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Study of HSV Color Space Deviations and Histograms in Image Steganography

Pankaj Sambyal

Department of Computer Science,
Kalindi College, University of Delhi, New Delhi, India

***Abstract*— Image Steganography is the process of hiding a secret image inside a cover image file to produce a fused image called stego image, so that the secret image cannot be recognized or recovered by unauthorized recipients. But in the process of Steganography, the cover image undergoes changes in several image parameters e.g. HSV (Hue-Saturation-Value), color, hue, brightness, saturation, quality, etc. The changes in HSV value depends majorly on the color changes. These changes can considerably distort the cover image to the extent where it may defy the purpose of the whole process which is to conceal information without raising suspicions. The present paper tries to analyze the effect of Steganography process on the cover image and study the various differences between the cover image before and after the process. The various histograms of different image parameters are also discussed. After that, performance is measured in terms of PSNR and mean deviation to study the amount of deterioration caused by Steganography process.**

***Keywords*— Steganography, histogram, steganalysis, HSV, HSB, color saturation**

I. Introduction

The Information hiding is a process to conceal secret messages into cover object with little distortion. It is a foundation for different applications, e.g., copyright protection (watermarking), secret communication (steganography), image authentication, etc. However, data hiding has two fundamental jobs to do. First, to reduce distortion. As far as security is concerned, the encoding changes in cover object should not be salient. And second, the ability to hide information should be enough to include a reasonable amount of secret messages. However, a tradeoff between the embedding distortion and the capacity of concealment is unavoidable. Obviously, the goal of data hiding is to design schemes with high potential for data concealment with slight distortion.

Steganography is a technique for covert information hiding so as to camouflage the existence of the secret message from unauthorized parties. All steganography algorithms have to comply with a few basic requirements. The current approaches in steganography domain could be divided into two categories i.e. spatial and transformation domains. In spatial domain, there are many strategies of image steganography based on manipulating the least significant bit (LSB) using direct replacing of least significant bit levels with the bits of secret image. In transform domain, secret message is embedded in the coefficients of cover media in frequency domain. In transform domain cosine, wavelet, etc. are used as transforms. Steganography in the frequency domain is one of the growing research areas in recent years because of its capability of providing robustness to attacks and posing a real challenge to anybody trying to discover and decode hidden messages. In the present paper, we try to study the data in spatial domain of HSV color space.

II. Image Steganalysis

The Steganalysis is the study of detecting messages hidden using steganography; this is analogous to cryptanalysis applied to cryptography. The purpose of steganalysis is to identify doubted cover images, determine whether or not they have a secret message encoded into them, and, if possible, recover that message. Unlike cryptanalysis, where it is obvious that intercepted data contains a message (though that message is encrypted), steganalysis generally starts with a heap of suspicious data files, but little information about which of the files, if any, contain a secret message. In layman terms, steganalysis lays the groundwork for the study of changes to which a cover media is subjected to when a secret message is encoded inside it.

A steganalyst is a forensic expert, who studies changes such as distortion, color, HSV values and tries to decode the intercepted messages. His work include reducing this set of data files (which is often quite large; in many cases, it may be the complete set of files on a computer) to the subset most likely to have been altered.

However, there are numerous domains in which steganalysis can be done e.g. color, quality, hue, saturation, separate RGB values, etc., the least studied domain is HSV color space.

III. HSV Color Space

If the visible portion of the light spectrum is divided into three components, the principal colors are red, green and blue (RGB). These three colors are considered the primary colors of the visible light spectrum. The RGB color space, in which color is specified by the quantity of Red, Green and Blue existing in the color, is the most prevalent color space. RGB is an additive and subtractive model, respectively, defining color in terms of the combination of primaries, whereas HSV color space summarizes information about a color in terms that are more accustomed to humans. In HSV color space, the color is disintegrated into hue, saturation and luminance (or brightness) value similar to the way humans tend to perceive color. That is why HSV can also be called HSB, where B stands for brightness.

Among the three components of HSV color space, hue is the property of a color, which decides which color it is. For the purpose of augmenting a color image, it should be realized that hue should not change for any pixel. If hue is altered, so does the color thereby distorting the image. The other common color spaces are CMYK (Cyan-Magenta-Yellow-Black), YPbPr, YCbCr, xvYCC, YIQ, YUV, YDbDr, CIE 1931 XYZ, CIELUV, CIELAB, CIEUVW, etc.

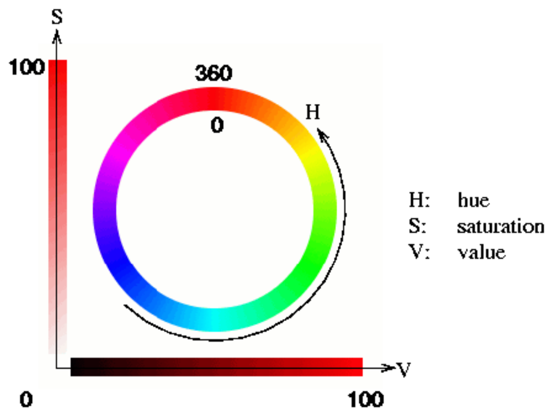

Fig. 1 SV plot and Hue

A. Hue

In HSV, hue represents color. Hue is one of the main properties (called color appearance parameters) of a color, defined technically as "the degree to which a stimulus can be described as similar to or different from stimuli that are labelled as red, green, blue, and yellow". Typically, colors with the same hue are identified with adjectives referring to their lightness and/or colorfulness, such as with "light blue", "pastel blue", "vivid blue". In this model, hue is an angle from 0 degrees to 360 degrees.

Angle	Color
0-60	Red
60-120	Yellow
120-180	Green
180-240	Cyan
240-300	Blue
300-360	Magenta

Fig. 2 Hue angle and the corresponding color

B. Saturation

Saturation is the colorfulness of a color relative to its own brightness. Saturation indicates the range of grey in the color space. It ranges from 0 to 100%. Sometimes the value is calculated from 0 to 1. When the value is ‘0,’ the color is grey and when the value is ‘1,’ the color is a principal color. A washed-out color is due to a lesser saturation level, which means the color contains more grey. Though this general concept is intuitive, terms like, saturation, purity, Chroma and intensity are often used without great accuracy, and even when well-defined, depend greatly on the specific color model in use.

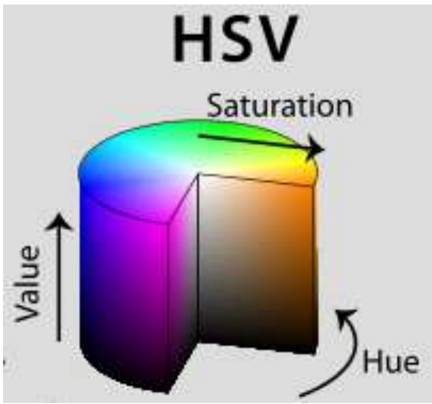

Fig. 3 HSV Cylindrical representation and saturation

C. Value/Brightness

Value is the brightness of the color and varies with color saturation. It ranges from 0 to 100%. When the value is ‘0’ the color space will be totally black. With the increase in the value, the color space brightness up and shows various colors.

D. HSV Representation

HSV model is exemplified as a cylindrical or conical object. When it is represented as a conical object, hue is characterized by the circular part of the cone. The cone is usually characterized in the three-dimensional form. The saturation is quantified using the radius of the cone and value by using the height of the cone. The HSV model can also be represented by using a hexagonal cone. The benefit of the conical model is that it is able to signify the HSV color space in a single object. Owing to the two-dimensional nature of computer interfaces, the conical model of HSV is suitable for choosing colors for computer graphics.

IV. Analysis and Image Histograms

We start by encoding a colorful image into a cover image showing considerable hue of a certain color. This step is important because the changes in hue can only be shown when there is a considerable change in the hue angle. The encoding process evidently changes the hue value of the cover image, thus showing major changes which are visible to anyone who isn't even looking for it. Therefore, it shows that a steganalyst who, if able to intercept the stego image, can judge that something is wrong with the image (if he has prior information about the cover image). Thus, it can be inferred that the changes between the cover image and stego image are visible to an extent which may prove to be a failure to the whole process. Battlefield Algorithm (battle steg) has been used for encoding of the secret message image into the cover image.

The encoding process can be represented as given in the figure 4. The data from the secret message image is scattered onto the LSBs of the cover image, thus forming a slightly different stego image.

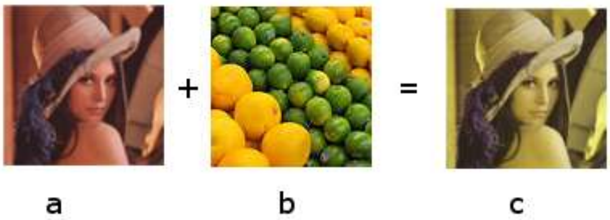

Fig. 4 Encoding process
(a. Cover Image, b. Message image, c. Stego Image)

Similarly, the decoding process can be represented as given in the figure 5. The stego image is subjected to the decoding algorithm and subsequently, the cover image and the secret message image can be reconstructed.

Fig. 5 Decoding Process
(d. Stego Image, e. Reconstructed Cover Image, f. Reconstructed Message Image)

Image histogram acts as a graphical illustration of the tonal distribution of a digital image. It essentially plots the number of pixels for each tonal value. The color saturation, hue values, luminosity, etc. can be arbitrated easily just by looking at an image histogram.

The horizontal axis of the graph represents the tonal variations, while the vertical axis signifies the number of pixels in that specific tone. The left side of the horizontal axis characterizes the dark or black areas, the middle represents medium grey and the light and pure white areas are represented by the right hand side. The size of the area that is captured in each one of these zones is represented by the vertical axis. Thus, the histogram for a very dark image will have the majority of its data points on the left or center of the graph. Contrariwise, the histogram for a very bright or light image with few dark areas or shadows will have most of its data points on the right side and center of the graph.

For example, the color saturation histogram in Figure 6 clearly shows a significant bump in the middle, which says the image is adequately saturated. Neither the most area of the image is dark nor light. However, we can easily tell the difference in the color saturation values between the cover image and stego image. The saturation values of the original cover image are represented by blue color and that of the stego image is represented by green color. The secret message image taken here is a bright colorful image to subject maximum HSV changes to the original cover image.

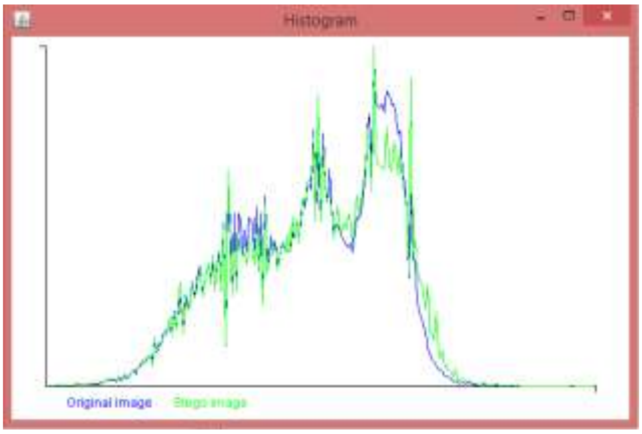

Fig. 6 Saturation Histogram showing color saturation changes in between the cover image and stego image

The Brightness of both cover and stego images can also be represented as given in the histogram in Figure 7. Again, the deviations are clearly visible.

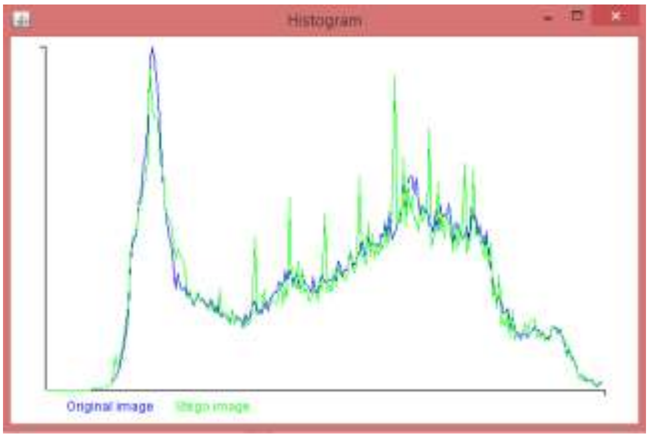

Fig. 7 Saturation Histogram showing color saturation changes in between the cover image and stego image

V. Benchmark and Performance Analysis

The benchmark analysis can be discussed as the study of various parameters pertaining to the images in question. The said parameters and their values are discussed here.

A. Peak Sinal to Noise Ratio

The Peak Signal-to-Noise Ratio one of the most important performance analysis parameter by which the quality of the stego image can be quantified. It can also be defined as the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. The stego image is compared with the original cover image and thus, PSNR can be calculated as:

$$PSNR = 20 \log_{10} (MAX_I) - 10 \log_{10} (MSE)$$

Here MAX_I = Maximum possible pixel value
MSE = Mean Squared Error

In this particular experiment,

$$PSNR = 37.31562278249992 \text{ dB}$$

B. Deviation (Average/Mean Absolute Difference)

The absolute deviation of an element of a data set is the absolute difference between that element and a given point. Typically the deviation is reckoned from the central value, being construed as some type of average, most often the median or sometimes the mean of the data set. In steganalysis, the deviation between the cover image and stego image can be quantified as,

$$Di = |x_i - m(X)|$$

Here D_i = Absolute Deviation
x_i = data element/image data
m(X) = measure of Central tendency

In this experiment,

$$Di = 4.564417009602195.$$

VI. Conclusion

It can easily be inferred from the given example that Steganography in images needs a certain improvement in various domains and parameters. The idea of hiding data into images seems feasible enough but a certain level of control and refinement can fine tune the process and eventually better PSNR and Absolute Deviation figures can be expected. Further research in this field can lead to improved algorithms in both spatial and transformation domains.

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