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Dynamic Range Enhancement of Images using Scalable Pyramids

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***Abstract*—Dynamic range enhancement is a process of correctly reproducing the highlights and shadows of high contrast scene on monitors and printers. There are basically two ways to increase the dynamic range of digital photographs namely exposure blending and tone mapping, but most of the display devices have limited dynamic range (LDR).Therefore various techniques have been proposed for compressing the dynamic range while retaining the important visual information, so the information can be displayed effectively. It would also desirable to retrieve an HDR image from an LDR image with minimal degradation through "companding".companding is a technique in which an HDR image is converted to an LDR image and later expanded back to high dynamic range. Hence in this paper we discuss a method to compand an image .The proposed technique preserves the features present in an image. Present technique is easy to implement and understand.**

***Index Terms*—high dynamic range, tone mapping, range compression, subbands, companding, haar wavelet, range expansion**

I. Introduction

Companding is a combination of two processes namely compressing and expanding. Thus if one is doing companding he is actually performing these two operations. Various companding algorithms A-law, µ-law, T-law [1] but few are there for companding images [2, 3, 4, and 5]

Image companding is specifically useful for the purpose of converting an image from higher resolution to lower resolution; or in other words, if one wants to represent an image using less number of bits per pixel. Various devices are available to capture images with high resolution or high dynamic range. There are devices which can display these images but major display systems available with the general consumers; like CRTs, LCDs, printed books, etc., have limited resolution, therefore, it is advisable to have a method which can convert the dynamic range of images in such a way that it can be efficiently displayed on the available range. The technique must be easy to understand and implement. The technique must also try to preserve the features and also avoid introducing unpleasant artifacts.

We will describe a technique that can for example turn an 8bit /channel image into a 3bit/channel TIFF, and later convert it back to a good approximation of the original 8-bit image.

II. Literature Review

The recent literature on HDR range compression has been extensively reviewed by others [[6] Tumblin 1999;[7] Dicarlo and Wandell 2001;[8] Devlin et al. 2002] and we refer the reader to these sources. The most straightforward techniques, sometimes called" global" tone-mapping methods, use compressive point nonlinearities.The image, I(x, y), is simply mapped to a modified image,I′ (x, y) = p(I(x, y)), where p() is a compressive function such as a power function, or a function that is adapted to the image histogram[[9]Tumblin and Rushmeier 1993;[10] Ward 1994;[11] Ferwerda et al.1996; [12]Larson et al. 1997]. The dynamic range is reduced, but the contrast of details is compromised and the images can look washed out. To compress the range while maintaining or enhancing the visibility of details, it is necessary to use more complex techniques. An early technique was described by [13]Stockham [1972], who observed that the image L(x, y) is a product of two images: an illumination image I(x, y), and a reflectance image, R(x, y). The illumination can vary greatly from region to region, which causes the dynamic range problems. Stockham estimated the local illumination as a geometric mean over a patch, and divided it out. This is equivalent to subtracting a blurred version of the image in the log luminance domain. The method unfortunately introduces artifacts known as "banding" or "halos" when there is an abrupt change of luminance, i.e., at large step edges. The size of the halo depends on the size of the blur. Multiscale techniques [[14]Jobson et al. 1997;[15] Pattanaik et al.1998; [16]Tumblin and Turk 1999], including some designed to capture properties of the human visual system, have reduced the visibility of the halos but have not removed them, and the computer graphics community has therefore explored other approaches.

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[17]Lee [2001] described a method that combines multiscale processing with traditional tone mapping. First, an image is run through a point non-linearity to reduce its dynamic range. The resulting image suffers from the usual reduced visibility of edges and other details. Lee then computes subband decomposition of the original image, and adds portions of the subbands back to the the tone-mapped image in order to augment the visibility of detail at various scales. Gain maps are used to control the amount of augmentation from the subbands. [18]Vuylsteke and Schoeters [1998] describe the use of several subband decompositions, including Laplacian pyramids, wavelets, and Gabor transforms, along with sigmoidal nonlinearities to limit the amplitude of the subband signals. This approach is effective, but can introduce distortions including haloes. We have explored a method to achieve good range compression and expansion using Haar wavelet pair with minimal artefacts.

III. Companding Of Hdr Images

Companding is a technique for compressing and then expanding (or decompressing) an analog or digital signal. It is a combination of two words "compressing" and "expanding".

Companding =compressing +expanding.

Companding has mainly two applications one would be in driving HDR displays with an LDR laptops and another application is HDR image compression which plays a major role in storing and transmission. Companding helps in retrieving an HDR image from an LDR image with minimal degradation. For instance we can turn a 12bit/channel image into an 8bit/channel image and later convert it back to a good approximation of the original 12-bit image. Since a great deal of hardware and software is designed around 8bit imagery, this could have many uses and most software applications today only handle 8bit images, and most video cards can only put out 8 bit images.

Companding of the HDR involves two operations

1. Range compression (encoding).
2. Range expansion (decoding).

Decoding should be fast and standard while encoding can be slow and versatile. So we first set a decoding (range expansion) technique. Then we iteratively search for an LDR image which gives a best approximation of the original HDR image when expanded using this technique. Here while companding an HDR image having 12 bit we use subband range compression and then invert the process to retrieve an12bit image.

IV. Range Compression (Encoding)

Range compression is performed using subband architecture having scalable pyramids. In subband range compression the input signal/image is decomposed into a set of

Band limited components, which is called subbands. Ideally, the subbands can be assembled back to reconstruct the original spectrum without any error. A general frame work for tone mapping of HDR images based on multiscale decomposition. The framework compresses HDR images.

A multi-scale decomposition splits s(x) (1d in this case) into n sub bands $b_1(x)$…., bn(x) with n filters f_1 to f_n, in a way the signal can be reconstructed as:

$$s(x) = \sum_{i=1}^{n} b_i(x) \quad (1)$$

Fig. 1 shows the block diagram of two-band filter bank with subsampling. At first, the input signal will be filtered into low pass and high pass components through analysis filters. After filtering, the data amount of the low pass and high pass components will become twice that of the original signal; therefore, the low pass and high pass components must be down sampled to reduce the data quantity. At the receiver, the received data must be up sampled to approximate the original signal. Finally, the up sampled signal passes the synthesis filters and is added to form the reconstructed approximation signal.

Analysis-synthesis filter banks are often implemented with hierarchical subsampling, leading to a pyramid. Here in this paper we are using Haar pyramid. Basically Haar wavelet pair consists of a low pass filter f_0= [1, 1] and a high pass filter f_1= [-1, 1] .In the figure input signal s(x) is split into a low band and a high band by convolution with *f*0 and *f*1. The filter outputs are subsampled by a factor of two, meaning that every

Other sample is dropped. If the input has *N* samples, each subband will have *N*/2 samples (sometimes called subband coefficients).The subbands are now upsampled by a factor of two by inserting a zero between each sample. Each of these zero-padded subband signals is convolved with a second filter, which is $g0 = [1, 1]$ for the low band and $g1 = [1, -1]$ for the high band. These signals are summed, and the original is reconstructed exactly. With the use of Haar pyramid the number of samples falls by 1/2 at each stage. The effective spatial scale of the corresponding high pass filters doubles, and the effective peak spatial frequency halves. Haar filters that we have used are the easiest filters to explain and implement.

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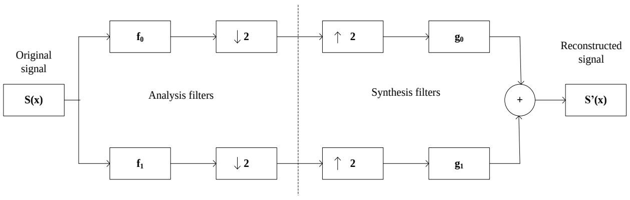

Figure 1.Two –band filter bank with subsampling

The main concept in range compression is to apply a gain control to each subband of the image .The first step in to build an activity map. The activity map is defined as:

$$A_i(x) = G(\sigma_i) \otimes |B_i(x)| \quad (2)$$

Where $G(\sigma_i)$ is a Gaussian kernel with $\sigma_i = 2^i \sigma_1$ which is proportional to i, the sub band scale. The activity map is used to calculate the gain map.

$$G_i(x) = p(A_i x) = \left(\frac{A_i x + \varepsilon}{\delta_i} \right)^{\gamma - 1} \quad (3)$$

Where $\gamma, \varepsilon [0,1]$ is compression factor and ε is the noise level that prevents the noise from being seen. $\delta_i = \alpha_i \sum_x A_i(x) / (M)$ is the noise control stability level where M is the number of pixels in the image, $\alpha_i \in [0,1,1]$ is a constant related to spatial frequency. Once the gain maps are Calculated, sub-bands can be modified:

$$B_i{}'(x) = G_i(x) B_i(x) \quad (4)$$

It is possible to calculate a single activity map for all sub-bands by pooling all activity maps:

$$A_{ag}(x) = \sum_{i=1}^{n} A_i(x) \quad (5)$$

From A_{ag} a single gain map G_{ag}= p (Aag) is calculated for modifying all sub-bands.

V. RANGE EXPANSION (DECODING)

The range expansion (RE) almost exactly the same as range compression(RC),but here the sub band coefficients are divided by the gain. The expansion operation is obtained by a straight forward modification of equation 4:

$$B'_{l,i}(x,y) = \frac{B_{l,i}(x,y)}{G_{l,i}(x,y)} \quad (8)$$

Next provided with range expansion method, we wish to find an LDR image I_l, that when expanded, well approximates a expected HDR image I_h.First step is to get I_l by compressing the range of I_h, using sub band decomposition and automatic gain control. Gain maps are computed from the sub bands $B_{h,i}$ of I_h,and are multiplied with the sub bands:

$$B_i{}'(x) = G_i(x) B_i(x)$$

If the transforms are orthogonal, and somehow G_h(x) is equal to G_l(x), then by performing the expansion in Eq.(8) we can have I_e .equal to I_h.This will not happen because $G_{h,i}$ and $G_{l,i}$ cannot be the same ,since one is obtained from the sub bands of I_l and other from the sub bands of I_h.But these will be close, as the sub bands of I_l and those of I_h are highly correlated, which makes because $G_{h,i}$ and $G_{l,i}$ highly correlated.

We can observe how much I_e and I_h differ and add a signal E_l to I_l in order to reduce error between I_e and I_h.We do this iteratively as shown in figure 2.encoding and decoding of the image using gain map, until we find a satisfactory result.

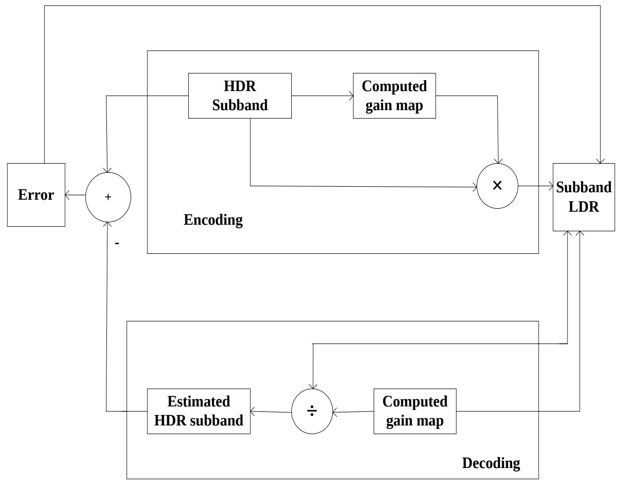

Figure.2.Encoding and Decoding of images using gain map

VI. ERROR FEEDBACK SEARCH

The search procedure illustrated in fig 3. Represents the optimized companding flow chart. We start the search by computing the range –compressed version of the original HDR image; this compressed image is quantized and made to pass through range expansion box. We feed the reconstruction error back into the loop and improve the compressed image.

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We calculate the difference between the expanded image and the original image, run this error image through range compression, and and add this to the previous quantized estimate. The resulting image is then quantized to get the updated estimate.

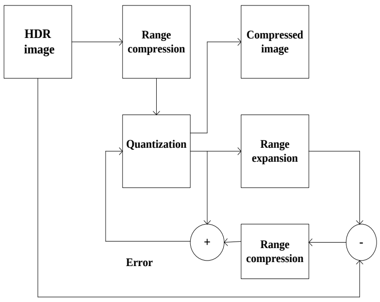


Figure 3.Optimised companding flow chart.

VII. RESULT

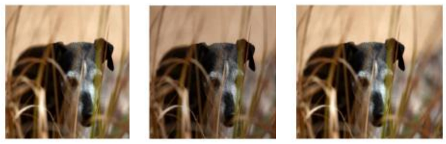
It is impossible to display a true HDR image in this paper, we will demonstrate an example in which the “HDR image” is 8bits, and the”LDR image” is 3 bits. That is we will compress an 8bit image to a 3 bit image- dropping its depth by 5 bits and then expanded back to 8 bits.

Figure.4, 5, 6.represents different companded images namely baby companding, ebony companding and sunrise companding respectively. Figures (a), (d), (g) shows an ordinary images at 8 bits (256) levels. Figure (b), (e), (h) represents the same image after it was scaled down to smaller range and linearly quantized to 3 bits., this image is shown with lower contrast and brightness, to suggest to a low dynamic range devices. This

Companding scheme provides us with an image that can be displayed directly on low dynamic range device. Figure (c),(f), (i), shows the 8 bit image that is reconstructed by the expansion technique.

(a) (b) (c)

Figure.4.Baby companding.
(a)original HDR image. (b)compressed LDR image. (c)expanded HDR image



(d) (e) (f)

Figure.5.Ebony companding.
(d)original HDR image. (e)compressed LDR image. (f)expanded HDR image

(g) (h) (i)

Figure.6.Sun rise companding.
(g)original HDR image. (h)compressed LDR image. (i)expanded HDR image

VIII. CONCLUSION

There are a number of techniques for expanding the low dynamic range images in such a way that they are viewable on high dynamic range displays. This expanding scheme is completely a reverse process of compression scheme.so that a low dynamic range image is expanded into a high dynamic range image with minimal degradation.

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