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Generation of YUV Color Channels for TMO Images – An Analysis

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Abstract:-- **Tone mapping is a technique used in image processing to map one set of colors to another to approximate the appearance of high dynamic range images to a medium that has more limited dynamic range. Tone Mapping Operators (TMOs) mostly operate on the image luminance channel intensities. In this paper, a Rani TMO has been proposed. Its performance is compared with three important tone mapping operators named Durand, Drago and Raman and analyzed for YUV color spaces. These results are obtained by first converting HDR image to LDR image using TMOs then processed for YUV color spaces. Objective assessment parameters such as MSE, mean, median, Luminance, PSNR and mPSNR have been calculated. The results reveals that proposed Rani TMO is more efficient compared to other TMOs. The work presented in this paper finds applications in the fields of remote sensing, digital photography, image editing and virtual reality.**

Keywords: **--Color Spaces, TMOs, HDR, LDR, Luminance.**

I. INTRODUCTION

With the unprecedented advent in the image acquisition renderers, the usage of HDR imaging is increasing tremendously in the recent past in the field of display technology since it permits the preservation of complete information on luminance values in the scene for each pixels. Initially, HDR images were obtained as the result of lighting simulation and physically based rendering of synthetically modeled scenes [1]. In high dynamic range (HDR) images, the range of intensity levels could be of the order of 10,000 to 1[2] where as for LDR displays the intensity levels are up to 400 to 1. Tone Mapping Operators (TMOs) have been evolved to map the difference in intensity levels between perceptual HDR images and LDR display devices. TMOs are also useful to enhance the ability to use LDR displays which have physically real light values. This allows an accurate representation of the luminance variations in real images, ranging from high intensities to low intensities. The significant TMOs such as Durand, Drago and Raman have been considered in this paper along with the proposed Rani TMO. Low Dynamic Range (LDR) Images obtained using above TMOs are further processed for color spaces. The objective parameters such as MSE, mean, median, luminance,PSNR and mPSNR have been calculated and analyzed.

II. TONE MAPPING OPERATORS

The concept of tone reproduction was first introduced by Tumblin and Rushmeier[3] to compress the dynamic range of an image to the range that can be displayed on physical devices in case that the luminance range of the images is much broader than that of physical devices. Tone mapping solves the problem of strong contrast reduction from the scene. It has the capability of preserving the image details and color appearance which are important to identify the original scene. The goal in realistic applications is to obtain a non-cognitive match between a real image and a displayed image. A number of tone mapping techniques have been presented, and most of them can be categorized into two groups: global and local operators. Global operators apply the same transformation to every pixel of an image while local ones adapt their scales to different areas of an image. Global techniques are simple and fast, but they can cause a loss of contrast. Contrast reduction and color inversion are examples of common global tone mapping methods. The local operators are based on the fast bilateral filtering methods. Local operators are complicated compared to the global operators. The local operators can show artifacts (e.g. halo effect and ringing). The output of Local operators looks unrealistic, but provides the best performance.

Drago[4] introduced a method which is called adaptive logarithmic mapping. This meets the need for a fast algorithm suitable for interactive applications. It automatically produces realistical images for a broad variation of scenes exhibiting high dynamic range of luminance. Drago is presented in equation – 1.

$$\log_{\text{base}}(L) = \frac{\log(L)}{\log(base)} \quad \ldots(1)$$

Log_{base} is ranging from $\log_2$ to $\log_{10}$. The $\log_{10}$ is applied for the brightest image pixel. For remaining pixels the logarithmic base is smoothly interpolated between values 2 and 10 as a function of their luminance.

Durand[5] has developed a TMO algorithm to adjust local contrast to bring out details of high dynamic range scenes. To do so the operator decomposes every image into a base layer and a layer with fine details, then compresses contrast of the base layer. Durand model is given in equation – 2.

D=log(L+2.3*1e^5) . . .(2)

Adjustment of contrast is performed only to the base layer to preserve details.

According to Raman TMO[6], for an image f(x,y) of size MxN, the functions σ_s and σ_r are used in a bilateral filter which represent the standard deviations for spatial and range Gaussian functions.

$$\sigma_s = k_1\ X min(M, N) \ldots (3)$$

$$\sigma_r = k_2 X\left(max\left(f(x,y)\right) - min\left(f(x,y)\right)\right) \ldots (4)$$

Where, K_1 and K_2 are positive real constants. K_1 and $K_2$are assigned the values of 1 and 1/10 respectively.

A Tone mapped operator in terms of preserving edges and avoiding halos, has been proposed by Ashikhmin. Equation – 5 gives the model developed by Ashikhmin

$$L_d(x) = \frac{L_w(x) f(L_w, a(x))}{L_w, a(x)} \ldots (5)$$

Where f is tone mapping function, $L_{w,}a(x)$ are local luminance adaptation and $L_w(x)$ is the luminance for the pixel location x.

A new model named Rani TMO has been developed and presented in this paper to overcome the drawbacks of Ashikhmin TMO such as high MSE and low mPSNR . The Rank TMO model is given in equation – (6)

$$L_d(x) = \begin{cases} \frac{x}{0.014} & if\ x \le 0.0034 \\ 2.4483 + \log(\frac{x}{0.034}) / 0.4027 & if\ 0.0034 \le x \le 1.0 \\ 16.5630 + \frac{x - 1.0}{0.4027} & if\ 1.0 \le x \le 7.2444 \\ 32.0693 + \log(\frac{x}{7.2444}) / 0.0556 & otherwise \end{cases} \quad \ldots (6)$$

The Rani TMO is compared with other significant TMOs and found superior among them.

III. COLOR SPACES

Most capturers and display devices have their own native color space, generically referred to as device dependent RGB. Color spaces have been demonstrated in two different concepts. First, they are represented by a set of formulas that define a relationship between a color vector and the standard CIE XYZ color space. This is most often given in the form of a 3-by-3 color transformation matrix, although there are additional formulas if the space is nonlinear. Second, a color space is a 2D boundary on the volume defined by a vector, usually determined by the minimum and maximum value of each primary color gamut. Optionally, the color space may have an associated quantization if it has an explicit binary representation. Color spaces have been classified as RGB, YUV and HSV Color spaces. Analysis on YUV color space for a HDR image is presented in this paper because it is used by the composite color video standards. The details of these color spaces have been presented in the following subsections.

3.1 RGB Color Space

The red, green, and blue (RGB) color space is widely used throughout computer graphics. Red, green, and blue are three primary additive colors and are represented by a three-dimensional Cartesian coordinate system. Therefore, the choice of the RGB color space simplifies the architecture and design of the system. However, RGB is not very efficient when dealing with "real-world" images. Because, all three RGB components should have equal band-width to generate any color within the RGB color cube.

3.2 YUV Color Space

The YUV color space is used by the PAL, NTSC and SECAM composite color video standards. The black-and-white system uses only Luma (Y) information; color

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information which is presented in U and V components was added in such a way that a black-and-white receiver would still display a normal black-and-white picture. A color receiver decodes the additional color information to display a color picture. The equations (7-12) are used to convert Gamma corrected RGB to YUV.Assume a digital image with R´G´B´ values in the range of 0– 255. Then, Y has a range of 0–255, U a range of 0 to 112, and V a range of 0 to 157. These equations are usually scaled to simplify the implementation in an actual NTSC or PAL digital encoder or decoder.

$$Y = 0.299R' + 0.587G' + 0.114B' \quad (7)$$

$$U = -0.147R' - 0.289G' + 0.436B' \quad (8)$$

$$V = 0.615R' - 0.515G' - 0.100B' \quad (9)$$

And

$$R' = Y + 1.140V \quad (10)$$

$$G' = Y - 0.395U - 0.581V \quad (11)$$

$$B' = Y + 2.032U \quad (12)$$

3.3 HSV Color Space

The hue, saturation and value (HSV) color spaces have been preferred for manipulation of hue and saturation for the purpose of shifting or adjusting the colors since it yields a greater dynamic range of saturation.

IV. OBJECTIVE ASSESSMENT PARAMETERS

The objective quality of the tone mapped images can be assessed based on the parameters such as PSNR and mPSNR(modified Peak Signal to Noise Ratio), MSE(Mean Square Error), Mean, Median and Luminance. mPSNR metricis based on Human Visual System characteristics and correlates well with the perceived image quality. It is expresses as given in equation – 13.

$$mPSNR = 10\log_{10}\frac{(col * 255^2)}{MSE} \quad (13)$$

If M denotes the number of pixels in an image then we write A = {a1 .. a_M} and B = {b1 .. b_M}. The MSE for images A and B is calculated using equation-(14)

$$MSE(A,B) = \frac{1}{M}\sum_{i=1}^{M}(a_i - b_i)^2 \quad (14)$$

The squaring of the deviations dampens small difference between the 2 pixels but increases large ones.

Let f(x,y) be the input image with intensity of A of size MxN, then the mean of image is given by

$$Mean = \frac{1}{MN}\sum_{i=1}^{M}\sum_{j-1}^{N}A_{ij} \quad (15)$$

The log-average luminance is determined by calculating the geometric mean of the luminance values of all pixels. In a gray scale image, the value of luminance is the pixel value. In a color image, the value of luminance is found by a weighted sum.

Luminance =0.213red+0.715green+0.072blue (16)

V. RESULTS AND DISCUSSION

In this paper, HDR image with a resolution of 803 X 535 shown in Figure-1 is used as input image. Tone Mapped Operators are applied on HDR image to convert it to LDR image. HDR image is initially processed to generate image corresponding to YUV luminance color space. In the second step, the YUV color space image has been tone mapped using different Tone Mapping Operators. This step produces LDR images for YUV channel. The LDR image obtained using Durand TMO for YUV channel is shown in Figure-2.

Figure 1. HDR input image

Figure 2. YUV Luminance channel image for Durand TMO

The YUV color space image has been tone mapped using Drago. The LDR image obtained for Drago TMO for YUV color space is depicted in Figure-3. Similarly produced Raman image for YUV is shown in Figure-4 and for proposed Rani TMO model image for YUV is presented in Figure-5.

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Figure 3. YUV Luminance channel image for Drago TMO

Figure 4. YUV Luminance channel image for Raman TMO

Figure 5. YUV Luminance channel image for proposed Rani TMO

To characterize the performance of TMOs, the significant objective assessment parameters such as Mean, Median, Luminance, Mean square error (MSE), PSNR and modified PSNR are calculated for the luminance channel images of three different TMOs and are tabulated in Table-I. The parametric values noted in table-1 reveals that better conversion to match the luminance of LDR displays and optimized PSNR values are obtained for proposed Rani TMO model compared to Durand, Drago and Raman TMOs.

Table 1: Objective Assessment parametric values for YUV Luminance Channel for different TMOs

Parameter	Tone Mapped Operators			
	Durand	Drago	Raman	Rani
MSE	2.5732	0.0447	0.1087	0.0379
Luminance	0.3694	0.7358	0.5792	0.8235
Mean	0.7737	0.2613	0.5759	0.2206
Median	2.0209	0.9997	0.7304	0.6381
PSNR	24.0314	23.2657	23.2738	25.3163
mPSNR	17.6874	14.47	10.3289	18.1684

Comparison plots have been drawn to observe the trend of variation in objective assessment parameters. The comparison plots corresponding to the values of mean, median and MSE is shown in Figure-6. The lesser the MSE the more the tone mapping in conversion. Though the MSE value of Drago TMO is less compared to Durand and Raman TMOs, Rani TMO has given much lesser MSE value. Hence, the proposed Rani TMO has produced better values.

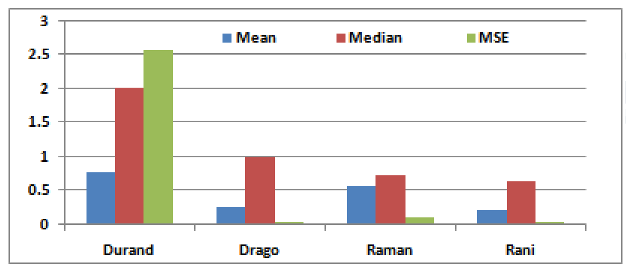

Figure 6. Comparison plot for Mean, Median and MSE for TMOs under study

The plots corresponding to the values obtained for Luminance, PSNR and mPSNR are depicted in Figure-7. The higher the PSNR and mPSNR, the more accurate the quality of LDR image. This criteria has been met more effectively by proposed Rani TMO model. Further, from the Figure-7, it is also clear

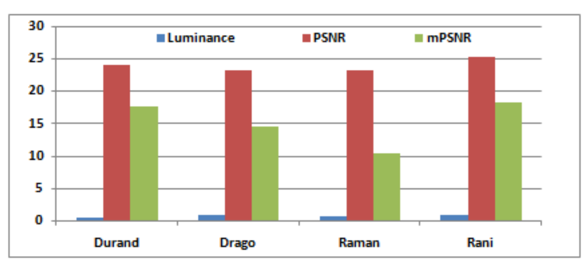

Figure 7. Comparison plot for Luminance, PSNR and m PSNR for TMOs under study

that luminance value obtained with Rani TMO is high which is wanted to map the luminances between HDR image and LDR image. The proposed model has produced the percentage of improvement in MSE by 66.89%, Luminance by 55%, PSNR by 5.3% and mPSNR by 2.7% compared to Durand TMO.

VI. CONCLUSION

The images corresponding to luminance channel YUV have been generated. The parametric values noted in tables 1 reveal that while all TMOs are generating luminance channel images, the optimum values for objective parameters under consideration have been obtained for proposed Rani TMO. Hence, Rani TMO has been found to be more useful compared to other TMOs under study.

The need of Tone mapped operators has been identified to display captured HDR images in commonly used LDR displays. Though, few TMOs such as Durand, Drago and Raman have already been developed, there is a requirement for evolution of more efficient TMOs to display images more realistically. With this motivation, a new TMO has been proposed in this paper. The performance and quality assessment parameters such as mPSNR, MSE, Mean, median and Luminance are calculated and reported. The values calculated for luminance channels reveal that the proposed Rani TMO has produced promising results when compared Durand, Drago and Raman TMOs. The work presented in this work finds applications in the fields of remote sensing, digital photography, image editing and virtual reality.

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