Layer Decomposition based Local Tone Mapping Operator

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Abstract— Dynamic range of an image directly defines the number of levels it can accommodate in an image. In general, a dynamic range of 256 is in use. Defining dynamic range of an image need to be done by considering the display unit on which the image will be displayed on. If the dynamic range extends over 256, the dynamic range is said to be high dynamic range. This range may extend up to 10,000. This kind of images can't be displayed on display units which can't differentiate that many pictorial information. This kind of pictorial information need to be converted so that the regular display units can adapt the format. This must be done without losing much information. This process is very crucial and is done by several tone mapping operators. Tone mapping operators are of two types, global and local. Global tone mapping operators apply same mapping function throughout the image while the local tone mapping operators use different mapping functions for local regions of the image. Though the quality of global TMOs is better, there are many halo effects in the converted image. In this paper, a global TMO based on decomposition is proposed intended to reduce these effects. Image is decomposed in to two layers, base, and detail. A hybrid decomposition and optimization are proposed to improve the quality of converted image.

Index Terms— base layer, detail layer, retinex decomposition, TMQI, Tone mapping

1 Introduction

Image capturing devices normally capture finite ranges of visual information. The original continuous visual information is enormous and will require huge memory as well as processing power. Instead, the practical capturing devices capture only finite levels hence lowering the need of memory and processing power. In the process, the infinite visual information is shrunk and lost. This is the case of standard dynamic range (SDR) image capturing devices. The SDR images are also termed as low dynamic range (LDR) images. In contrast to this, the high dynamic range image capturing devices, capture though not the whole, the maximum visual information.

The image captured using HDR is converted into a raw file. This raw file contains the whole information irrespective of the storage and display considerations. If we consider a specific display unit, the raw image is extracted at the output of the display unit. The conversion of HDR into LDR or SDR is called tone mapping. The operator who does is known as tone mapping operator. The main role is to get the output image without any loss of data from the raw image and to convert high dynamic range image into low dynamic range. The tonal values are adjusted so that the HDR images can be displayed at the output.

The TMOs are categorized into 2 types: 1. global TMOs and 2. Local TMOs. The most popular TMOs are Gamma correction and Reinhard TMOs. In the Global TMOs we consider only a single relative function. When a single curve is considered for the whole image the amount of useful information would be lost. In the local TMOs for every block we consider a curve so that we can overcome the information loss.

If we consider the relation between the raw data and the mapped image in case of global tone mapping operator the pixels are same. Here comes the overall image consideration, when all the visualization includes multiple background or multiple objects and wide range of appearances then some amount of data will be lost. This algorithm is faster in execution and simple to design [1]-[3].

In case of Local tone mapping operator, the mapping of pixels to a raw file uses a different relation. The dynamic range is defined as the lightest of the light and darkest of the dark of the image [4]-[6].

2 Gamma Correction

2.1 Introduction

Gamma correction is used to display an image perfectly on a computer screen. The overall brightness of an image is controlled by gamma correction. The image maybe breached or dark the brightness is corrected by gamma correction. The correction takes place not only on the brightness but also on the varying ratios of red, blue and green. Whatever the computer monitor may be the manufacturer considers only about the intensity to voltage response. For any computer monitor the intensity to voltage response varies roughly upto 2.5 power function. Let us consider an example, if we send an image to the input of the monitor and the certain pixel of an image with intensity be x. Then the output of the monitor is defined to be x^2.5. But the voltage value of the monitor ranges between 0 and 1. So we can find that the output value of the monitor ranges less than 2.5. Hence the gamma correction comes into usage so that the brightness of the image is adjusted. In the real-world applications, every monitor must work in the same way as the gamma corrector [7]. The power law equation for a gamma correction is defined as the

$$Vout=A.Vin^{\gamma}$$

Here we can get the output by the product of a constant with the input voltage.
Here A can either be 0 or 1. if gamma value less than 1 it is called encoding gamma and called as gamma compression [8].

If the gamma value greater than 1 it is called decoding gamma and called as gamma expansion. The gamma concept can be used at any nonlinear devices like cathode ray tubes. When the above equation is converted into logarithmic form then it can be defined as follows:

$$\gamma = d\log(Vout)/d\log(Vin)$$

Its application can be found in film photography and CRTs. The characteristic curve of a photo film is defined as

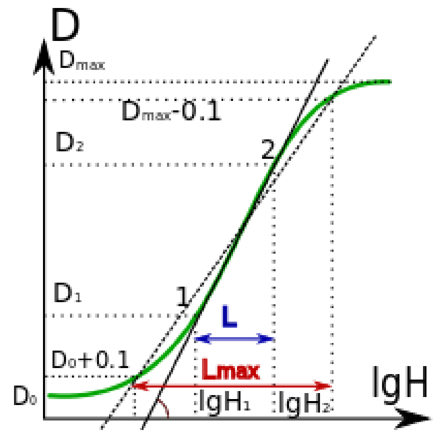


Fig. 1 Photo Film Characterization

2.2 Color Correction

It is a systematic process applied in stage lighting, television, cinematography and in other aspects. To alter the overall color of the light it uses color gels or filters. The color of the light is measured by a scale called as color temperature. If the color gels are not applied the image or a video may have a variety of colors. If color gels are applied in front of the light sources, it can alter the color of the light sources. Undesirable aesthetic can be produced by mixed lighting when it is displayed on a television or in a movie theater [9].

On the other side these color gels are mainly used in motivated lighting and in tint lights for artistic effect. It is a technical process that overcome the color issues and makes the image more natural as possible. The main aim behind the color correction is to make the image clearer as possible that human can see with the naked eye in the real world. The name itself suggests correcting the color issues by making the white appears white, black appears black and even more natural.

Its applications are mainly found in photoshop. It is a software used to edit and change the images, to create a clipped path and to get the desired image. One can use multiple tools to match, change or correct parts of an image. Making the process simpler we differentiate the color image into 3 parts: brightness, contrast, and color balancing. The first two can be categorized into tonal adjustments [10].

Basically, this color correction is a step-by-step procedure. Usually, data stored is 12 bits of information in a 16-bit file.so the image appears black or even dark when opened immediately. So, in order overcome this we must fill that range in the 16 bits. In the next step of procedure to set black for the point of reference as the maximum relative levels of RGB channels in an RGB image so that the image surface should be black is black.

The image now we can view is black is black. In this step we can find the saturated pixels of an image. With the help of curve adjustments, we can make the picture more natural to our naked eye.

3 Retinex-based Decomposition

A The basic retinex model of an image is given below.

$$S = R.L$$

where S is the original image, R is reflectance and L is illumination. The retinex theory was developed in 1971 by Land and McCann [11], is used as a fundamental theory in many core image processing schemes. The problem of intrinsic images is stated as follows:

Given an image $I : H = \{1,...,H\} \times W \rightarrow 255^3$ with N=HW and a set of images $I_1,\ldots,I_T$ or a video $V : H \times W \times T \rightarrow 255^3$ with N=HWT, estimate the respective reflectance image **R** and shading image **S** for each image. The above stated problem is originally stated by Barrow and Tenenbaum [12]. Land and McCann [11] introduced the retinex theory with an assumption of Mondrian world. A painting of Dutch painter Mondrian is shown in Fig. 1 along with the reflectance computation by Land and McCann [11]. The intuition behind the theory of Retinex is stated as follows.

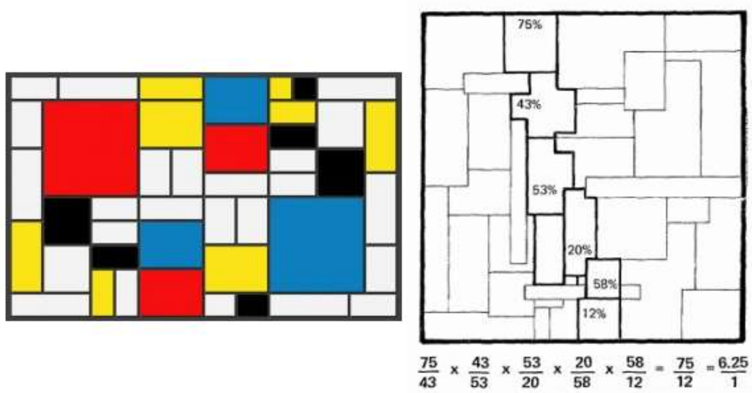


Fig. 2 Mondrian painting and the reflectance computation by Land and McCann [13]

Along the path, multiply the measured intensity ratios. These mechanisms are later formalized [14] and extended to color images [15]. The reflectance of each pixel in the channel I_C is calculated by building a family $\{x_k\}_{k=1}^{K_j} \subseteq H \times W$ of **J** paths. The reflectance $R_c(x_c)$ of pixel x_n in the channel **C** is calculated as follows.

$$R_C(x_n) = \frac{1}{J}\sum_{j=1}^{J}\sum_{k=1}^{K}\lambda\left(I_C(x_k) - I_C(x_{k+1})\right)$$

where

$$\lambda(x) = \begin{cases} |x| \; if \; |x| > \tau \\ 0 \; otherwise \end{cases}$$

The problem of this method is to choose the paths $\{x_k\}_{k=1}^{K_j}$ so that the above equation can calculate the reflectance accurately.

4 L0-L1 LAYER DECOMPOSITION

The optimization is given by

$$\min_{B} \sum_{p=1}^{N}\left\{\left(S_p - B_p\right)^2 + \lambda_1 \sum_{i=\{x,y\}}\left|\partial_i B_p\right| + \lambda_2 \sum_{i=\{x,y\}} F\left(\partial_i\left(S_p - B_p\right)\right)\right\}$$

Here the pixel is indexed by p and the total number of pixels is N. The optimization model contains three terms. The first term in the expression $\left(S_p - B_p\right)^2$ enforces the difference between the base layer original image to be very less. The second term $\left|\partial_i B_p\right|$ is an ℓ_1 gradient sparsity term which includes the partial derivative. The third term express the structural property of detail layer. It is expressed as an ℓ_0 gradient sparsity stretch. The term includes a representing function F(x) which is unity for x≠0 and zero for x=0.

The above objective function is non-convex. This is because of ℓ_0 regularization component contained in the third term. An irregular direction scheme of multipliers is presented to resolve this problem. The objective function is rewritten below with matrix terms.

$$\min_{b}\left\{\frac{1}{2}\|s-b\|^2 + \lambda_1\|\nabla b\|_1 + \lambda_2 1^T F\left(\nabla(s-b)\right)\right\}$$

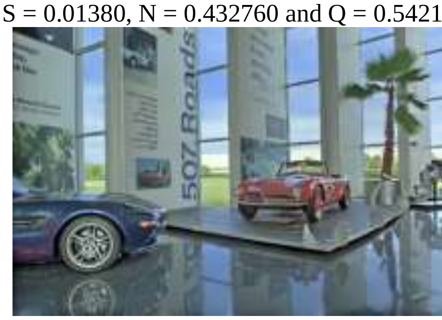
Here s and b belong to $\Re^N$ which are concatenated versions of ***S*** and ***B***. ∇ denotes a combination of multiple gradient operations given as

$$\nabla = \left[\nabla_x^T, \nabla_y^T\right]^T \in \Re^{2N \times N}$$

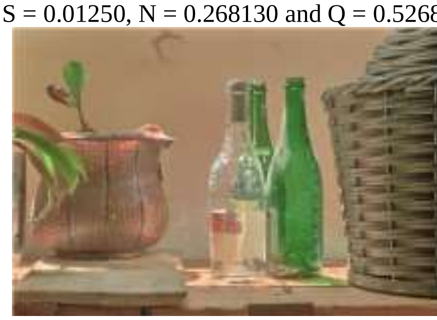
The ***F*** function performs elementwise non-zero indication. The resulting Lagrangian function is given below.

S = 0.01380, N = 0.432760 and Q = 0.54210

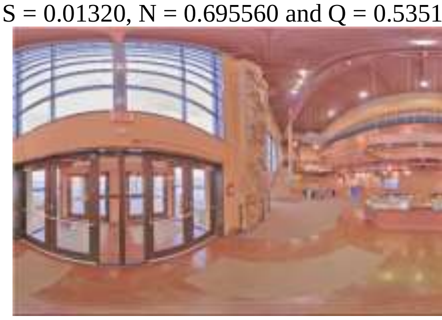
S = 0.01250, N = 0.268130 and Q = 0.52680



S = 0.01320, N = 0.695560 and Q = 0.53510

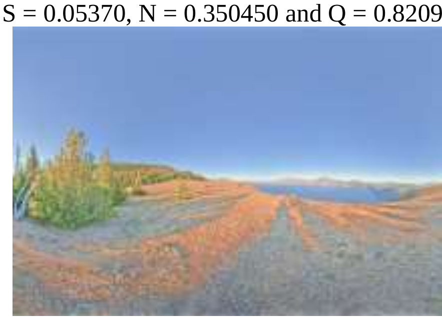


S = 0.01220, N = 0.488250 and Q = 0.52250

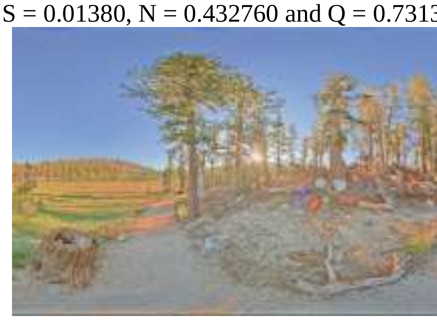


S = 0.05370, N = 0.350450 and Q = 0.82090

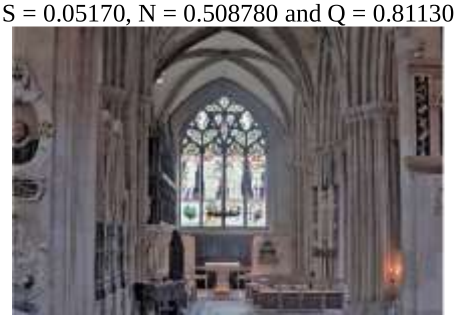
S = 0.01380, N = 0.432760 and Q = 0.73130



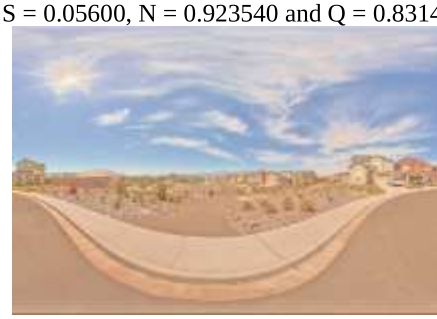
S = 0.05170, N = 0.508780 and Q = 0.81130



S = 0.05600, N = 0.923540 and Q = 0.83140



S = 0.01380, N = 0.153160 and Q = 0.54250



S = 0.05610, N = 0.652790 and Q = 0.83160

Fig. 3 Simulation Results using the proposed Tone Mapping

$$L(b,c_1,c_2,y_1,y_2)=\frac{1}{2}\|s-b\|_2^2+\lambda_1\|c_1\|_1+\lambda_2 1^T F(c_2)+(c_1-\nabla b)^T y_1$$
$$+(c_2-\nabla(s-b))^T y_2+\frac{\rho}{2}\left(\|c_1-\nabla b\|_2^2+\|c_2-\nabla(s-b)\|_2^2\right)$$

where y_i are Lagranian dual variables. The quadratic programming problem which will be resulted by splitting c_1^k, c_2^k, y_1^k and y_2^k can be solved using FFT effectively. When this $\ell_1 - \ell_0$ decomposition is applied to the radiance map, a piecewise smooth base and constant detail layers can be obtained.

5 Results and Discussions

Simulation results and performance comparison of the proposed technique are discussed in this section. The denoising, deblurring and compression operations are widely used. Tone mapping is widely used in image processing operations and it does not contain any reference image. In 2013, H. Yeganeh and Z. Wang proposed an objective quality assessment in the form of Tone Mapped image Quality Index (TMQI) [16][17]. This parameter balances the importance of two existing objective measures. They are Structural fidelity (S) and Naturalness (N). The structural fidelity is defined as follows.

$$S = \prod_{l=1}^{L} S_l^{\beta_l}$$

Here L is the number of scales and β_l is the weight for l^{th} scale. The structural fidelity is defined by dividing the image into patches. The local fidelity S_l is defined by the following relation where x and y are the respective patches from HDR and tone-mapped images [18]-[21].

$$S_{local}(x, y) = \frac{2\sigma'_x \sigma'_y + C_1}{\sigma'^2_x + \sigma'^2_y + C_1} . \frac{\sigma_{xy} + C_2}{\sigma_x . \sigma_y + C_2}$$

Here σ_x, σ_y and σ_{xy} are the auto and cross correlations. C_1 and C_2 are the positive stabilizing constants. Naturalness is basically a subjective measure; but a quantitative analysis is presented for this parameter. Histograms of mean and deviations are the measures of intensity and contrast. Correspondingly, the Naturalness is defined as

$$N = \frac{1}{K} P_m P_d$$

Here K is a normalization factor given by K = max $\{P_m\ P_d\}$. P_m and P_d are the density functions of mean and deviation respectively. The TMQI is defined in terms of these two parameters as follows.

$$TMQI = aS^{\alpha} + (1-a)N^{\beta}$$

The Fig. 3 shows the tone mapped image along with the objective measures.

6 Conclusions

In the described project, a layer decomposition is defined as the separation of input image into base and detail layers. This technique is mainly used for the image restoration purpose. Comparatively this technique preserves much useful data in the raw image. In the Global TMOs we have overcome the halo effect and over enhancement effect. The dynamic range has been reduced in base layer and whereas the spatial structure has been increased in detail layer. These are the common drawbacks in the global tone mapping which can overcome with these multi tone mapping technique and visual quality is good in multi tone mapping. Technique applied on some images proved that this is worthy with high quality.

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