An Improved Framework for Backlight Scaled Images and Videos

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Abstract— **Now-a-days, the major problem found in the portable multimedia devices of today is of maintaining the image quality under various lighting conditions. The brightness of an image influences the battery capacity of a device. Reducing the backlight increases the battery life of these devices. In this paper an image enhancement algorithm is proposed that enhances an image at low backlight, by taking the human visual property into consideration. The just noticeable difference theory (JND) is applied and an image is decomposed into two layers namely, the HVS response layer and the background luminance layer. The operations of the proposed algorithm are performed in the background luminance layer so that luminance gradient reversal can be avoided. The algorithm is further extended to enhance dim backlight videos.**

Keywords— **Backlight, JND, HVS, background luminance.**

I. INTRODUCTION

The battery life of portable multimedia devices like smartphones can be extended by reducing the backlight intensity level. However reducing the backlight intensity affects the image quality. Enhancing such an image can affect the contrast of the image.

All previous methods on image enhancement rely on dynamically adjusting the backlight and applying various luminous compensations, until the image is enhanced. There are methods that maintain the image brightness by simply boosting the pixel value based on the property that LCD transmissions increase with pixel value [4]. However this method suffers from detail loss and color degradations. Most of the previous methods for enhancing the dimmed images deal with 50 % or more backlight [2]-[6]. These methods divide the image into two layers and lower the contrast in one of the layers. Unfortunately all the methods preserve the image fidelity, but the details of the low intensity regions remains unaffected. Another major drawback of these methods is the over enhancement of dark regions.

In particular, the luminance of dark image regions should be boosted. When the backlight intensity is sufficiently low, the content of an image is hardly seen. When the luminance value is below a specified threshold, the image details become invisible. This threshold value depends on the luminance of the ambient light. This property called the HVS property is implemented in this algorithm. Since the perceived image quality is related to the response of the human visual system (HVS) to image signal, a perception based approach that takes this HVS property is highly desirable. The paper is organized as follows. Section II describes the features of Human Visual System. The available methods for enhancing dim images are described in section III.The proposed algorithm is explained in section IV.
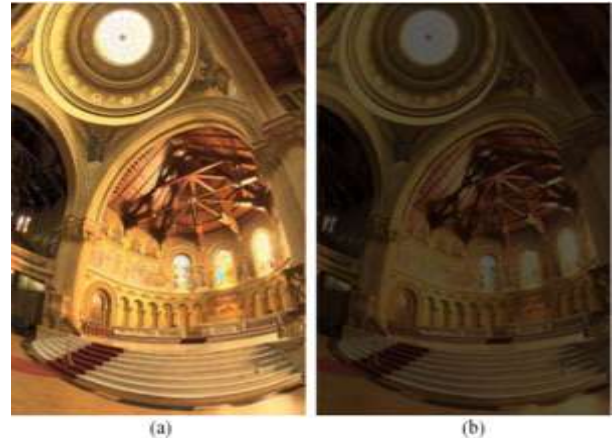

Fig. 1. An image displayed on an LCD with (a) 100 % backlight and (b) 10 % backlight.

II. BACKGROUND

A. Just Noticeable Difference

JND can be defined as the smallest difference in a specific area of input sensory that could be identified by a human being. When comparing with the background luminance of an image, JND is an increasing function. Let L represent the luminance of an image. Then JND can be represented as &L.

There are many models that describe the relationship between L and &L . If L denote the background luminance and &L denote the corresponding JND, then the human visual system cannot detect a foreground stimulus if its luminance value is between L-&L and L+&L.

A more simplified relation is proposed by Iranli [10].

$$\&L = J (L) = 0.0594(1.219 + L^{0.4})^{2.5} \qquad (1)$$

J (.) returns the JND of a given luminance. The value of &L is called threshold stimulus and a value above &L is called superathreshold stimulus. From Wilson's approach [2], a transducer function can be derived that models the HVS response to suprathreshold stimulus, by assuming the value of HVS response changes by one unit per JND difference [7]. This is illustrated in figure 2.

B. Human Visual Response

The relation between human visual perception response and the image luminance can be modeled by a non-linear function. This relationship is used by the HVS model by taking the luminance value as input and converting it into a non-negative integer as output. The difference of 1 results in the JND in luminance.

The human visual system model can be implemented by computing

$$L1=L0+J(L0) \qquad (2)$$

The above equation can be calculated in a recursive procedure. In most case L values till L4 is usually calculated at minimum.

C. Undesirable effects of dim backlight

The visual perception of an image or video can be significantly affected in the presence of dim backlight. Firstly, the image details become less clear. Secondly, it causes the color to degrade. The color degradation is directly proportional to the available backlight. The same defects correspond to video sequences as it is composed of several frames. The dimmer the backlight, the more the color degrades.

By examining the graph plotted between responses of human cone cells to luminance, the effect can be seen. The cone response is an s-shaped curve [11].

$$\frac{V}{V_m} = \frac{I^{0.74}}{I^{0.74} + \sigma^{0.74}},$$

Where V/Vm, is the normalized response, *I* is the perceived light intensity and sigma is the saturation parameter.
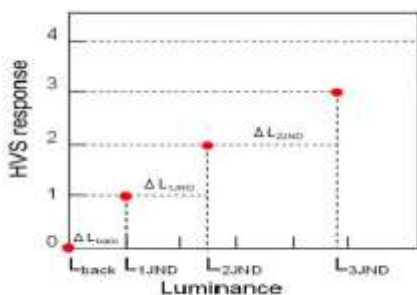

Fig. 2. Relationship between JND differences and HVS responses

III. APPROACH

In particular the luminance of the dark image regions should be boosted or enhanced. There are a number of ways to achieve this.

In the figure the maximum luminance supported by the display at 10 % backlight is represented by the top dash line. The minimum perceptible luminance level is given by the bottom line
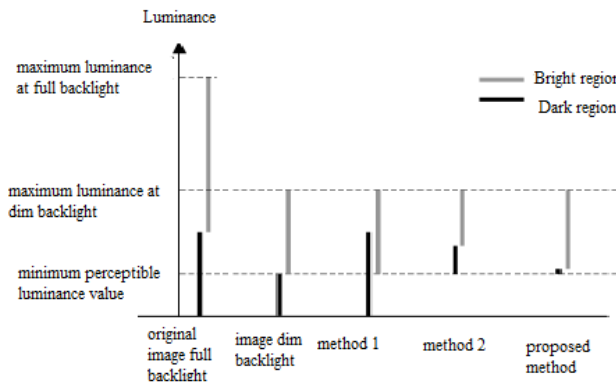

Fig. 3. Comparison with previous methods.

Method 1 boosts the dark regions in such a way that the resulting luminance range of boosted dark region is equal to its luminance range at 100 % backlight [1]. Even though the dark regions get enhanced there are two drawbacks. First since a portion of dark region is still below the minimum perceptible level, the dark region is only partially visible. Secondly there can be an overlapping between luminance range of dark regions and bright regions [1]. This in turn introduces the phenomenon of luminance gradient reversal.

But method 2 proportionally scales the luminance of the entire image. This method enables the entire image to fit within the predefined maximum and minimum luminance levels .However this method suffers a limitation [1]-[2]. The boosting operation degrades the perceptual contrast of bright region. The methods described in [7]-[9] compress the dyanamic range in the gradient domains. The ABIE method applies brightness compensation to the low frequency part of an image and local contrast enhancement to the high frequency part of the image.

Therefore the existing systems suffer from two major limitations. Loss of details and color degradation over enhancement of dark region.

IV. PROPOSED ALGORITHM

To enhance a backlight scaled image or video, two problems has to be resolved. First, determine the minimum perceptible luminance threshold. Second implement the boost and compression idea [1].The proposed algorithm can effectively enhance a video sequence with dim backlight. Even though a great deal of works has been completed in the field of enhancement of dim video clips, none of them used the combination of Just Noticeable Difference (JND) theory and human visual system model. All previous approaches related to JND theory were restricted to images alone

A. Determining the detailed loss effect

The viewing condition affects the cone response of HVS and this phenomenon can be easily modeled. In all the previous approaches the detailed loss effect is modeled by exploiting Huang et al.'s visibility model [8]. This model has 3 inputs, an image, a backlight intensity level and an ambient light intensity level. The output of the model is a map that represents the probability of visibility of each pixel in the input image. In this

work the probability of visibility of each pixel in the input image is calculated twice, one with full backlight intensity level and other with dim backlight intensity level. The difference of the two probabilities was used to model the detailed loss effect. But this model requires a threshold value. The threshold value is reasonably set to 0.5 as it indicates that 50 % of viewers are expected to see detail loss effect [8].

However this particular method has a limitation. The above model requires a set of two images. One with full backlight, while the other at dim backlight. Maintaining a set of two images affects the available memory. The method of finding the detailed loss effect could be simpler by finding the loss from a single dim backlight scaled image. This paper utilizes such a method. The method used in this paper, is particularly effective for sharpening major edges by increasing the steepness of transition while eliminating a manageable degree of low-amplitude structures [3]. The effect is achieved in an optimization framework making use of LO gradient minimization, which can globally control how many non-zero gradients are resulted in to approximate prominent structure in a sparsely control manner. Unlike other edge-preserving smoothing approaches, this method does not depend on local features, but globally locates important edges.

B. *Enhancement of invisible pixels*

Fig. 4.   Input image at 10% backlight

To enhance a backlight scales video sequence we need to boost and scale the luminance of pixels in the invisible regions
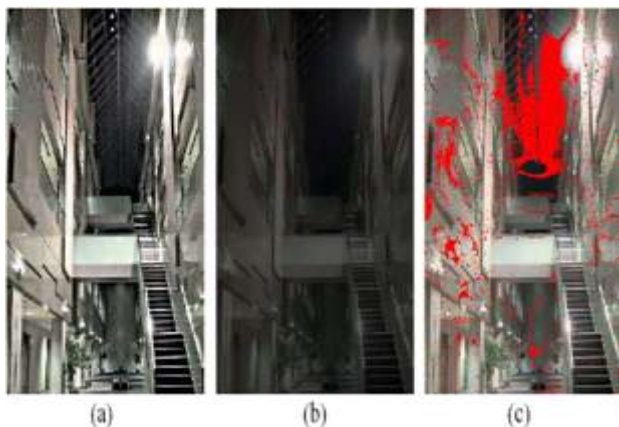

Fig. 5.   Visibility loss.(a)Original image at full backlight.(b)Original image at dim backlight.(c)detail loss.All visible pixels that become invisible are marked red.
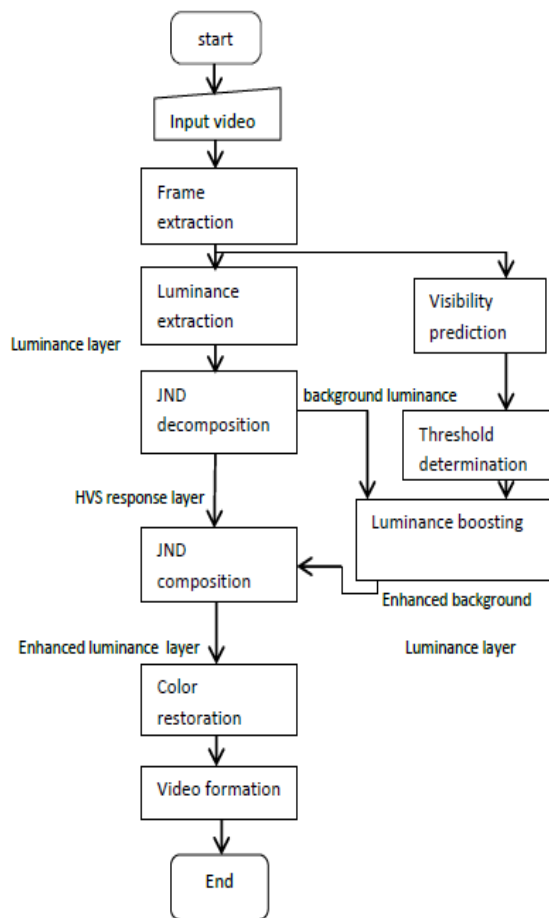

Fig. 6.   Flowchart of the proposed method

The flowchart of the proposed algorithm is shown in fig. (6)

The algorithm first extracts the frames of a video sequence. The frames are then divided into two layers: the HVS response layer and the background luminance layer. The luminance of the background luminance layer is boosted and the HVS response layer is kept unchanged. Before an image is decomposed, The HVS response function is created first [1].The HVS response function is a continuous function. It is made continuous by linear interpolation.
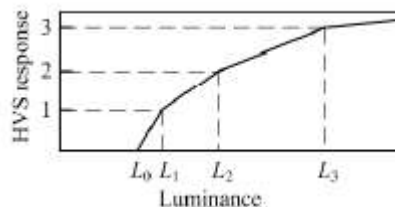

Fig. 7.   Linear interpolation of the HVS response curve

As illustrated in fig. (7) for a given background luminance L0, only the HVS responses of L0, L1, L2 and L3 are defined originally. The values of other HVS responses can be interpolated linearly. The JND decomposition [1] steps are described in fig. (8).
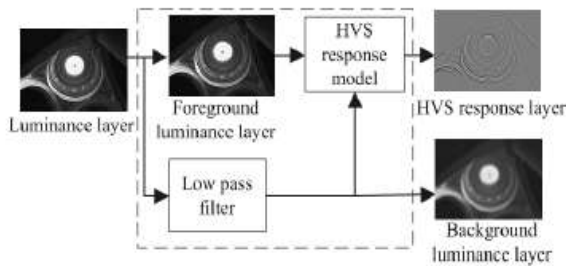

Fig. 8. Steps describing JND decomposition

As described in section III, we want to boost the luminance of dark pixels of an image to a perceptible range and at the same time preserve the perceptual contrast of the bright pixels. This seems to be a paradox, but this conflict can be easily be resolved. To achieve this following operation is performed.

$$B' = \begin{cases} BS, & BS \geq B_t, \\ B_t, & \text{otherwise}, \end{cases}$$

After boosting, JND composition is performed. This function takes the HVS response value and the boosted and compressed background value of each pixel as input and an enhanced luminance value is given as output. Let Le denote the enhanced luminance layer image. Then the enhanced color image is obtained by

$$M_e = M_o \left(\frac{L_e}{L_o} \right)^{\frac{1}{\gamma}},$$

Where Lo is the luminance value of original image, Mo is the original value of a color channel, Me is the enhanced pixel value of the color channel and gamma is a parameter for display. Other undesirable artifacts like halo effect can be compensated by using a bilateral filter which is used as an edge preserving filter. All the frame on which the algorithm is applies is finally combined to obtain the enhanced video sequence.

RESULTS AND DISCUSSION

The proposed method was compared with all the previously available methods, like ABIE, CBCS, TABS, and GD. Based on the evaluations it is evident that the proposed method scores high when used to enhance a dim image.

This method can easily be applied to a video sequence. Each frame of a video clip gets enhanced using the proposed algorithm
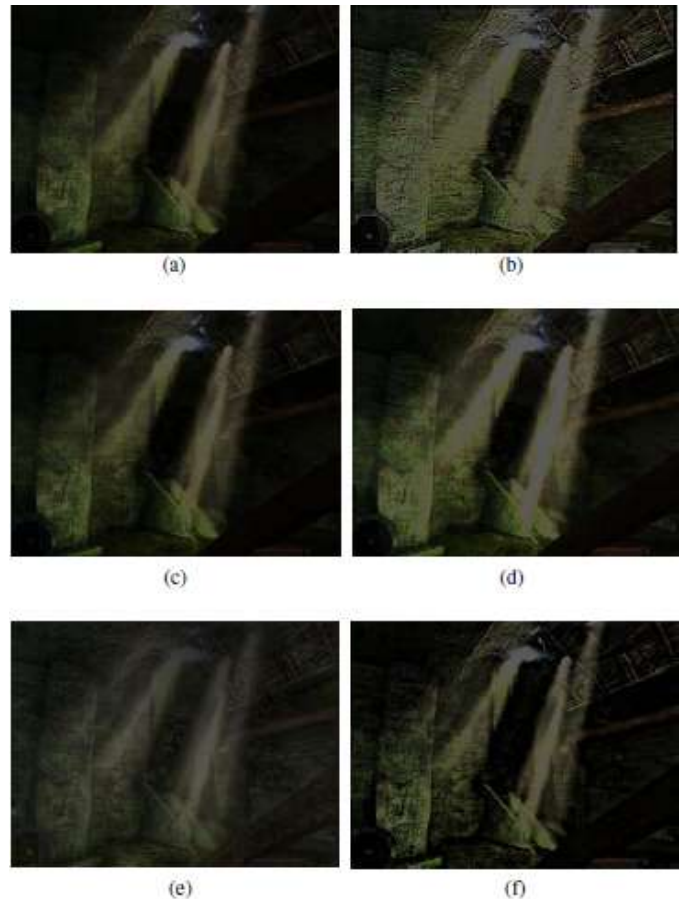

Fig. 9. A test image at 10 % backlight.(a) Original (b) ABIE (c) CBCS (d) TABS (e) GM (f) proposed method

CONCLUSION

In this paper, a perceptual algorithm is used to enhance backlight scaled image and video. The algorithm uses basic concepts of JND theory and the HVS model to achieve this goal. The method described in this paper effectively enhances the visibility of image details of dark regions without affecting the perceptual contrast of the bright regions. The algorithm when applied to a dim video provides an enhanced output video.

The algorithm can be developed as an application so that it could be used in mobile phones and LCD devices. Since using dim backlight scaled images can extend the battery life, such images can be equipped in all portable devices. These images could be later enhanced using the algorithm. Further improvements to the algorithm can enable video clips to be played even at absolutely low battery levels.

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