# Non-linear Interpolation for Color Images

**Jongho Kim, Wonki Kim, Donghyun Yeom, and Jechang Jeong**
**Dept. of Electrical and Computer Eng., Hanyang University, Seoul, Korea**
**Phone: +82-2-2292-6457, E-mail: {angel, stwon, raheader, jjeong}@ece.hanyang.ac.kr**

## Abstract

*In this paper, we propose a non-linear interpolation of chrominance components based on the property of luminance signals to display color images effectively. The proposed method is more useful, in particular, for the images including stair-typed signal changes around edges. Experimental results show that the proposed method is superior to conventional methods in both objective and subjective performance.*

## 1. Introduction

According to recent growth of multimedia technology, various artificial images such as animation pictures and computer graphics have been an important part of the image processing. In general, these images contain apparent edges compared to natural images, and the signals around the edges are changed abruptly like a staircase. Therefore, it is not enough to apply the conventional interpolation and filtering methods for effective display of color images to the apparent-edged images [1, 5]. To solve the problem, we propose a new interpolation method, in which chrominance signals are interpolated considering the edge positions of luminance signals.

To evaluate the proposed method, we select a computer graphics image and an artificial image. The proposed method has the following advantages compared to the conventional methods: computational complexity is reduced due to exclusion of the convolutional filtering processing; the visual quality of reconstructed images is improved remarkably.

The remaining parts of the paper are as follows. We describe the conventional interpolation method for color images, specifically the MPEG-2 method in Section 2. In Section 3, the proposed interpolation method is explained in detail with two cases of the stair-typed pattern and the hat-typed pattern. Finally, experimental results are presented with discussion, and conclusions are made in Section 4 and 5, respectively.

## 2. Conventional Color Format Conversion

Color images can be displayed in appropriate composition of each RGB (Red, Green, Blue) color. From the viewpoint of amount of information, however, it is not effective because each color plane is highly correlated and each color signal occupies the same bandwidth. Therefore, conversion of RGB space to another signal space is strongly required in many applications. Practically, YUV format is used for representing color signals, which is composed of Y signals for luminance and U/V signals for chrominance signals, respectively, in TV standards such as NTSC, PAL, SECAM, etc., and in multimedia standards such as MPEG and ITU-T. YUV signals can be obtained in unit of each pixel using [1, 2, 4]

$$\begin{bmatrix} Y \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.147 & -0.289 & 0.436 \\ 0.615 & -0.515 & -0.100 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \qquad (1)$$

By using (1), we convert RGB color coordinate, in which each component is highly correlated, into YUV color coordinate, in which correlation between each component is removed. The color coordinate removing correlation is very useful in image compression and processing, since each color component can be processed independently.

Specifically, since HVS (Human Visual System) is more sensitive to luminance change than to chrominance change, we decimate the U/V signals to reduce amount of information [1]. We call 4:4:4 format when the chrominance signals are not decimated, 4:2:2 format when the chrominance signals are decimated one time in horizontal direction, and 4;2:0 format when the chrominance signals are decimated in horizontal and vertical directions, respectively [1, 2, 4].

To avoid the aliasing effect in decimation processing, we use an appropriate low-pass filter. Conversely, an appropriate low-pass filter should be used when the decimated signals are interpolated in order to avoid the imaging effect. Since each filter in decimation and interpolation processing, is mainly linear low-pass filter, the blurring effect is included in the images with apparent edges such as animation images and computer graphics by the filtering. To solve the problem, MPEG-2 introduces the 4:2:2 profile [3, 5] but we cannot guarantee the blurring effect, since this profile also include the filtering process one time. down-sample The meaning By using (1), we obtain YUV signals, in which correlation between each component is removed, from RGB signals, in which each component is highly correlated.

## 3. Proposed Non-linear Interpolation for Displaying Color Images

In order to solve the problem mentioned in Section 2, we describe the proposed interpolation method in detail with two cases of the stair-typed pattern and the hat-typed pattern.

### 3.1 Non-linear Interpolation using Characteristic Value α

We can assume that the edges in luminance images and chrominance images are located at the same position even though the actual values are different each other. According to the assumption, we can interpolate the decimated chrominance images considering the property of luminance images, which are not decimated, in order to avoid the blurring effect of images caused by using linear filter.

RGB images are converted YUV images using (1) followed by 2:1 down-sampling of U/V signals. Conversely, in order to interpolate chrominance signals, the characteristic value, α, is obtained using (2) in which the values of A, B are from luminance images as shown in Figure 1.

$$\alpha = \frac{C-B}{A-B} \tag{2}$$

where C is a luminance signal between A and B, which is located at the same position of the chrominance signal to be interpolated. Then, we apply the characteristic value, α ($0 \le \alpha \le 1$), to chrominance signals using

$$C' = \alpha A' + (1-\alpha)B' \tag{3}$$

where C' is a chrominance signal between A' and B', which is a signal to be interpolated. In (3), A' and B' are actual values of a decimated chrominance image, and C' is a value not determined yet. As shown in Figure 1, each signal is located at the same position, that is, A and A', B and B', and C and C' are located at the same position, respectively, even though the actual values may be different each other.

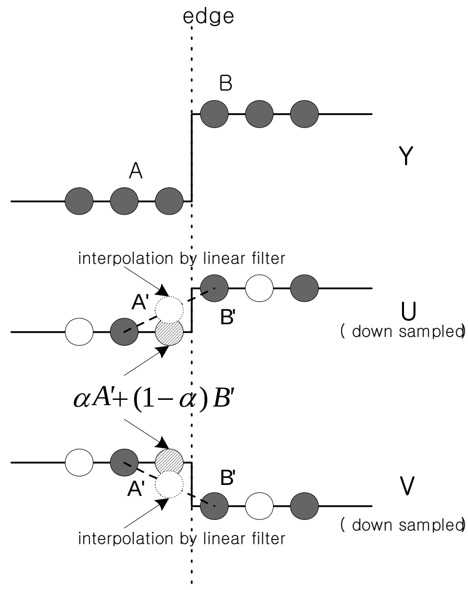


Figure 1. Conceptual illustration for reconstruction of a chrominance signal based on the proposed non-linear interpolation.

In Figure 1, the shaded dots, white circles, and line-filled circles represent the actual signals, padding signals with the nearest signal, and interpolated signals by the proposed method, respectively. In addition, the signals denoted by white circles with dashed-line in U and V signals, represent the interpolated signals by linear filter. We can see that the characteristic value, α, is a weighting factor of the dividing point between A and B, and it indicates which level of signal C' is closer to the level of the existing signals, A and B. This property of α makes the interpolation effective to the stair-typed signal pattern.

### 3.2 Non-linear Interpolation using Estimation of Signal Shape

When the conventional linear interpolation methods are used, we are faced with the following problem. In case where the image has a hat-typed pattern instead of stair-typed pattern as shown in Figure 2, the levels of neighboring signals in decimated chrominance images can be equal each other. The conventional methods interpolate a signal with the same value of neighboring signal due to lack of information.

To solve the problem, we propose additional non-linear interpolation method. Since the edge position is similar in luminance image and in chrominance image, we select a cross-point as the location of a to-be-interpolated pixel using the previous pixels of the chrominance image. The cross-point is estimated by extension of two neighboring pixels.

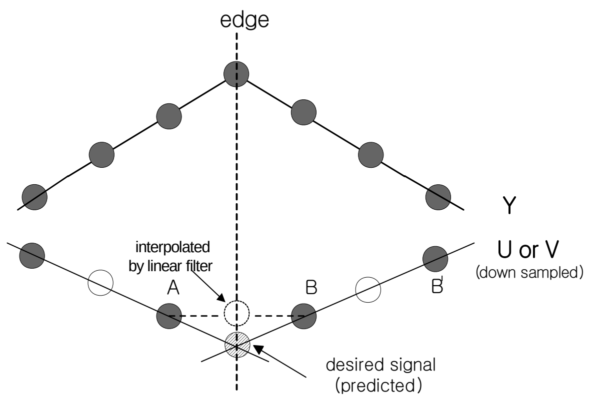


Figure 2. Conceptual illustration for reconstruction of a chrominance signal based on estimating the signal pattern.

In Figure 2, the shaded dots, white circles, and line-filled circles represent the actual signals, interpolated signals using linear filtering in chrominance signals, and interpolated signals by the proposed method, respectively. We can see that luminance signals and chrominance signals have the same edge position even though the actual values are different each other. In this figure, we obtain a strait line using A and A', similarly another strait line using B and B', and then we select the position of interpolation as the cross-point of both lines. This method makes the pattern of chrominance signals similar to the pattern of luminance signals, so that the blurring effect can be avoided and the edge that is more apparent can be obtained.

## 4. Experimental Results

We evaluate the proposed method using simple computer graphics images, "*Circle and Box*" image and "*Geometry*" image. *Circle and Box* image includes some simple geometrical figures, and the colors are changed completely at the edges. *Geometry* image is a general computer graphics image with apparent edges. Both test images have 256×256 resolution and 24 bits per pixel (8 bits are assigned each color component of RGB). For both test images of 4:2:0 format, we compare the PSNR (Peak Signal-to-Noise Ratio) of U and V signals using the proposed method with the case using the conventional decimation/linear filtering, i.e., MPEG-2 method. In addition, we compare the PSNR of each converted RGB signal. Tables 1 and 2 summarize the PSNR results for *Circle and Box* image and *Geometry* image, respectively, and Figures 3 and 4 show the interpolation results including partially enlarged figures for the subjective quality test.

Table 1. PSNR results for *Circle and Box* image (dB)

| | MPEG-2 method | Proposed method |
|---|---|---|
| U signal | 30.6118 | infinite |
| V signal | 33.6979 | infinite |
| RGB image | 29.4066 | 50.6624 |

Table 2. PSNR results for *Geometry* image (dB)

| | MPEG-2 method | Proposed method |
|---|---|---|
| U signal | 33.0763 | 38.9782 |
| V signal | 34.9640 | 40.2497 |
| RGB image | 31.2043 | 36.3799 |

In Tables 1 and 2, it can be seen that the proposed method is superior to the MPEG-2 interpolation method in spite of somewhat simple images. We can see that the proposed method improves PSNR much more in the images that is simple and that includes more apparent edges.

Figure 3 (a) represents the original *Circle and Box* image with 256×256 resolution, and (b) to (d) shows partially enlarged images to emphasize the effects of interpolation by four times of original image, from the MPEG-2 method, and from the proposed method, respectively. Figure 4 (a) represents the original *Geometry* image with 256×256 resolution, and (b) and (c) shows partially enlarged images to emphasize the effects of interpolation by three times from the MPEG-2 method and from the proposed method, respectively. In both figures, the color blurring occurs around edges by the MPEG-2 interpolation method; on the other hand, the proposed method interpolates the color images more completely. We can observe clear and apparent edges that are the property of computer graphics images as shown in Figures 3 and 4. This is compared with the linear filter degrades edge, and thus colors around the edges are blurred.

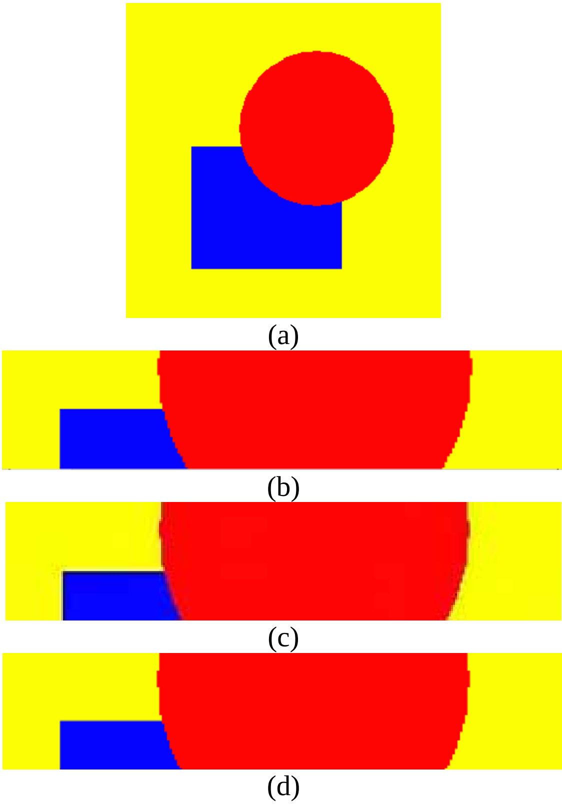


Figure 3. Result image for *Circle and Box* image. (a) original image, (b) partially enlarged original image, (c) partially enlarged image from MPEG-2 method, (d) partially enlarged image from the proposed method.

## 5. Conclusions

This paper addressed a non-linear interpolation method which preserves the apparent edges in color images so that we can avoid the blurring effect. Some images such as animation images and computer graphics have the apparent edges. The original properties could not maintain when we apply the conventional methods to these images due to filtering process. In addition, the filtering process can degrade the visual quality of natural images that require the studio quality. According to the experimental results, the proposed method converts the color format somewhat without quality degradation.

## 6. Acknowledgements

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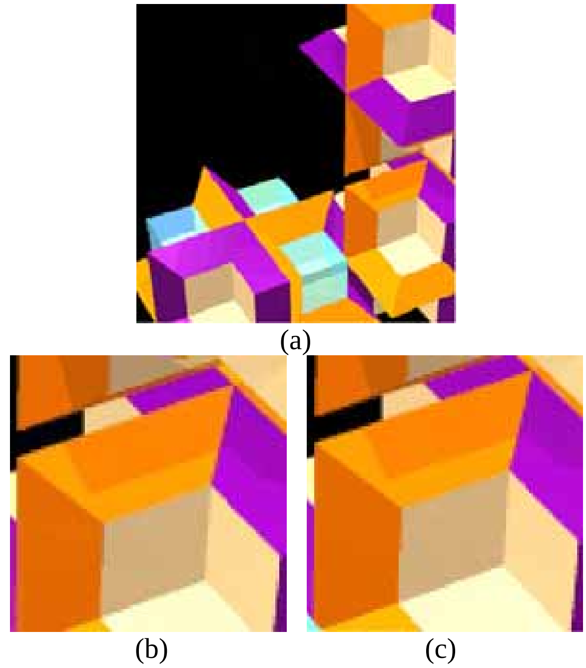


Figure 4. Result image for *Geometry* image. (a) original image, (b) partially enlarged image from MPEG-2 method, (c) partially enlarged image from the proposed method.

## 7. References

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