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Suitability of the RGB Channels for a Pixel Manipulation in a Spatial Domain Data Hiding Techniques

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Abstract

The aim of this research was to determine which channel in RGB color space is the most suitable (regarding perceptibility) for a pixel manipulation in a spatial domain data hiding techniques. For this purpose three custom test targets were generated. The research also shows the behavior of two closely related colors in the PS (Print-Scan) process. The results are interpreted using both a quantitative method (statistical comparison) and a qualitative method (visual comparison).

Keywords:

Print-Scan Process, Image Processing

1. Introduction

There are many ways to represent and communicate color of a digital image. The common factors in all of image processing are the capture and display of images *(Gonzales & Woods, 2008)*. Color imaging devices such as scanners, cameras and printers have always exhibited some variability or personal characteristics *(Russ, 2007)*. The primary digital image capturing devices are the digital scanner and the digital still camera. In the CCD design, the sensor performance is generally specified in terms of its dark noise, saturation level, noise variation and photo-response non-uniformity (PRNU). The analog-to-digital converter (ADC) in the system is primarily specified in terms of the number of bits used for quantization, the differential non-linearity, integral non-linearity and sampling rate *(Baxes, 1994)*. Each of these have a significant effect on the quality of the scanned image. Owing to the effect of metamerism it is quite possible that spectra that appear the same to the standard human observer may look quite different to the digital scanner *(Trussell & Vrhel, 2008)*. This is because the spectral response of the color scanner is not related by linear transformation to the CIE color matching functions *(Hunt & Breedlove, 1975)*.

Commercial printing methods rely on pressing the ink onto the paper. Color ink-jet engines commonly use four colors: cyan, magenta, yellow and black (CMYK). However, six color engines are prevalent, where a light magenta and light cyan are introduced to reduce the visibility of halftone artifacts in high reflectance regions and expand the gamut of the printer. In any real system, there will be various sources of noise that affect the quality of the printing process. Some factors affecting the variability include: the half-toning method, variation in dot size, shape and location, as well as chemical and physical interaction of the inks and media *(Hays, 1991)*.

The rest of the paper is organized as follows. In section 2 we describe the most typical model of image degradation. Section 3 explains the experiment procedure. In section 4, results are presented, followed by the conclusion in section 5.

2. Image degradation

2.1. Model of image degradation

Model of image degradation process is shown in Fig 1. *(Gonzales & Woods, 2008)*:

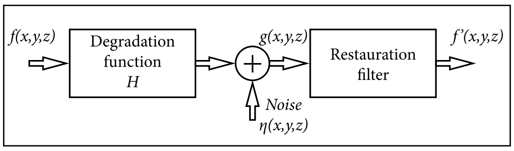

Figure 1. A model of the image degradation and restoration process

If we presume that degradation function $H[x]$ is linear and position invariant we can write:

$$g(x,y,z)=H[f(x,y,z)]+\eta(x,y,z) \qquad (1)$$

where $g(x,y,z)$ is the intensity of the degraded pixel on the coordinates (x,y) and on the RGB plain (z), $f(x,y,z)$ is the intensity of the original pixel on (x,y,z) location, and $\eta(x,y,z)$ is noise. For difference between two pixels we have:

$$g_m(x,y,z)-g_n(x,y,z)=H[f_m(x,y,z)-f_n(x,y,z)]+\eta(x,y,z) \qquad (2)$$

We want to see what is happening to the difference of two closely related colors; therefore, the determination of degradation function is not important, and we will assume that it is an identity operator. On the other hand degradation due to additive noise has to be determined in order to make a valid comparison between patches.

2.2. Noise

Any measurable quantity is a subject to noise. There is always an uncertainty caused by the finite precision of a measuring device. In the digital world, there is an uncertainty caused by the finite number of bits that are used to represent quantity. In many cases, the noise characteristics can be determined by an experiment and testing prior to the actual recording of data. Noise can be classified by several characteristics. Electronic noise at sensors is usually modeled as additive with zero mean. Because electronic noise is usually signal independent, many systems include a preprocessing step to subtract noise prior to subsequent processing. Many of the processing techniques are based on mean square error minimization. Since the Gaussian process is completely determined by its mean and variance, it is mathematically tractable in spatial domain. Because of this fact, Gaussian noise models are very often used in practice *(Gonzales & Woods, 2008)*.

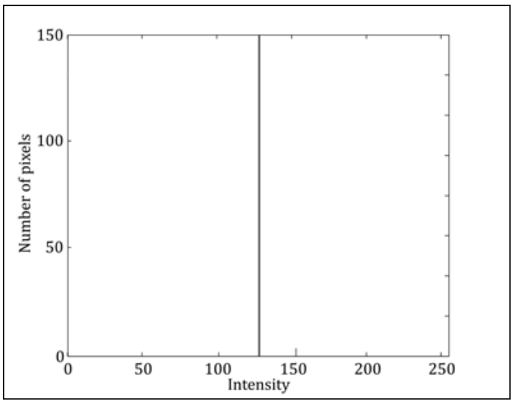

Figure 2. The histogram of a reproduced unit impulse in process without degradation

Assuming that noise is spatially independent and uncorrelated with respect to image itself, the type of noise can be estimated by the shape of histogram of the output function if the input function is unit impulse. To determine the type of noise as an input in the process we reproduced and then scanned a patch that has only one level of intensity. In a process without degradation histogram would have a shape shown in Fig.2.

For unit impulse as the input function the process gave output function that has histogram show in Fig 3. From the figure it is obvious that the noise has Gaussian noise probability density function PDF.

$$p(I) = \frac{1}{\sqrt{2\pi\sigma}} e^{\frac{-(I-\bar{I})^2}{2\sigma^2}} \qquad (3)$$

Where *p(I)* is the probability of the occurrence of a pixel with intensity *I*, and $\bar{I}$ is the mean value of intensities of all pixels.

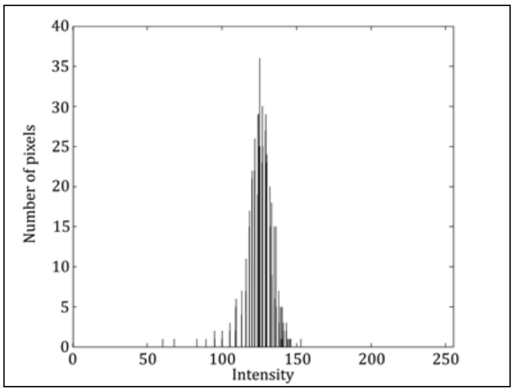

Figure 3. The histogram of a unit impulse reproduced in process with Gaussian noise

We have already mentioned it is presumed that the degradation function is identity operator. This model is shown on fig.4

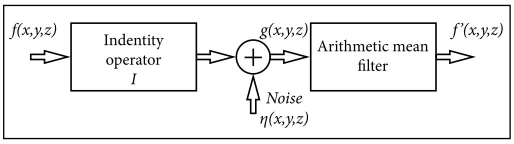

Figure 4. A model of the image degradation with identity operator as the degradation function, and arithmetic mean filter as the restoration filter

To eliminate Gaussian noise we used arithmetic mean filter:

$$f'(x,y,z) = \frac{1}{mn}\sum g(x,y,z) \qquad (4)$$

Where *f'(x,y,z)* is estimated pixel value and mn is size of the filter

Therefore, the difference between two color patches can be estimated using the equation:

$$f_1'(x,y,z) - f_2'(x,y,z) = \frac{1}{mn}\sum\left[g_1(x,y,z) - g_2(x,y,z)\right] \qquad (5)$$

3.Experiment

3.1. Test targets

RGB color patches are generated from a set S = (0, 128, 255) to get 27 color patches with a different combination of RGB values. Each RGB patch was divided into two halves in such a way that one half of the patch was left unchanged, and RGB values of the other half were modulated with a value from the set M = (- 15, - 10, -5, - 3, 0, 3, 5, 10, 15) first just R value was modulated then just G value, and then just B value. As a result we got 3 different color test targets with 243 patches divided into two halves *(Fig.5)*.

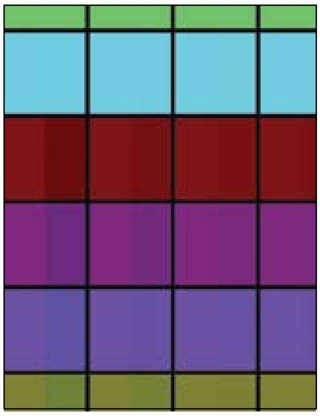

Figure 5. Part of the color test target

Generated test targets were printed on paper on Epson Stylus pro 3800 inkjet color printer. All color management options were disabled and color information was transformed between different color spaces using only the built in printer driver. After printing, test targets were scanned with Microtek Scanmaker 8700 scanner with the same resolution as it was printed (300 dpi), to avoid scaling. Furthermore, scanned image was cropped to exactly the same size as the original test target to make further processing easier.

3.2. Statistical comparison of the patches

All calculations and processing have been done in Maltlab application. To compare pairs of patches, noise had to be neutralized. Since we have shown that noise of the degradation in a PS process has Gaussian probability density function we calculated mean values from 20*20 pixel area from for every patch. In this way we have eliminate the influence of noise.

3.2. Visual comparison of the test targets.

Visual comparison was carried out by evaluation of differences in a viewing booth under the light sources D65, and D50. Six subjects where asked to rate the differences from 1 to 3, where 1 means the least different, and 3 means the most different. Grades were summed and the mean value was calculated

4. Results

4.1. Quantitative results

After printing and scanning, the values of generated and scanned color patches were compared. Standard deviation and mean were determined for each changes in R, G and B channels. The results are shown in *Table 1* (for R modulation), *Table 2* (for G modulation) and *Table 3* (for B modulation).

The results show that degradation due to PS process is not so big to destroy the difference of two closely related colors. However, the differences are in general attenuated after PS process, and it seems that the difference value ± 5 is strong enough to survive the degradation. It should be noted that standard deviation in general was less than 3, with the noticeable difference for patches that were modified with ± 15 difference value. This can be explained with the fact that two colors with difference that is larger than 10, are so different that we can not presume that degradation function H[x] is identity operator anymore.

We can see that R values change very little when other channels are modulated, while B values are much more influenced by modification in R and G channel. Therefore, from quantitative point of view, one should modify only B-channel.

Table 1. Differences in RGB values for a test target in which R channel was modulated

Δ	-15	-10	-5	-3	0	3	5	10	15
ΔR-mean	-18,17	-8,35	-3,87	-2,52	-0,27	2,79	3,47	7,99	16,85
ΔR-std	7,34	2,91	1,29	1,6	0,74	1,55	1,69	3,14	5,71
ΔG-mean	-7,83	-2,68	-1,18	-0,65	-0,37	0,63	0,65	2,01	5,88
ΔG-std	4,71	1,76	0,95	0,76	0,53	0,83	1,17	1,91	3,34
ΔB-mean	-2,96	-0,26	-0,22	-0,02	-0,22	0,16	-0,86	-0,58	1,85
ΔB-std	3,41	1,83	0,73	0,77	0,93	0,93	2,55	1,23	1,77

Table 2. Differences in RGB values for a test target in which G channel was modulated

Δ	-15	-10	-5	-3	0	3	5	10	15
ΔR-mean	-0,73	0,75	0,39	0,32	-0,15	-0,56	-0,22	-0,56	1,23
ΔR-std	5,77	1,67	0,82	0,56	0,34	0,97	0,9	1,27	2,25
ΔG-mean	-13,18	-4,99	-2,94	-1,28	-0,21	1,08	3,12	5,28	13,72
ΔG-std	5,54	2,06	1,49	0,88	1,03	1,27	2,01	3,03	5,65
ΔB-mean	-7,74	-2,46	-1,75	-0,95	-0,29	0,27	1,81	2,46	10,02
ΔB-std	6,46	2,58	1,65	1,55	1,79	1,73	2,26	2,83	4,54

Table 3. Differences in RGB values for a test target in which B channel was modulated

Δ	-15	-10	-5	-3	0	3	5	10	15
ΔR-mean	-1,49	-0,16	-0,24	0,02	0,07	-0,17	0,68	0,01	4,07
ΔR-std	6,19	1,06	0,89	1,03	1,03	1,05	1,07	1,58	3,57
ΔG-mean	-3,06	-0,43	-0,46	0,47	-0,1	-0,06	0,71	0,04	3,21
ΔG-std	4,85	1,36	0,98	1,48	1,78	1,43	1,72	2,14	2,84
ΔB-mean	-16,34	-5,86	-3,74	-0,84	0,52	1,61	3,36	5,88	13,94
ΔB-std	12,7	4,15	3,07	1,89	1,08	1,43	1,91	3,04	5,71

Table 4. Results of the visual comparison of the test targets. (Bigger number means smaller visual difference)

Test target	D50	D65	Overall
R channel modified	3	2,67	2,83
G channel modified	1,67	2,17	1,92
B channel modified	1,33	1,17	1.25

4.2. Quantitative results

From *Table 4* it can be seen that the smallest visual difference between patches is on the test target were the B channel was modified. The biggest visual difference is for modulation of R channel. This can be explained if we look how other channels are behaving when we modify one of them. With the modulation of B values, R and G values change only slightly. When we modify R values, G values are changed significantly. When we modify G channel, both R values and B values are also changed. All this leads to significant visual differences between patches on test targets where R channel and G channel was modified.

5. Conclusion

In this paper we have shown the behavior of two closely related colors in a PS process. We also showed that the degradation function of the process behaves as identity operator for such colors. Further, B channel is the most independent, which means that modulation of B values, changes R values and G values just slightly. The modulation of G channel gives the worst results. The same thing is concluded from a visual comparison. The test target where B channel was modified. It can be concluded that the most suitable channel for a pixel manipulation in a spatial domain data hiding techniques is B channel.

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