit (PFOM) has been used [6]. It is calculated by comparing the edge map generated by using the proposed method with an "ideal" edge map of the same scene. To apply this evaluation procedure, one needs the reference edge map. If the two edge maps, after the edges in both maps are thinned, are identical, the PFOM will be equal to unity. The results of the PFOM generated from the image is shown in Table 1, indicating that, compared to that of the Canny and the existing one, the edge map generated by the proposed method can detect more edges.The results of the PFOM are displayed in Table 1, which is demonstrated qualitatively that the edge map produced by the proposed method has significantly more likeness to the "ideal" one than those by the two other detections.

Table 1: PFOM values obtained by three different methods

Sobel Method	Canny Method	Existing System	Proposed System
0.8482	0.8463	0.8916	0.9332

a. Original Image

c. Canny Method

b. Sobel Method

d. Existing Method

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e. Proposed Method

Conclusion:

In this paper, we have proposed a method for edge detection. This method includes, as a pre-process, bi-histogram equalization and then discussed a scheme of multiple filtering processes. Instead of segmenting an image into regions for different processes, it is done by applying0 each of the processes to the original image to generate multiple filtered images and a selection algorithm is used to select the largest magnitude at a position. The Bi-Histogram Equalization, which utilizes independent histogram equalizations over two sub-images obtained by decomposing the input image based on its mean. The ultimate goal behind the Bi-Histogram Equalization is to preserve the mean brightness of a given image while enhancing the contrast of a given image. Later a filtering process is applied to the contrast enhanced image.

It uses multiple simple operators, each of which is designed to extract gradient signals under one of the signal deformation conditions. The gradient signals are modulated in a discriminative manner according to the features of signal deformation. This discriminative modulation is implemented by three simple filters to generate three filtered images. A simple selection algorithm is applied to produce the edge map containing detail information of the original image in all regions, even though a lot of it has been damaged in the original one. The evaluation results including subjective observations and objective measurements show that the proposed method can effectively detect edge signals in HDR images.

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