PSYCHOVISUAL EVALUATION OF THE EFFECT OF COLOR SPACES AND COLOR QUANTIFICATION IN JPEG2000 IMAGE COMPRESSION

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ABSTRACT

JPEG2000 is an emerging standard for still image compression. It is not only intended to provide rate-distortion and subjective image quality performance superior to existing standards, but also to provide features and additional functionalities that current standards can not address sufficiently such as lossless and lossy compression, progressive transmission by pixel accuracy and by resolution, etc. Currently the JPEG2000 standard is set up for use with the *sRGB* three-component color space.the aim of this research is to determine thanks to psychovisual experiences whether or not the color space selected will significantly improve the image compression. The *RGB*, *XYZ*, *CIELAB*, *CIELUV*, *YIQ*, *YCrCb* and *YUV* color spaces were examined and compared. In addition, we started a psychovisual evaluation on the effect of color quantification on JPEG2000 image compression. the final results indicate that the *YCrCb* color space is very suitable for this standard as mentioned in the amendement2.

1. INTRODUCTION

In 1996, the *JPEG* (the Joint Photographic Expert Group) committee began to investigate possibilities for a new definition of still image compression standard to serve current applications and more specially the future ones. This new definition was called *JPEG2000* and it consists in a comprehensive standard (ISO 15444 ITU-T Recommendation T.800) that is being issued in six parts.

The *JPEG2000* standard make use of several recent advances in compression technology in order to achieve these features. For example, the low-complexity and memory efficient block *DCT* of *JPEG* has been replaced by the full-frame discrete wavelet transform (*DWT*). To encode the binary bitplanes of the quantizer index, *JPEG2000* has replaced the Huffman coder of baseline JPEG with a context-based adaptive binary arithmetic coder with renormalization-driven probability estimation. several review papers about *JPEG2000* have recently appeared in the literature [1, 2, 3, 4].

Figure 1 shows the fundamental building blocks of a typical *JPEG2000* encoder as described by Rabbani[4].

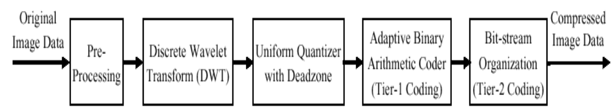

Fig. 1. JPEG2000 fundamental building blocks.

Color management in *JPEG2000* was an important topic in the development of the standard and the issue of presenting color properly is becoming more and more important as systems get better and as a wider range of systems are doing similar things. In the past, color has been targeted as an area of least concern with the overall presentation. Today, with so many different systems using color slightly different, a presentation on one system can look totally different on the next.

only *sRGB* was defined in Part-1. Most of the current *JPEG* applications including Internet, printing, etc. use YC_bC_r colorspace. Initial applications of *JPEG2000* will follow the same case. There were a very strong demand from the consumer side to handle colorspaces other than *sRGB* [5, 6, 7].

Starting from these interrogation we proposed a core experiment on the evaluation of the addition of color spaces to *JPEG2000*. In this work, we have studied the effect of color spaces and color quantification on *JPEG2000* compression thanks to a psychovisual evaluation. The paper is organized as follows. In section 2, the experimental color spaces used in this study are described. Section 3 is dedicated to color quantification. In section 4, we describe the psychovisual evaluation schemes.

2. EXPERIMENTAL COLOR SPACES

As was previously mentioned,the seven experimental color spaces used for this psychovisual evaluation were *RGB*, *XYZ*, *CIELAB*, *CIELUV*, *YIQ*, YC_bC_r and *YUV*. These sight color spaces were selected because they represent some of the more widely used color spaces in industrial and academic settings. All of the intermediate transforms for all of the color spaces were done using a floating point data type and only the displayed *RGB* image was quantized. the following section summarizes the equation used to define these color spaces. The *CIE* tristimulus space known under the name *XYZ* is one of the most important colorimetric models from which other color spaces are computed. It describes with enough precision the perception of color as it is received by Human Visual System *HVS*. *XYZ* color space [8] was used for years by all the professionals who needed a very precise control of the color. The linear transform can be expressed as 3x3 matrix defined in Eq.(1).

$$\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} 18.78 & 17.50 & 11.72 \\ 6.68 & 35.36 & 4.82 \\ 0.71 & 5.36 & 62.90 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}, \quad (1)$$

the next two color spaces are all created to be visually more uniform than the *XYZ* color space. Both *CIELAB* and *CIELUV* use nonlinear transforms to generate an approximately visually uniform space. *CIELAB* was defined in 1976 by the CIE (Commission internationale de l'clairage), this model is based on the way by which the human eye perceives the colors. the *CIELAB* color space is based on the *XYZ* color space and can be computed using Eqs.(2) through (7).

$$L^* = 116\left(\frac{Y}{Y_0}\right)^{\frac{1}{3}} - 16 \text{ for } \frac{Y}{Y_0} > 0.008856, \quad (2)$$

$$L^* = 903.3\left(\frac{Y}{Y_0}\right) \text{ for } \frac{Y}{Y_0} \leq 0.008856, \quad (3)$$

$$a^* = 500\left[f\left(\frac{X}{X_0}\right) - f\left(\frac{Y}{Y_0}\right)\right], \quad (4)$$

$$b^* = 200\left[f\left(\frac{X}{X_0}\right) - f\left(\frac{Z}{Z_0}\right)\right], \quad (5)$$

where

$$f(T) = \sqrt[3]{T} \text{ for } a > 0.008856, \quad (6)$$

$$f(T) = 7.787\ T + \frac{16}{116} \text{ for } T \leq 0.008856. \quad (7)$$

The *T* used in Eqs.(6) and (7) is a dummy variable. The values X_0,Y_0 and Z_0 are the tristimulus values of the white point of the monitor, *D90*.

The other nonlinear color space is *CIELUV*. It is very similar to the first one but it is based on a chromaticity diagram. the first step is to transform the tristimulus values X, Y and Z to $u'v'$ space using Eqs.(8) and (9):

$$u' = \frac{4X}{X + 15Y + 3Z}, \quad (8)$$

$$u' = \frac{9Y}{X + 15Y + 3Z}. \quad (9)$$

The u' and v' coordinates are then transformed to the *CIELUV* coordinates u^* and v^* according to the formulae:

$$u^* = 13L^*(u' - u'_0), \quad (10)$$

$$v^* = 13L^*(v' - v'_0), \quad (11)$$

where u'_0 and v'_0 are the $u'v'$ coordinates of the device peak white.

The next three color spaces are used in the television industry and consist of a luminance channel (used for black and white television) and two chrominance channels.

YIQ which was defined for *NTSC* television standard is based on some properties of the *HVS*. It grants more importance for luminosity changes rather than hue and saturation. It can be linearly computed thanks to Eq.(12).

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.275 & -0.321 \\ 0.212 & -0.528 & 0.311 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (12)$$

YUV is the color space used for the *PAL* television standard and YC_rC_b is a subset of *YUV* that scales and shifts the chrominance values into the range of 0 and 1. The two color spaces are respectively defined by Eqs.(13) and (14).

$$\begin{bmatrix} Y \\ U \\ V \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ -0.147 & -0.289 & 0.436 \\ 0.615 & -0.515 & -0.100 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix}, \quad (13)$$

$$\begin{cases} Y = 0.299R + 0.587G + 0.114B \\ C_r = (B - Y)/2 + 0.5 \\ C_b = (R - Y)/1.6 + 0.5 \end{cases} \quad (14)$$

3. EXPERIMENTAL COLOR QUANTIFICATION METHODS

In order to examine the effect of the quantification in the improvement of the JPEG2000's compression ratio, we used algorithms of quantification on our images. These algorithms allow to reduce the number of colors of an image by deteriorating the less possible the image. Among used methods, we have the median cut described by Heckbert [9], split and merge described by Brun [10], octree [11] and the local pallets method described by Larabi [12].

4. PSYCHOVISUAL EVALUATION

For our experimental needs, we used images classified in four categories (Portraits, outdoor scenes, indoor scenes and Computer-generated images). These categories were chosen because they provide a range of natural and artificial colors and textures. All of the images were with a precision of eight bits per channel and three channels per pixel.
As shown by figure 2, the observers were seated 3ft from the calibrated CRT in a darkened room in order to enhance the visualization quality.

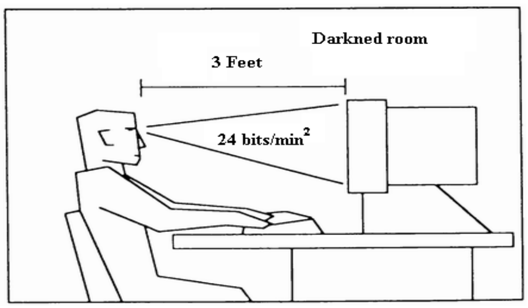

Fig. 2. Experimental viewing conditions.

4.1. Organization tests by forced choice

The aim of this test is to make a classification (from the best to the worst) of an image series with regard to the original image. For the needs of this psychovisual experimentation [13], we retained as device of study, a process that shows 9 images on the screen . In this device the original image is placed in the centre and eight images to be studied are situated around it as showed in figure 3.

Fig. 3. Experience of organization tests by forced choice.

Then, the human observer is asked to indicate by a mouse click, the image which he sees most qualitatively distant from the original image. This image is then masked and the same question is then asked and this until the eight images are masked in the presentation device. This technique allows to have a classification of the images with regard to a reference image (often considered as the original image). Contrary to the classic techniques where the observer has to classify images in increasing or lessening quality order, this technique presents the advantage to never put the observer in a complex position of choice. Indeed, he just has to answer every time: *" here is the image I don't appreciate"*.

4.2. Best and worst test

This test allows to have the best and the worst image from image series. This test proposes to the human observer three images with the original in the centre and two images on both sides(cf. Fig. 5). Then, he has to choose the best of the two images situated on both sides of the original.
The diagram of the figure 4 shows the selection algorithm. Four tests two by two are made. Then, the four best images are separated from the others and we make some tests two by two. Finally, we obtain the two best images and the two worst, we still have only two tests to make.

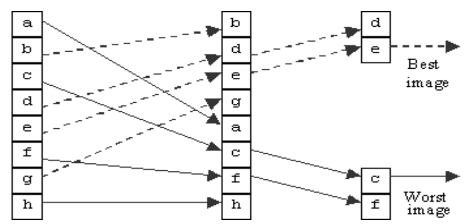

Fig. 4. best and worst algorithm.

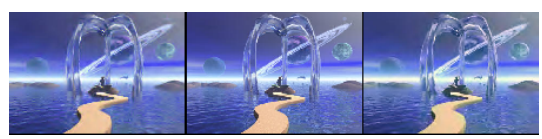

Fig. 5. Experience of best and worst test.

5. EXPERIMENTATION

For the color spaces experimentation, we have used different images classified in the categories described above. Each image is compressed using different color space and different compression ratio. Several images have been prepared for the observers. For each compression rate, we presented to the observer the images in different color spaces using the psychovisual protocols described in section 4. The responses for all the observers were combined together and analysed by calculating a frequency matrix for each image.

The proportionality matrix is then computed by dividing each of the element of the frequency matrix by the number of observations. Finally the proportionality matrix is transformed using the logistic function given by Eq.(15).

$$V = \ln \left[\frac{f + 0.5}{N + 0.5 - f} \right], \tag{15}$$

where V is the computed logistic value, f is the proportionality matrix value and N is the total number of observations. The results of the logistic analysis are shown in Fig.6. Experiment shows that the $CIELAB$ and YC_rC_b are the best color compression spaces. It shows also that the XYZ is the worst color compression space followed by the RGB.

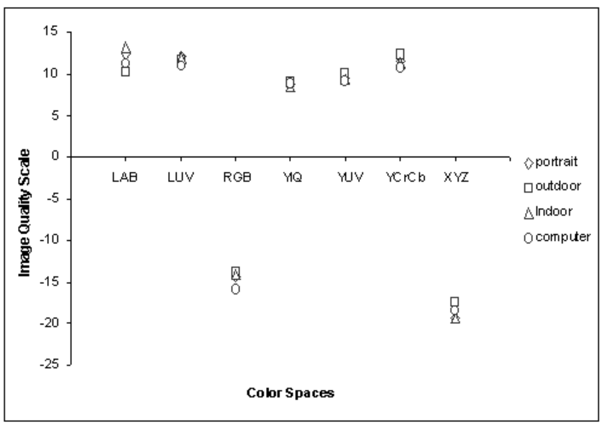

Fig. 6. Image quality scales.

For the color quantification experimentation, we applied for each of the experimental images a quantification in 256 and 512 colors. A psychovisual evaluation campaign is started but not finished yet. The first results show that the quantification effect is not visible for the observer for 512 colors. Moreover the first compression results seem to show a light compression enhancement to be confirmed by the global results.

6. CONCLUSION

In this paper, the effect of color spaces and color quantification have been studied using a psychovisual evaluations. The results of this research show that not only is JPEG2000 an image-dependant algorithm, but it is also a color-space-dependant algorithm. The study have suggested that the $CIELAB$ and YC_rC_b can improve the compression. Due to the algorithmic complexity of the $CIELAB$, the YC_rC_b color space can be seen as the best color space from the color spaces we experimented in this work.

7. REFERENCES

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