Gamut Mapping for Tone Mapping Operations

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***Abstract*—Gamut mapping is a process to map colors from a higher gamut range to a lower gamut range or vice versa. To view UHD content in HD displays we need to map the out of BT.709 gamut colors to BT.709 gamut. This can be done in any colorspace and with various projection techniques. In this paper, we present a hybrid approach of the existing two methods of Closest Point and Towards White Point and take more samples between the points obtained by these two methods. We have used the LAB colorspace and CIE ΔE2000 to compare the original color codes and color codes obtained by all our sample points to generate a Look-Up Table for gamut mapping.**

***Index Terms*—Gamut Mapping, UHD, CIE DeltaE 2000, sampling points, midpoints**

I. Introduction

With the arrival of UHD displays, the content providers have pushed for generating more and more UHD content. The major difference between UHD and HD content, apart from brightness range, is that it accesses color points which are not inside the HD color gamut. The Chromaticity diagram is a representation of all the colors visible to the human eye. Gamut is a subset of colors which can be displayed by a display and is defined by its white point and color primaries. Every display cannot show the same range of colors. So different gamuts are defined to represent which displays can show which colors. Some standard gamuts are sRGB, AdobeRGB etc.

The gamut that contains HD color points is known as ITU-R recommendation BT.709 or Rec.709 [3] and similarly, the gamut for UHD color points is known as ITU-R recommendation BT.2020 or Rec.2020 [2]. BT.709 covers 35.9% of the chromaticity plane and BT.2020 covers 75.8% of the chromaticity plane. To distribute and view the UHD content for HD displays we need to map the content from the wider gamut of BT.2020 to the narrow gamut of BT.709. As we go from higher gamut to lower gamut we need an efficient process of mapping so that we can get as low a color difference as possible between the original and mapped color codes. For this, we will first look into existing approaches of gamut mapping process and then we will propose our hybrid approach for gamut mapping of BT.2020 to BT.709.

II. Existing Approach

There are two major existing approaches to map color values from higher gamut to lower gamut which are Closest point [4] and Towards White Point.

A. Closest Point

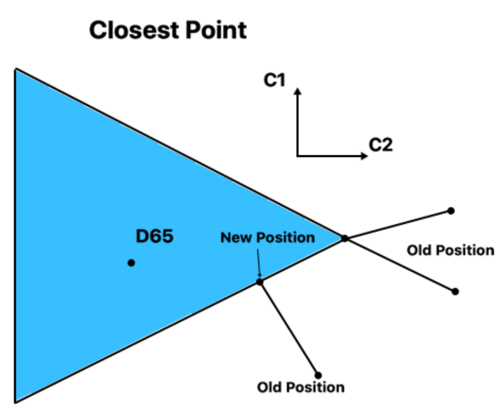

Fig. 1. Illustration of Closest Point

The Closest Point algorithm projects out of gamut pixels to the closest possible position inside the color gamut as shown in Figure. This algorithm maps the wider gamut's color codes to a line that yields the minimum Euclidean distance between the source and mapped color value. If clipping is used, the intersection of this line and the gamut border will be the mapped color. This algorithm will, therefore, alter the hue as well as the saturation even in color spaces where the hue lines are perfectly straight. The idea is that if the color space is perfectly perceptually uniform, the error between the mapped and original will also be the smallest perceptual difference. This projection technique is also quick compared to towards white point.

B. Towards White Point

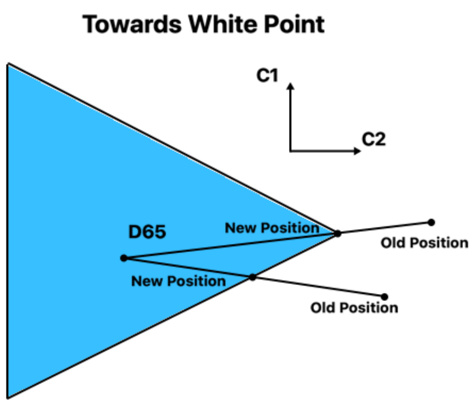

Fig. 2. Illustration Towards White Point

This algorithm projects out of gamut pixels to the intersection between the boundary of the color gamut and the segment line defined by the white point and the pixel positions. Therefore, the color will be projected to the line that connects the original value of color to the white point. This is illustrated in Figure. In cases where the compression method is used the destination color can be any point of the corresponding projection line, which lies inside the gamut.

C. Hybrid Approach Between Closest Point and Towards White Point

The Hybrid Mapping approach [1] maps each R'G'B' color code using 10 bits in the UHD or BT.2020 gamut to the corresponding color code of HD or BT.709 gamut using 8 bits. This method uses 6 color spaces xyY, Yu'v',Yuv CIELUV, CIELAB and ICaCb and two projection techniques, namely,Towards White Point and Closest Point. Each color point from the larger gamut can be mapped using the mentioned color spaces and projection techniques. Out of these color spaces, ICaCb color space has hue lines constant whereas except xyY, all other spaces are perceptually uniform. The LUT formed was of a large size and consisted of minimum error points obtained by two projection techniques.

Fig. 3. Proposed Workflow

III. Proposed Method

The previous hybrid approach used 6 color spaces and two projection techniques to find the least error point for each corresponding point in BT.2020. For our approach we are using only LAB color space and taking more than two sample points for each corresponding color code in BT.2020. We chose LAB color space as along with LUV color space, it is the most perceptually uniform color space. Also, Previous papers [5] show that CIE LAB gives minimum error and least distortion for both TWP and Closest Point. Hence we have decided to work in CIE LAB space.

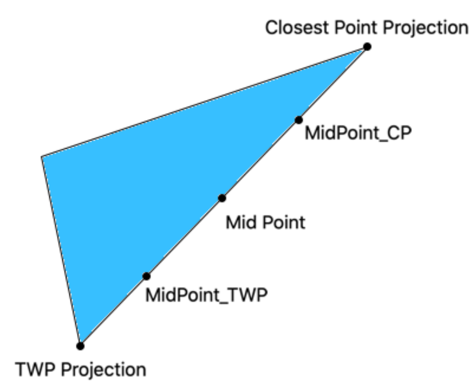

Fig. 4. Proposed Workflow

We first calculate closest point and towards white point for each corresponding input point in BT.2020. For this project we have taken the entire BT.2020 space, that is, 107374182 or 2^{30} points. Then we calculated the error for both the projected points and the point with lower error is referred to as the lower bound and that with higher error is referred to as the upper bound. Then we took a median of the line segment forming between these two points. The next step included taking a midpoint of the median and the lower bound and another midpoint between the median and the upper bound. Then the error is calculated for all three of these points corresponding to each input point. Finally,a look up table is resulted out of all these points corresponding to each of the original points. Therefore, In our hybrid gamut mapping technique, we generate five points for each input points namely, TWP, CP, Midpoint, Midpoint_TWP and Midpoint_CP.

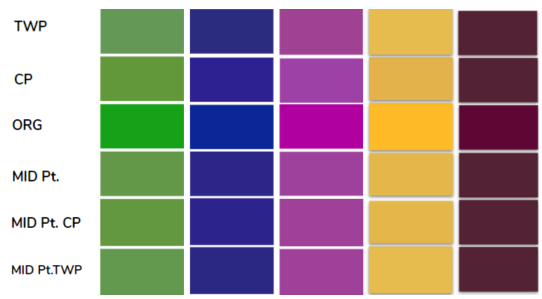

Fig. 5. Visual Comparison of various projection techniques

To calculate the error we are using the DeltaE Performance metrics. It is a metric to understand how the human eyes perceive the colors. The available DeltaE metrics are ΔE76 [9], ΔE94 and ΔE2000 [6]. From all available ΔE metrics we are using ΔE2000 as it is the most complicated yet most accurate ΔE metric. As for our work we need the most accurate metric we chose ΔE2000 and calculate error for the entire UHD gamut points.

IV. Results And Discussion

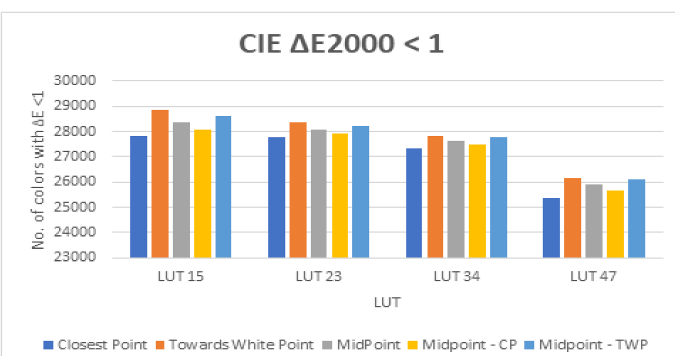

Fig. 6. Comparison-I between two projected methods

Fig. 6 presents the results of the proposed hybrid gamut mapping method. We selected CIELAB as it has the least average error among all color spaces in [5] and is perceptually uniform. It can be observed that the trends depict that the percentage of colors points with an error value of less than one should increase for the newly proposed projection points (Midpoint and Midpoint - TWP). This is an important aspect since the CIE Δ E2000 metric returns a value greater than

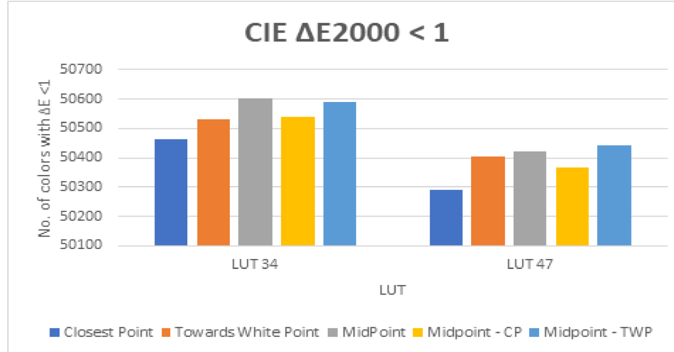

Fig. 7. Comparison-II between two projected methods

1 only if the difference between the two tested colors is noticeable.The increase in the number of colors with error less than 1 means that more colors can be mapped below the visible threshold and the overall Quality of Experience increases for the customer.

However, it can be observed in Fig. 7 that there is no one best projection method and point with which the best result can be obtained by comparing the CIE Δ E2000 values of all the sampling points. The results indicate that as CIE Δ E2000 error increases in the LUT, Mid-Point projection tends to perform better than both towards white point and closest point projection techniques. It was also observed in a few cases that Midpoint – TWP performed better than every other method.

Our method has been computed offline and is implemented in a Look-Up Table (LUT). The challenge faced with this method was the sheer size of the LUT. By categorizing the color pixels based on the B channel, the computation time was reduced to a considerable amount and with powerful machines can be further reduced.

A. Future Works

The Look Up Tables obtained for each of the five points for all the colors in BT.2020 gamut along with their CIE ΔE2000 error are generated.One possible way to decrease the size of these LUTs is by considering only out of gamut values in the LUT and ignoring the sampling points which lie outside the hue line in the LCH color space. Such a LUT could be implemented, to guarantee that each color code is mapped to a color code resulting in the lowest perceptual distortion possible.Further optimization can be done by generating a master lookup table that selects the points having least possible error amongst the five points. The 10 bit input image or video is then fed to LUT and the output will be the image or video in BT.709 gamut with least color error.

V. Conclusion

In this paper, we proposed a hybrid gamut mapping technique to convert BT. 2020 color code values to the BT.709 gamut using the Closest Point and Towards White Point and the sampling points in the line joining the towards white point and closest point. The results showed that our method will reduce the overall error introduced by the mandatory gamut conversion. The results indicate that there is no one best projection method, but a combination of the different methods has the least color distortion. Assuming further optimization is carried out on the created LUT, computation time could be reduced to a vast extent and could make it more practical.

Gamut Mapping	Number of Pixels with error <1
Mid-Point-CIELAB	339042988
Mid-PointTWP-CIELAB	336989991
Mid-PointCP-CIELAB	336819936

Fig. 8. Results of the Hybrid(Mid-Point) Gamut Mapping

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