

# INTER-PLANE PREDICTION FOR RGB VIDEO CODING

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## Abstract

*This paper presents an efficient video coding method in RGB space. Generally RGB space is regarded as a bad space from a compression point of view. Each RGB component contains the color information along with luminance information. This redundancy degrades the coding efficiency. To exploit the inter-color redundancy, the RGB space is usually converted into another color space. But it inevitably causes color distortion due to the rounding operation involved. For professional applications it is essential to maintain the original color fidelity. To cope with these problems we propose an inter-plane prediction (IPP) that increases the coding efficiency in RGB space while avoiding color distortion. The proposed IPP exploits the redundancy of the residual images, which exists even after intra/inter prediction in MC-DCT based codec. The simulation results show that by applying the IPP to the MPEG-4 AVC/H.264 4:4:4 codec we can achieve up to 40% higher coding efficiency than that of the coding without IPP option. We also show there exists an achievable PSNR limit if color space conversion is involved. In other words, coding in a given space is important to keep the fidelity of the original data for professional applications.*

## I. INTRODUCTION

In this paper, we present a new video coding technology in RGB space. Generally, RGB space is regarded as a bad space from a compression point of view [1]. Each R, G, and B component contains the color information along with the luminance information. This redundancy degrades the coding efficiency. To exploit the inter-color redundancy, the RGB space is usually converted into other color space such as YCbCr. Since most of the spatial information is in Y component, Cb and Cr components can be further subsampled to compress the data without significant loss of image quality. But in professional applications such as digital cinema and professional television production and post production markets, it is very important to maintain the original color fidelity. But the color space conversion from RGB to YCbCr and back

to RGB involves rounding error [2].

To cope with these problems, we propose to use an inter-plane prediction (IPP) coding that avoids the color distortion caused by the color space conversion, by coding directly in the given RGB space. This method can achieve higher PSNR than the color space converted coding methods as detailed in Section II. At the same time, it maintains great coding efficiency that YCbCr space can achieve. By applying the IPP to the MPEG-4 AVC/H.264 4:4:4 codec, we achieved up to 40% higher coding efficiency than that of the coding without IPP option.

In Section II, we describe the proposed IPP technology in detail and show how the color space conversion results in the color distortion. The simulation results are summarized in Section III followed by the conclusion in Section IV.

## II. INTER-PLANE PREDICTION CODING

### A. Color Distortion Due to Color Space Conversion

In this section, we analyze the color space conversion error and show that there exists an achievable PSNR limit due to this rounding error. This analysis assumes that we use 8 bit fixed-point RGB data ranging from 0 to 255 and use the same number of bits of precision to map the RGB data to another color space and to come back to the RGB space. We can generalize this analysis for any N-bit data.

The RGB to YCbCr conversion using the Rec. BT.601 is performed as follows:

$$\begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} = \begin{bmatrix} 0.2126 & 0.7152 & 0.0722 \\ -0.1146 & -0.3854 & 0.5 \\ 0.5 & -0.4542 & -0.0458 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (1)$$

After the conversion, the rounding operation is applied which introduces 1/12 rounding error due to uniform rounding quantization error.

The YCbCr to RGB conversion is performed as follows:

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1.0 & 0.0 & 1.5748 \\ 1.0 & -0.1873 & -0.4681 \\ 1.0 & 1.8556 & 0.0 \end{bmatrix} \begin{bmatrix} Y \\ Cb \\ Cr \end{bmatrix} \quad (2)$$

The rounding operations here introduce  $\frac{1}{12}a^2$  rounding error from each component (Y, Cb, Cr) where  $a$  is the coefficient of the color conversion matrix in (2). It is due to the inherent rounding error from RGB to YCbCr conversion. For example, we have the following rounding error for G component:

$$Error = \frac{1}{12}(1^2 + 0.1873^2 + 0.4681^2).$$

The overall conversion error for G component,  $E_G$ , is:

$$E_G = \frac{1}{12}(1^2 + 1^2 + 0.1873^2 + 0.4681^2) = 0.1878.$$

We can calculate the conversion error for the other components using the same method.

$$E_R = \frac{1}{12}(1^2 + 1^2 + 0^2 + 1.5748^2) = 0.3733,$$

$$E_B = \frac{1}{12}(1^2 + 1^2 + 1.8556^2 + 0^2) = 0.4536.$$

Since we use 8 bits for each component, the achievable PSNR value for each component is

$$PSNR_G = 10 \cdot \log \frac{255^2}{E_G} = 55.4 \text{ dB},$$

$$PSNR_R = 10 \cdot \log \frac{255^2}{E_R} = 52.4 \text{ dB},$$

$$PSNR_B = 10 \cdot \log \frac{255^2}{E_B} = 51.6 \text{ dB}.$$

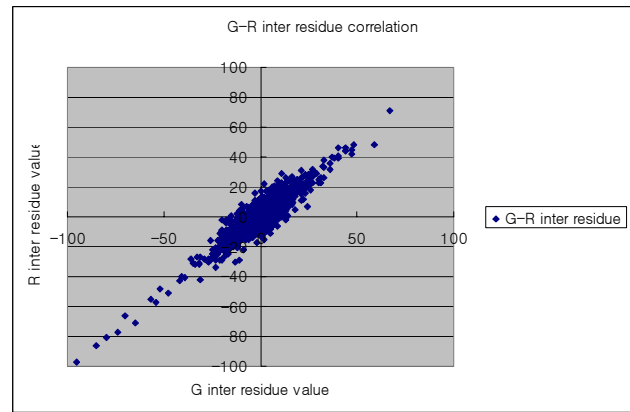
## B. The Proposed Inter-Plane Prediction Coding

In the previous section, we showed that coding by converting the given color space causes inevitable color distortion. Based on this observation, we propose to code the data in the given space. But the RGB space is generally regarded as a bad space from the compression viewpoint as

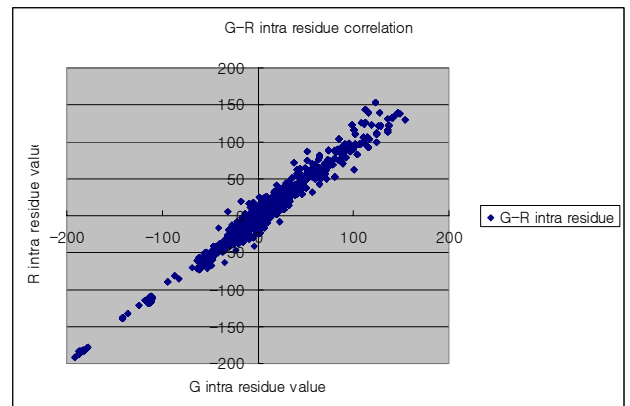
addressed earlier. To increase the coding efficiency in RGB space, we propose to use IPP that exploits the redundancy between color components. For our tests, we modified the MPEG-4 AVC/H.264 codec [3] that uses the intra/inter prediction. The modified codec supports 4:4:4 chroma format to take RGB input directly.

To see whether there is still redundancy after the intra/inter prediction, we plot the correlation between the residue signals of each component. As shown in Figure 1, after the intra/inter prediction, there still exists very strong correlation between residue images. To reduce this redundancy we applied linear regression predictor [4]  $F(\cdot)$ :

$$F(x) = m_y + r \frac{\sigma_y}{\sigma_x}(x - m_x)$$



(a)



(b)

Figure 1: Inter-color correlation between G and R residue components. (a) shows the correlation after inter prediction and (b) shows after intra prediction. The correlation between G and B components shows the similar characteristics.

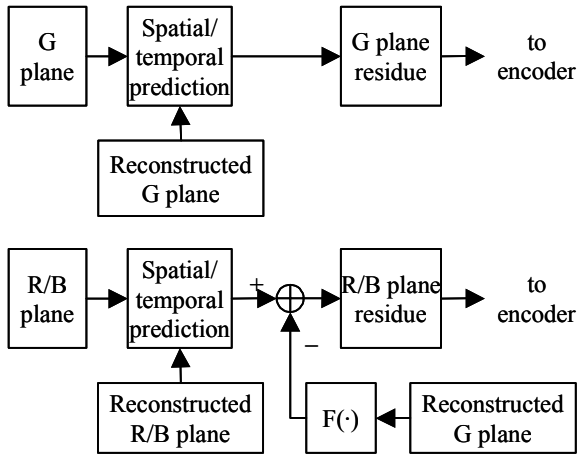


Figure 2: Block diagram of the proposed inter-plane prediction.

where  $m$  and  $\sigma$  denotes mean and standard deviation. To support integer implementation the coefficients can be chosen to be dyadic rational. We chose these coefficients by analyzing statistical properties of residual images. Our experimental data showed identity function is good enough [5-8]. So we subtracted the reconstructed G residue image from the R and B residual images as shown in Figure 2.

### III. SIMULATION RESULTS

This section summarizes the simulation results. For this test we modified MPEG-4 AVC/H.264 reference software to support 4:4:4 chroma format and N-bit input data.

Since the proposed method is mainly targeted for the high quality applications, images with high quality and high resolution are selected such as high definition (HD) materials with  $1280 \times 720 @ 60\text{fps}$ , 8 bit per pixel, and film materials with  $1920 \times 1080 @ 24\text{fps}$ , 10 bit per pixel. Both are in 4:4:4 chroma format and captured using progressive scan method.

Figure 3 and 4 show the simulation results when the IPP is applied to HD and film materials, respectively. They clearly show the efficiency of the inter-plane prediction.

Figure 3 shows that there exists an achievable PSNR limit if we code images by converting them into another color space as explained in the previous section. Coding RGB data directly without the IPP option shows poor coding efficiency even though it can achieve high PSNR values. Note that there is a crossover point between the RD-curves of the proposed method and that of the YCbCr coding results. The coding efficiency of the proposed method is slightly reduced in the low bit-rate compared to the YCbCr coding. However, the proposed method can

preserve the color fidelity better than the YCbCr coding since there was no color space conversion, at the same time the computational complexity is reduced for the same reason.

Figure 4 shows the results for the film materials. The film material has a lot of noises so-called “film grain” which increase the bit-rate much. The experimental results confirm the effectiveness of the proposed method for the various kinds of images.

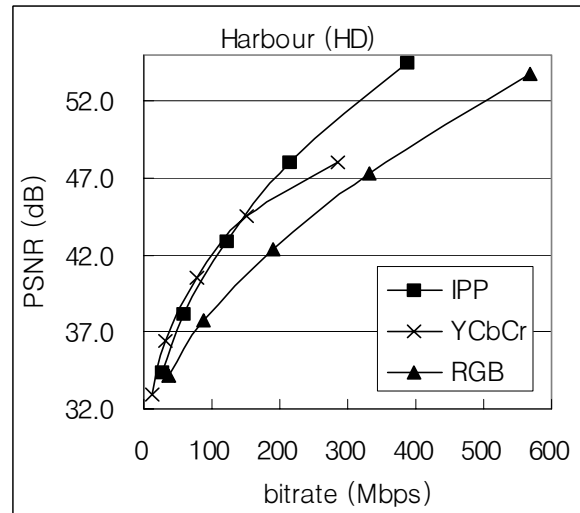
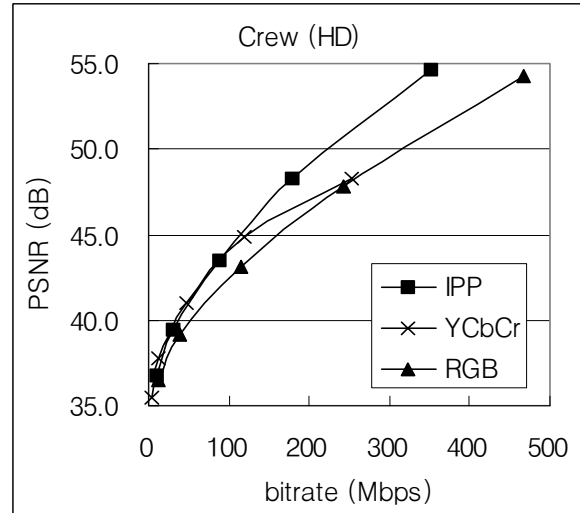


Figure 3: Simulation results for HD materials.

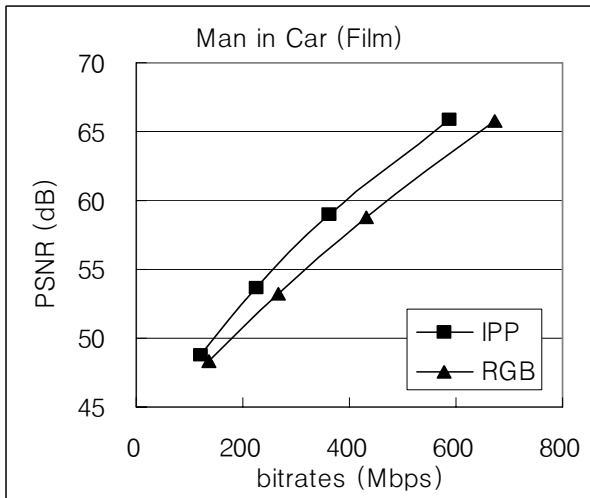
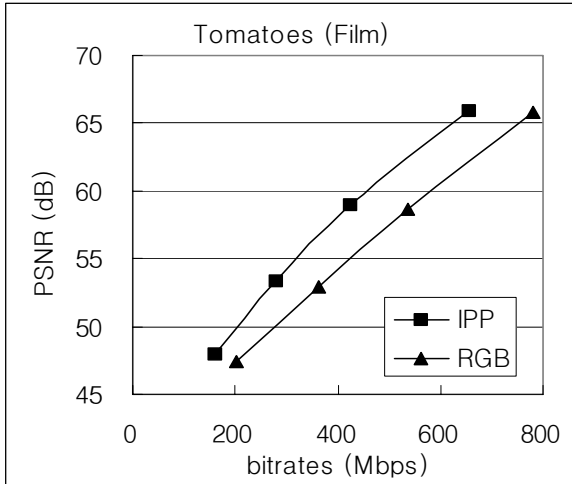


Figure 4: Simulation results for film materials.

#### IV. CONCLUSIONS

In this paper, we introduced an inter-plane prediction that resulted in high coding efficiency for RGB space. We showed that coding in a given space was important to keep the fidelity of the original data by deriving the achievable PSNR limit when the color space conversion is involved using the theoretical analysis and the experimental results. The proposed coding technology avoids the color distortion and achieves high PSNR values that are essential for professional applications. The proposed technology works well over various image sets including film data. It makes the proposed IPP ideal for digital cinema or other mastering applications.

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