Optimal Color Model for Information Hiding in Color Images

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Abstract

In present work the effort has been put in finding the most suitable color model for the application of information hiding in color images. We test the most commonly used color models; RGB, YIQ, YUV, YCbCr1 and YCbCr2. The same procedures of embedding, detection and evaluation were applied to find which color model is most appropriate for information hiding. The new in this work, we take into consideration the value of errors that generated during transformations among color models. The results show YUV and YIQ color models are the best for information hiding in color images.

Introduction

Color space (model) is mathematical representation of a set of colors, the most popular color models are RGB (used in computer graphics); YUV, YIQ and YCbCr (in video systems). All of the color models can be derived from the RGB information supplied by devices such as cameras and scanners [1]. In the field of information hiding in color image researches, there are various attitudes about the preferable color space. Elisa et al [2] reported that "In general, it is better to watermark the RGB color components than the luminance components" .Chae et al [3] indicated that "a robust data embedding scheme can be achieved in YUV color space. Patrizio et al [4] stated that "The YIQ color space is ideal for watermarking color image". khan et al [5] distributed the watermark over YUV components. Gilani et al [6] indicated that "it is found that linear and uncorrelated color transforms YUV & YIQ are most suitable for watermarking". In this work we will try to find which color model is most appropriate for information hiding. The same procedures of information embedding, detection and evaluation will be applied on the tested color models .The paper structured as follows: in section 2 the color spaces are represented. In section 3 the proposed method is presented. In section 4 measurements and a set of experiments and corresponding results are given. Finally, in section 5 conclusion is drawn.

Color Spaces

1. RGB Color Model

The red, green, and blue (*RGB*) color space is widely used throughout computer graphics and image processing. Since color cameras, scanners and displays are most often provided with direct *RGB* signal input or output, this color model is the basic one, which is, if nececssary, transformed into other color models.

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2. YUV Color Model

The *YUV* color space is used by the PAL (Phase Alternation Line), NTSC (National Television System Committee), and SECAM (Sequential Color with Memory) composite color video standards. The black-and-white system uses only luminance (*Y*) information; color information (*U* and *V*) was added in such a way that a black-and-white receiver would still display a normal black-and-white picture [7].

3. YIQ Color Model

The *YIQ* color space is derived from the *YUV* color space and is optionally used by the NTSC composite color video standard. (The "I" stand for "inphase" and "Q" for "quadrature" which is the modulation method used to transmit the color information.) [8].

4. YCbCr1 Color Model

This color model is closely related to YUV model. It is appropriate for digital coding standard TV images. This color model is used in the process of video sequences encoding on videodisks [7].

5. YCbCr2 Color Model

The YC_bCr2 color space was developed as part of ITU-R BT.601 during the development of a world-wide digital component video standard. YC_bC_r2 is a scaled and offset version of the *YUV* color space. *Y* is defined to have a nominal 8-bit range of (16-235); C_b and C_r are defined to have a nominal range of (16-240). YC_bC_r is used in image compression (e.g. JPEG format) [9].

The applied techniques

1. The color transformation process

Four color models beside RGB have been represented (YIQ, YUV, YCbCr1, and YCbCr2). The algorithms of transformation from RGB to other color models (forward transformations) are shown in algorithms (1, 3, 5 and 7) where backward transformations are shown in algorithms (2, 4, 6 and 8).the details of these algorithms can be seen in [1] and [10].

2. The information hiding process

The image of size 256 * 256 pixels is divided into 32 * 32 blocks. In each block we insert an identification number; in binary format, represents the location of intended block in spatial domain. Each bit of the identification number replaces the first significant bit of predefined pixel location in the block. These procedures were applied; with the same pay load, for each band of every color model. If the imbedded information could not retrieval after color model transformations, we exclude this band from our evaluation .The details of imbedding and retrieving process can be seen in our previous work mentioned in [11].

3. Quality Metrics Measurements Techniques

For fair benchmarking and performance evaluation, the visual degradation due to the embedding is an important issue. Most distortion measures or quality metrics used in visual information processing, belong to the group of difference measures [12]. These measures are all based on the difference between the original, undistorted and the modified, distorted image. When we refer to a "perceptual model", we mean more precisely a function that gives a measure of distance between the original image, *O*, and the watermarked image, *R*. One of the simplest distance functions is the mean squared error (MSE). This is defined as:

$$MSE = \frac{\sum_{x,y}\left[O(x,y) - R(x,y)\right]^2}{W * H} \quad (1)$$

Where *O(x,y)* represents a pixel, whose coordinates are *(x,y)*, in the original (undistorted image), and *R(x,y)* represents

Algorithm 1 : Convert image from RGB color model to YUV color model

```
W = Wid - 1: H = Hgt – 1
For y = 0 To H: For x = 0 To W
    YUV(x,y).Y = 0.299 * RGB(x,y).R + 0.587 * RGB(x,y).G  +0.114*RGB(X,Y).B
     YUV(x,y).U = -0.147 * RGB(x,y).R - 0.289 * RGB(x,y).G + 0.436 *  RGB(x,y).B
     YVV(x,y).V = 0.615 * RGB(x,y).R - 0.515 * RGB(x,y).G  - 0.1 * RGB(x,y).B
Next x: Next y
End
```

Algorithm 2 : Convert YUV image data model to RGB color model

```
W = Wid - 1: H = Hgt – 1
For y = 0 To H: For x = 0 To W
   RGB(x,y).R = (YUV(x,y).Y + 1.14 * YUV(x,y).V)
   RGB(x,y).G = (YUV(x,y).Y - 0.395 * YUV(x,y).U- 0.581 *(YUV(x,y).V)
   RGB(x,y).B = (YUV(x,y).Y + 2.031 * YUV(x,y).U)
Next x: Next y
End
```

Algorithm 3 : Convert image from RGB color model to YIQ color model

```
W = Wid - 1: H = Hgt – 1
For y = 0 To H: For x = 0 To W
    YIQ(x,y).Y = (0.299 * RGB(x,y).R + 0.587 * RGB(x,y).G + 0.114 * RGB(x,y).B)
   YIQ(x,y).I  = (0.596 * RGB(x,y).R - 0.275 * RGB(x,y).G - 0.321 * RGB(x,y).B)
   YIQ(x,y).Q = (0.212 * RGB(x,y).R - 0.523 * RGB(x,y).G + 0.311 * RGB(x,y).B)
Next x: Next y
End
```

Algorithm 4: Convert YIQ image data model to RGB color model

```
W = Wid - 1: H = Hgt – 1
For y = 0 To H: For x = 0 To W
   RGB(x,y).R = (YIQ(x,y).Y + 0.9561 * YIQ(x,y).I + 0.621 * YIQ(x,y).Q)
   RGB(x,y).G = (YIQ(x,y).Y - 0.2721 * YIQ(x,y).I - 0.647 * YIQ(x,y).Q)
   RGB(x,y).B = (YIQ(x,y).Y - 1.1071 * YIQ(x,y).I + 1.704 * YIQ(x,y).Q)
Next x: Next y
End
```

Algorithm 5 : Convert image from RGB color model to YC_bC_{r1} color model

```
W = Wid - 1: H = Hgt – 1
For y = 0 To H: For x = 0 To W
    YCbCr1 (x,y).Y  = (0.2989 * RGB(x,y).R + 0.5866 * RGB(x,y).G + 0.1145 * RGB(x,y).B)
    YCbCr1 (x,y).Cb = (-0.168* RGB(x,y).R - 0.33 * RGB(x,y).G +0.498 * RGB(x,y).B)
    YCbCr1 (x,y).Cr =(0.498 * RGB(x,y).R – (0.417 * RGB(x,y).G) –( 0.081 * RGB(x,y).B))
Next x: Next y
End
```

Algorithm 6 : Convert YC_bC_{r1} image data model to RGB color model

```
W = Wid - 1: H = Hgt - 1
For y = 0 To H: For x = 0 To W
    RGB(x,y).R = YCbCr1 (x,y).Y + 1.4075 * (YCbCr1 (x,y).Cr )
    RGB(x,y).G =YCbCr1 (x,y).Y – (0.34656 * YCbCr1 (x,y).Cb) – ( 0.71711 * (YCbCr1 (x,y).Cr)
    RGB(x,y).B =YCbCr1 (x,y).Y  + 1.77804 * (YCbCr1 (x,y).Cb)
Next x: Next y
End
```

Algorithm 7 : Convert image from RGB color model to $YCbCr_2$ color model

```
W = Wid - 1: H = Hgt – 1
For y = 0 To H: For x = 0 To W
    YCbCr2 (x,y).Y  =  0.2125 * RGB(x,y).R + 0.7154 * RGB(x,y).G + 0.0721 * RGB(x,y).B
    YCbCr2 (x,y).Cb =(-0.114 * RGB(x,y).R) - 0.384 * RGB(x,y).G + 0.498 * RGB(x,y).B
    YCbCr2 (x,y).Cr = 0.498 * RGB(x,y).R - 0.452 * RGB(x,y).G- 0.046 * RGB(x,y).B
Next x: Next y
End
```

Algorithm 8 : Convert YCbCr2 image data model to RGB color model

```
W = Wid - 1: H = Hgt - 1
For y = 0 To H: For x = 0 To W
  RGB(x,y).R =  (YCbCr2 (x,y).Y  +( 1.58163 * YCbCr2 (x,y).Cr + 0.00131* YCbCr2 (x,y). ).Cb
  RGB(x,y).G = YCbCr2 (x,y).Y  - (0.18817 * (YCbCr2 (x,y).Cb ) -  0.46978 * (YCbCr2 (x,y).Cr
  RGB(x,y).B =  YCbCr2 (x,y).Y + 1.86324 * (YCbCr2 (x,y).Cb
Next x: Next y
End
```

a pixel, whose coordinates *(x,y)*, in the watermarked image. W & H represent the width and height of image respectively [13].Nowadays, the most popular distortion measure in the field of image and video coding and compression is the *Peak Signal to Noise Ratio (PSNR).* Generally the value of PSNR above (38) dB are visually satisfactory, even for the professionals [14]. Its popularity is very likely due to the simplicity of the metric [15]. It is defined as:

$$PSNR = 10\log_{10}\frac{(255)^2}{MSE} \qquad (2)$$

Results

Six images were tested, they are; Monaliza, Kids, Lena Child, Baboon and Arctic Hare. To display the image directly it should be in RGB color space (according to the existing manufacturing technology of computer's monitors). The transformation algorithms mentioned in (2.1) were used for transformations among color models. During the forward and backward processes of color model transformation; there are some errors have been registered, table (1) shows the values of these errors. In fact these errors appear because of the nature of mathematical equations of color transformation systems. We put in consideration these errors as a noise, so we exclude them when MSE is calculated. Table (2) shows PSNR values for the first band of each color model (the luminance) where the embedded identification numbers are totally retrieved. These PSNR values are shown with and without errors generated through color model transformations.

Conclusion

From the results of this work we conclude the following:

1. The values of color transformation errors are variant from one image to another according to the nature of image. The average shows the maximum error is in YIQ and YCbCr2 color models then YUV, while the minimum values of error in YCbCr1 (RGB color model is excluded).
2. By depending on PSNR measurement evaluation we find YUV and YIQ color models are the most suitable color models for information hiding.

Table (1): Error values result from color model transformation with RGB

Image Name	Color Model				
	RGB	**YUV**	**YIQ**	**YCbCr1**	**YCbCr2**
Monaliza	0	266	230	279	248
Kids	0	260	266	254	254
Lena	0	239	241	166	250
Child	0	222	237	141	250
Baboon	0	210	239	127	254
Arctic Hare	0	181	178	160	135
Average	0	229.667	**231.833**	187.833	**231.833**

Table (2): PSNR values

Color Model		Image Name						Average
		Baboon	Monaliza	Child	Kids	Lena	Arctic Hare	
RGB	⬬	59.178	59.213	59.218	59.197	59.196	59.109	59.185
	▬	59.178	59.213	59.218	59.197	59.196	59.109	59.185
YUV	⬬	48.544	46.953	48.164	47.073	47.666	49.492	47.982
	▬	65.891	67.962	66.158	67.318	66.719	64.897	**66.490**
YIQ	⬬	47.698	47.928	47.731	46.894	47.602	49.492	47.890
	▬	67.013	66.434	66.719	67.318	66.719	64.22	**66.403**
YCbCr1	⬬	51.302	46.575	50.824	47.225	49.942	50.069	49.322
	▬	62.282	67.962	63.006	67.013	64.005	63.392	64.610
YCbCr2	⬬	47.256	47.38	47.349	47.225	47.349	51.108	47.944
	▬	67.318	66.719	67.013	67.013	67.013	63.006	**66.347**

⬬ : PSNR before excluding errors.

▬ : PSNR after excluding errors.

References

1. Sangwine S.J. and Horne R. E. N, 1998, "*The Color Image Processing Handbook*", Chapman & Hall, London.
2. Elisa Sayrol, JosepVidal, Cabanillas S. and Santamaria S., 1998, "*Optimum Watermark Detection in Color Images*", polytechnic university, Spain.
3. Chae J.J., Mukherjee D. and Manjunath B.S., "*Color Image Embedding using Multidimensional Lattice Structures*", Proceedings of the IEEE, 1-1998.
4. Partrizo Campsi and Kundur D., "*Compressive Data Hiding: An Unconventional Approach for Improved Color Image Coding*", Eurasip Journal on ASP, April, 2001.
5. Khan E. and Ghanbari M., "*Embedded Color Image Coding With Visual SPIHT*", Proceedings of the IEEE, 2002, 0-7803-7402.
6. Gilani S.A.M., Kostopoulos I. and Skodras A.N., "*Color Image-Adaptive Watermarking*", Proceedings of the IEEE, 0-7803-7503, 2002.
7. Sangwine, S.J., and Horne, R. E. N., 1998, "*The Color Image Processing Handbook*", Chapman & Hall, London.
8. International Telecommunications Union ITU-R BT., 2002, "*Parameter Values for the HDTV Standards for Production and International Program Exchange*" 709–5.
9. International Telecommunications Union ITU-R BT., 1995, "*Studio Encoding Parameters of Digital Television*", 601–5.
10. International Telecommunications Union, 2002, "*Parameter Values for the HDTV Standards for Production and International Program Exchange*", ITU-R BT.709–5.
11. Ali Kadhim, 2008 " *Tamper Detection In Color Image*", Um-Salama Science Journal, 5 (1) : 155-159.

12. Khalid Sayood, 2000, "*Introduction to Data Compression*", San Francisco: Morgan Kaufmann Publisher.
13. Kutter M. and Petitcolas F.A., 1999, "*A fair benchmark for image watermarking systems*", Security and Watermarking of Multimedia Content, SPIE-3657 :226-239.
14. Katzenbeisser S., and Petitcolas A.P, 2000,"*Information Hiding Techniques for Steganography and Digital Watermarking*", Artech House, Inc.
15. Kundur D. and Hatzinakos D., 1999, "*Attack Characterization for Effective Watermarking*". Proc. Of 99 Int. Conf. on Image Processing, 2:240-244.

النظام اللوني الأمثل لإخفاء البيانات في الصور الملونة

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الخلاصة:

في هذه العمل جرى البحث لإيجاد أفضل نظام لوني يمكن أن يستخدم في تطبيقات أخفاء المعلومات في الصور الملونة. جرى اختبار أشهر نظم الألوان المستخدمة (RGB ، YIQ ، YUV ، YCbCr1 ، YCbCr2) .

و لغرض إجراء التقويم المقارن على أفضل صورة جرى اعتماد الخطوات نفسها في طمر المعلومات واستخلاصها وجرى اعتماد الطريقة ذاتها في تقويم النتائج لإيجاد النظام اللوني الأفضل بين النظم المختبرة لإخفاء المعلومات. الجديد في هذا البحث إن الأخطاء المتولدة نتيجة التحويلات الرياضية المستخدمة للتحويل بين نظم الألوان جرى احتسابها وأخذها بنظر الاعتبار عند تقويم النتائج . بينت نتائج الاختبار أن نظامي الألوان YUV و YIQ يمثلان الأفضل بين النظم اللونية المختبرة لإغراض إخفاء المعلومات في الصور الملونة.