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Performance Comparison of the Color Coordinate Systems Applied on Satellite Images

Yas Abbas AL-Sultanny
Department of Computer and Information System
University of Applied Science, Jordan Amman 11931 P.O.(17)

Abstract: The Spot and Landsat satellite images carrying a lot of information, therefore the processing of these images controlled by two important parameters, the time and the performance of the processing. In this research the different types of color coordinates models are tested on the Spot satellite images, to compare the performance of the two parameters. The algorithms of color coordinate transformation tested on satellite images of different sizes and types, by converting the color images from the basic RGB model to LHS, HSI, YIQ, HSV, CMY, principle component transformation (PC) and visa versa. The results shows that the YIQ model takes the smallest time than the other models, and the RGB model takes the longer time, and becomes unpractical for satellite images of big size, the principle component will be more effective in multi-band satellite images (Spot of 3 bands, Landsat of 7 bands), since the process will be applied to only one band, not to all the bands, in this case the transformation work well in reducing the process time, with a less performance.

Keywords: Color coordinates, Image Processing, Satellite Images, Color image

Introduction

For computer applications, color is usually described in terms of the red, green, blue, or RGB, color systems (Gonzalez, 1992). Color images originating from film are represented in RGB format when produced by digital scanner having red, green, and blue filter (Lindbloon, 1989). The tri-stimulus theory of colors is based on the hypothesis that there are three kinds of cones in the retina of the eye, each with peak sensitivities to light of either red, green, or blue hue (Morse, 1995). Most colors can be described as a mixture of these tri-stimulus colors with different weights. This how the red, green, and blue phosphor dots on a color CRT are used to display arbitrary colors.

However, the RGB color system does not model well the human perception of color. Applying image processing techniques in the RGB system will often produce color distortion and artifacts. Therefore, color coordinates system based on the human perception of color may be beneficial. Much research has been done to develop theories, standards of color, and measurement techniques, but there is not any one-color coordinate system, which corresponds to human perception that is universally accepted. In fact, there are many coordinate systems that are presently being used for color image processing for different applications, such as in remote sensing for satellite images. They include LHS, HSI, YIQ, HVS, and CMY. Several of these involve three dimensions which are hue, saturation, and brightness. Brightness refers to the perceived luminance. Hue represents the "redness", "greenness" and "blueness". Therefore, the hue depends on the relative mixture of red, green, and blue in the color. If the amounts of red, green, and blue are the same, then the hue is gray. Saturation is the purity of the color. The lower the value of the saturation, the closer the color is to the gray (Yang and Rodriguez, 1997). If more white light is added to the color, then the saturation will decrease (Van *et al.*, 1995) and (Hearn and Baker, 1986).

Basic RGB Color Space: The RGB space is the most frequently color space used for image processing. Since color cameras, scanners and displays are most often provided with direct RGB signal, this color space is the basic one, which is transformed into other color spaces. The color gamut in RGB space forms a cube as shown in Fig. 1. Each color, which is described by its RGB components, is represented by a point and can be found either on surface or inside the cube. All gray colors are placed on the main diagonal of this cube from black (R=G=B=0) to white (R=G=B=max). The main disadvantages of the RGB color space in applications are:

- Involving natural images of a high correlation between its components: about 0.78 for B-R, 0.98 for R-G and 0.94 for G-B components
- Psychological non-intuitivity, i.e. it is hard to visualize a color based on RGB components,
- Non-uniformity, i.e. it is impossible to evaluate the perceived differences between colors on the basis of distance in RGB space (Sangwine, 1998).

Fig. 2 shows the three separate bands the red, the green, and the blue to image of 24 bits in RGB space, with their histograms.

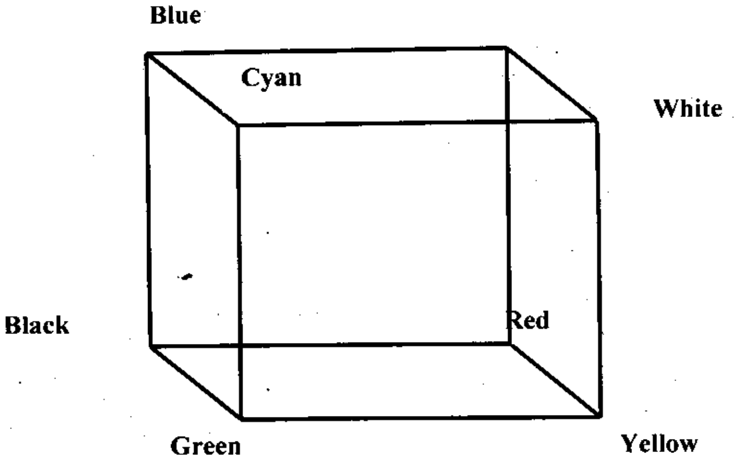
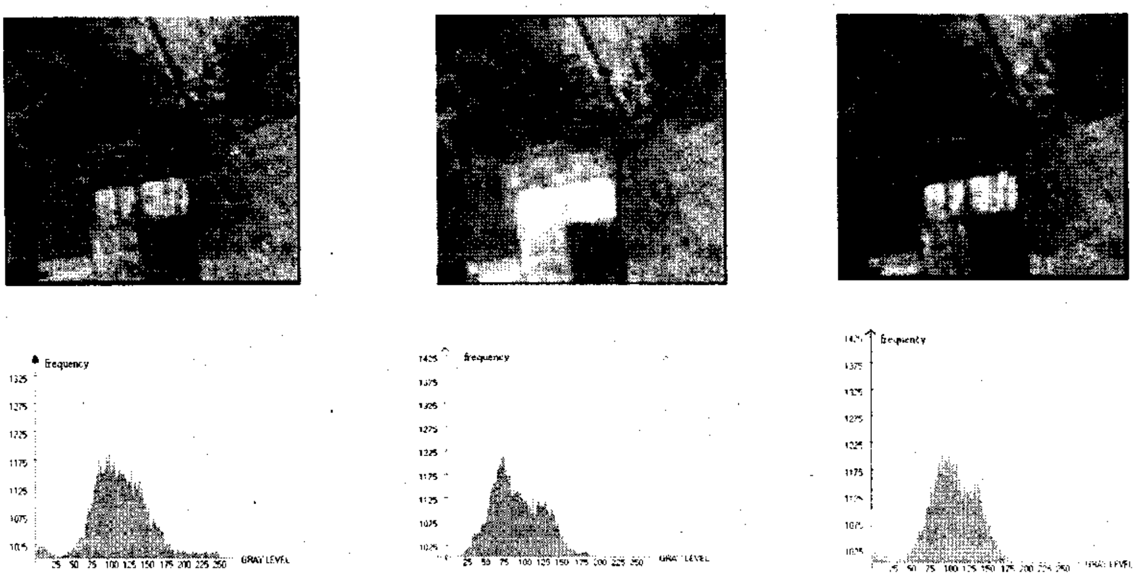


Fig.1: The Cube representation of the color in the RGB color space



(a) (b) (c)

Fig. 2: The three bands of the RGB image of with their histograms

a. The red band, with it is histogram
b. The green band, with it is histogram
c. The blue band, with it is histogram

LHS Space: Fig. 3: shows the physical arrangement of the LHS system. The luminance, ***L***, is represented by the vertical axis. The perpendicular distance from the luminance axis measures the saturation, ***S***. The hue is defined as the angle around the vertical axis (Morse, 1995). The luminance in the LHS system is defined as:

$$L=0.299R + 0.587G + 0.114B \qquad (1)$$

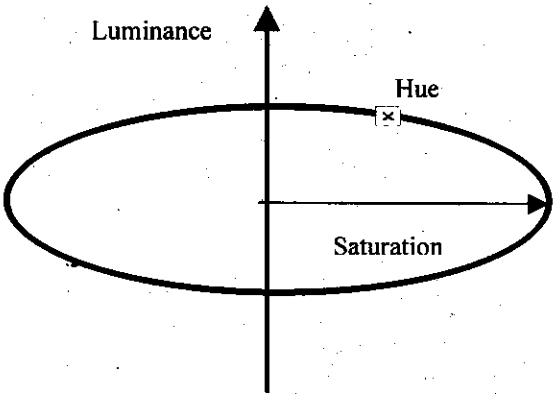


Fig. 3: The LHS system

The RGB and LHS systems can be represented geometrically as shown in Fig. (4), the length of the vector ***op*** is related to the luminance. The triangle with vertices at the maximum values of the RGB axes called the Maxwell triangle.

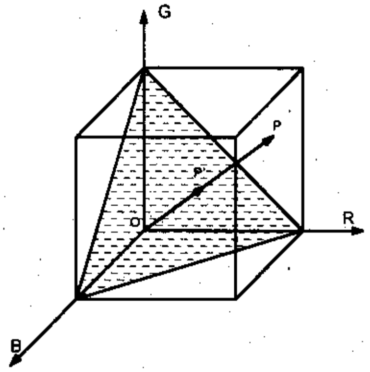


Fig. 4: The RGB and LHS Color Cube

The intersection point of the vector ***op*** with the Maxwell triangle determines the hue and saturation. Fig. (5) shows the relationship between the intersection point ***p'*** and the hue and saturation. The saturation is defined as the ratio of the length ***CP'*** to the length ***CQ.*** The hue is defined as the angle,***θ***, between the vectors, ***CP'***, and ***CR***. Equations for the hue ***H,*** and saturation ***S,*** are as follows: (Yang and Rodriguez, 1997) and (Foley *et al.*, 1995)

$$H=\begin{cases}\cos^{-1}(x) & if \quad G>B\\ 360-\cos^{-1}(x) & if \quad G<B\end{cases} \qquad (2)$$

where

$$x=\frac{0.5\left[(R-G)+(R-B)\right]}{\left[(R-B)^2+(R-B)(G-B)\right]^{1/2}}$$

$$S=1-\frac{3\min(R,G,B)}{R+G+B} \qquad (3)$$

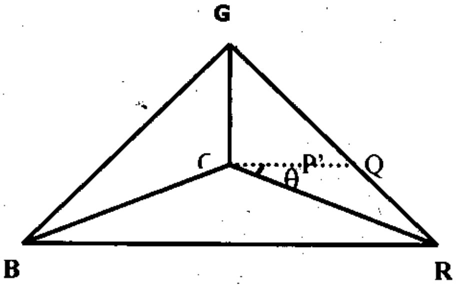


Fig. 5: Maxwell plane

The inverse transformation from LHS to RGB equations is summarized as follows: Assume R, G, B ∈ (0,K), where K the maximum gray value, then:

$$R=Rtemp\frac{L}{0.299Rtemp+0.387Gtemp+0.114Btemp} \qquad (4)$$

$$G=Gtemp\frac{L}{0.299Rtemp+0.387Gtemp+0.114Btemp} \qquad (5)$$

$$B=Btemp\frac{L}{0.299Rtemp+0.387Gtemp+0.114Btemp} \qquad (6)$$

Where ***Rtemp***, ***Gtemp***, and ***Btemp*** are computed as follows

If $0 \le H \le 2\pi/3$

$$Rtemp=\frac{K}{3}+\left(K\left(\frac{2\pi\,3-H}{2\pi\,3}\right)-\frac{K}{3}\right)S$$

$$Gtemp=\frac{K}{3}+\left(K\left(\frac{H}{2\pi/3}\right)-\frac{K}{3}\right)S$$

$$Btemp = \frac{K}{3}(1-S)$$

$$If\ 2\pi/3 \le H \le 4\pi/3$$

$$Rtemp = \frac{K}{3}(1-S)$$

$$Gtemp = \frac{K}{3} + \left(K\left(\frac{4\pi/3 - H}{2\pi/3}\right) - \frac{K}{3}\right)S$$

$$Btemp = \frac{K}{3} + \left(K\left(\frac{-2\pi\ 3 + H}{2\pi\ 3}\right) - \frac{K}{3}\right)S$$

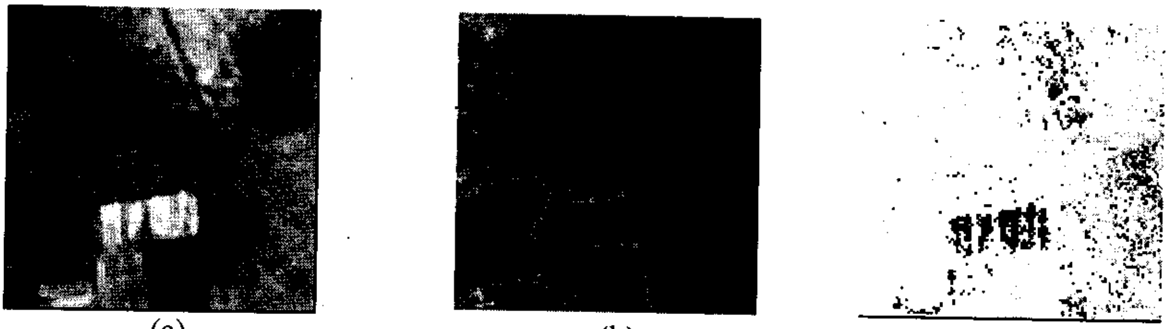
$$If\ 4\pi/3 \le H \le 2\pi$$

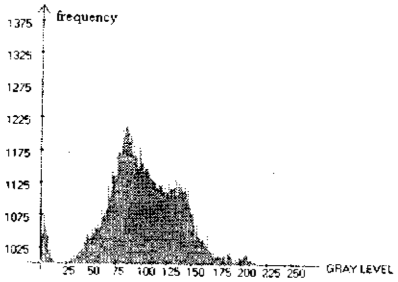
$$Rtemp = \frac{K}{3} + \left(K\left(\frac{-4\pi/3 + H}{2\pi/3}\right) - \frac{K}{3}\right)S$$

$$Gtemp = \frac{K}{3}(1-S)$$

$$Btemp = \frac{K}{3} - \left(K\left(\frac{2\pi - H}{2\pi\ 3}\right) - \frac{K}{3}\right)S$$

Fig. (6 a, b, c) shows LHS components to the RGB components of the image shown in Fig. (2), the histogram of luminance is shown in Fig. (6 d).


(a) (b) (c)



(d)

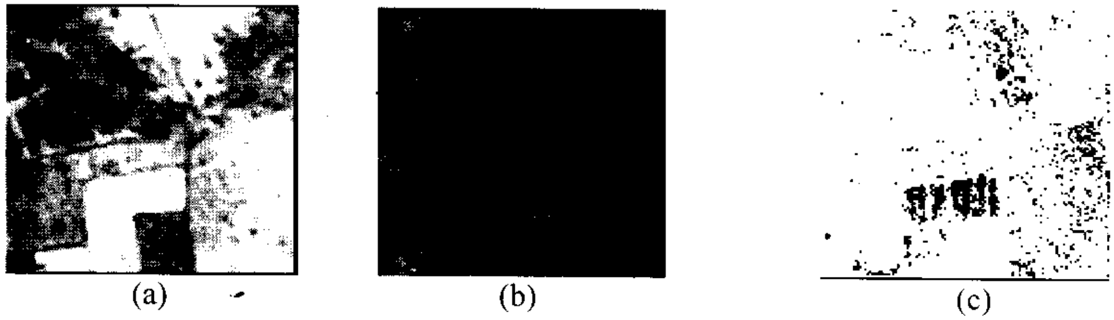
Fig.6: The LHS color system components

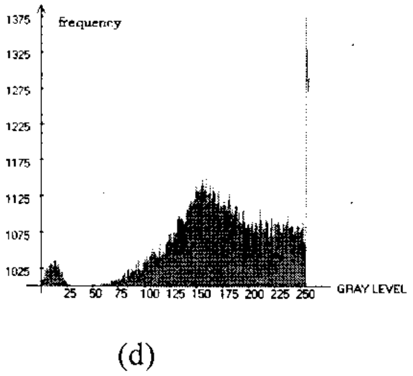
a-The luminance component
b-The saturation component
c-The hue component
d-The luminance histogram

HSI Space: The definition of hue and saturation is exactly the same as in the LHS system. However, HSI uses intensity I for brightness instead of luminance L used in the LHS system. The definitions of hue, and saturation in LHS and HSI are equivalent. The intensity is defined as follows:

$$I = (R+G+B)/\sqrt{3} \quad (7)$$

The inverse transformation from HSI to RGB is the same as the transformation from LHS to RGB, except that I is substituted for L in the equations (4,5,6) [7,8]. Figure (7 a, b, c) shows HSI components transformation to the RGB image shown in figure (2). Figure (7d) shows the histogram of the component intensity.


(a) (b) (c)



(d)

Fig. 7: The HSI color system component example

a-The intensity component
b- The saturation component
c- The hue component
d- The histogram of the component intensity

YIQ Space:

In the development of the United States color television system, the N.T.S.C fromulated a color coordinate system, YIQ. It is found widespread use in commercial color television broadcasting and other applications Turkowski, 1986). The ***Y*** value is the same as the ***L*** component in the LHS system, the ***I*** and ***Q*** values jointly describe the hue and saturation. Transforming the rectangular coordinate system of ***IQ*** to a polar coordinate system, the radius corresponds to the saturation and the angle corresponds to the hue (Morse, 1995).

Moreover, the YIQ system is designed to be more sensitive to changes in luminosity than to changes in hue or saturation, which is similar to the human visual system. Therefore, ***Q*** and ***I*** can be represented by fewer numbers of bits compared to ***Y***. i.e., the bandwidth of ***I*** and ***Q*** can be limited without noticeable degradation. The RGB color system transformed to the to YIQ performed by following:

$$\begin{bmatrix} Y \\ I \\ Q \end{bmatrix} = \begin{bmatrix} 0.299 & 0.587 & 0.114 \\ 0.596 & -0.274 & -0.322 \\ 0.211 & -0.523 & -0.312 \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \qquad (8)$$

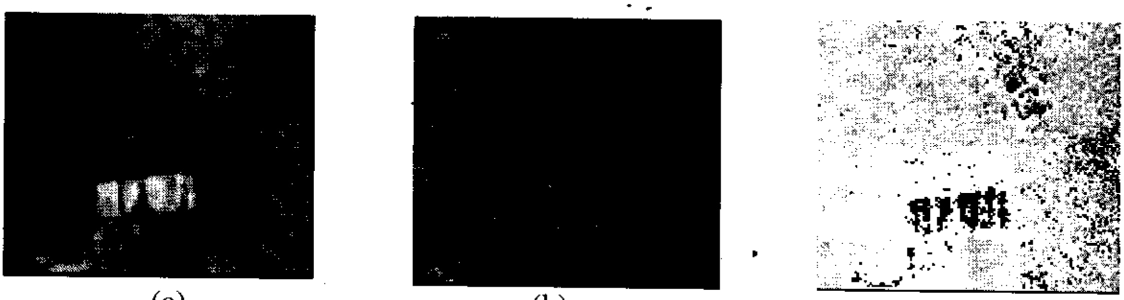
$$Hue = \tan^{-1}\left(\frac{Q}{I}\right) \qquad (9)$$

$$Saturation = \sqrt{I^2 + Q^2} \qquad (10)$$

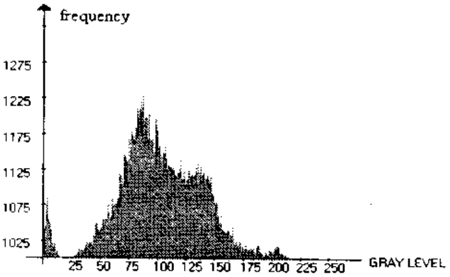
The hue and saturation here are not defined to be the same as those in the LHS and HSI systems. The inverse transformation from YIQ to RGB can be computed by multiplying the YIQ values by the inverse of above matrix: (Yang and Rodriguez, 1997).

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1.000 & 0.956 & 0.621 \\ 1.000 & -0.273 & -0.647 \\ 1.000 & -1.104 & 1.701 \end{bmatrix} \begin{bmatrix} Y \\ I \\ Q \end{bmatrix} \qquad (11)$$

Fig. (8a,b, c) shows Y, H,S components to the RGB image shown in Fig. (2), Fig.(8d) shows the histogram of Y component.



(a) (b) (c)



(d)

Fig. 8: The YIQ color system components

a- The Y component
b- The saturation component
c- The hue component
d- The histogram of the Y component

HSV Space: The HSV (Hue, Saturation, and Value) system also known as the Hexcone model. It is named the Hexcone model because the space of the HSV system is a Hexcone, as shown in Fig. 9. The purpose for this system is mainly aesthetic, accessing color by family, purity, and intensity. The value, ***V***, is the darkness, lightness of a color. The hue and saturation are similar to those used in the LHS and HSI systems. Adding black pigment corresponds to decreasing ***V***, and adding white pigment corresponds to decreasing ***S***, the defining equations for the HSV system are as follows:

$$S = \begin{cases} \dfrac{\max(R,G,B) - \min(R,G,B)}{\max(R,G,B)} & \text{if } \max(R,G,B) \neq 0 \\ 0 & \text{if } \max(R,G,B) = 0 \end{cases} \qquad (12)$$

$$H = \begin{cases} \dfrac{-(B+G)\pi/3}{\max(R,G,B) - \min(R,G,B)} & \text{if } \; R = \max(R,G,B) \\ \dfrac{-(R+B)\pi/3}{\max(R,G,B) - \min(R,G,B)} & \text{if } \; G = \max(R,G,B) \\ \dfrac{-(G+R)\pi/3}{\max(R,G,B) - \min(R,G,B)} & \text{if } \; B = \max(R,G,B) \\ \text{undefined} & \text{if } \; R = G = B \end{cases} \qquad (13)$$

$$V = \max(R,G,B) \qquad (14)$$

The inverse transformation is as follows: (Foley *et al.*, 1995 and Hearn and Baker, 1986).

$$I = floor\left(\frac{3H}{\pi}\right)$$

$$f = H - I$$

$$p = V(1 - S)$$

$$q = V(1 - Sf)$$

$$t = V(1 - S(1 - f))$$

$$[R,G,B] = \begin{Bmatrix} [Vtp] & if & I = 0 \\ [qVp] & if & I = 1 \\ [pVt] & if & I = 2 \\ [pqV] & if & I = 3 \\ [tpV] & if & I = 4 \\ [Vpq] & if & I = 5 \\ [000] & if & S = 0 \end{Bmatrix} \qquad (15)$$

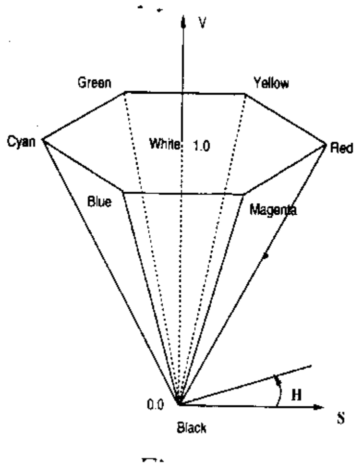
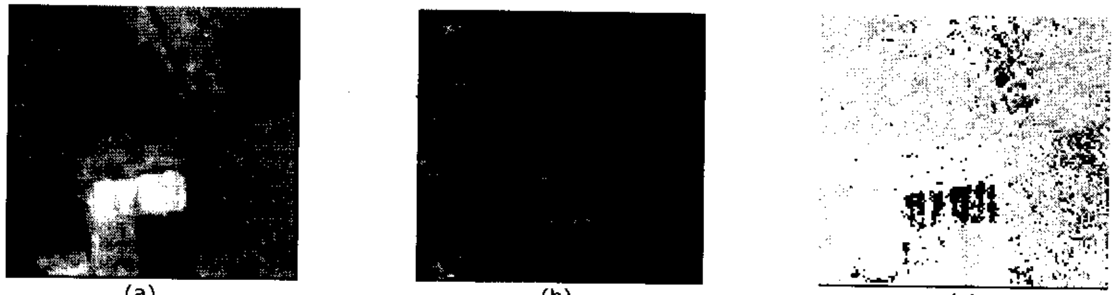


Fig. 9: The HSV Space

Fig. (10 a, b, c) shows HVS components to the RGB image shown in Fig. (2), Fig. (10 d) shows the histogram of the component value.



(a) (b) (c)

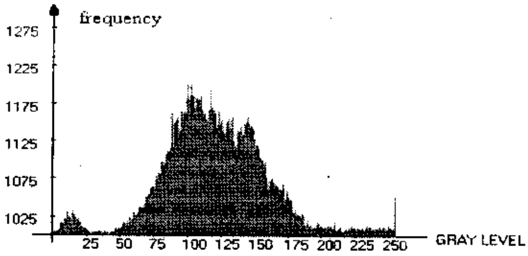


Fig. 10:) The HVS color system components

(d)

a- The value component
b- The saturation component
c- The hue component
d- The histogram of the value component

CMY Color System

The Cyan, Meganta, and Yellow are the complements of red, green, and blue, respectively. The subset of the Cartesian coordinate system for the CMY model is the same as that for RGB except that white (full light) instead of black (no light) is at the origin (Morse, 1995).

The CMY is used when dealing with hardcopy devices that deposit colored pigments onto paper such as Electro-static and ink-jet plotter (Turkowski, 1986).

The relationship between the RGB and CMY mode is defined by the equation;

$$\begin{bmatrix} C \\ M \\ Y \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} R \\ G \\ B \end{bmatrix} \qquad (16)$$

The inverse transformation equation is;

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix} - \begin{bmatrix} C \\ M \\ Y \end{bmatrix}. \qquad (17)$$

Fig. 11: shows the relation ship between RGB and CMY coordinate systems (Hearn and Baker, 1986).

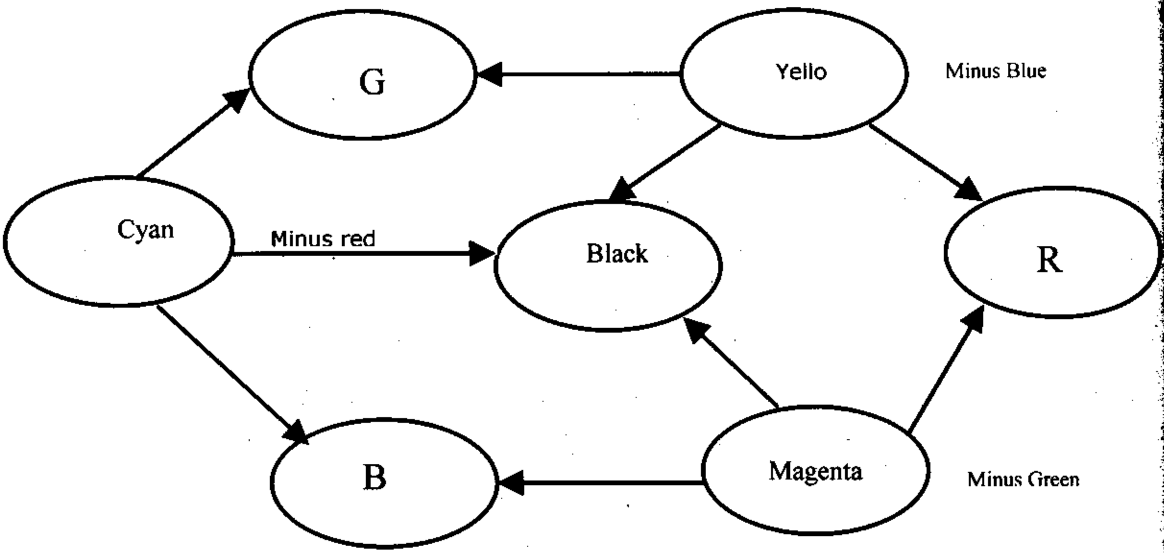
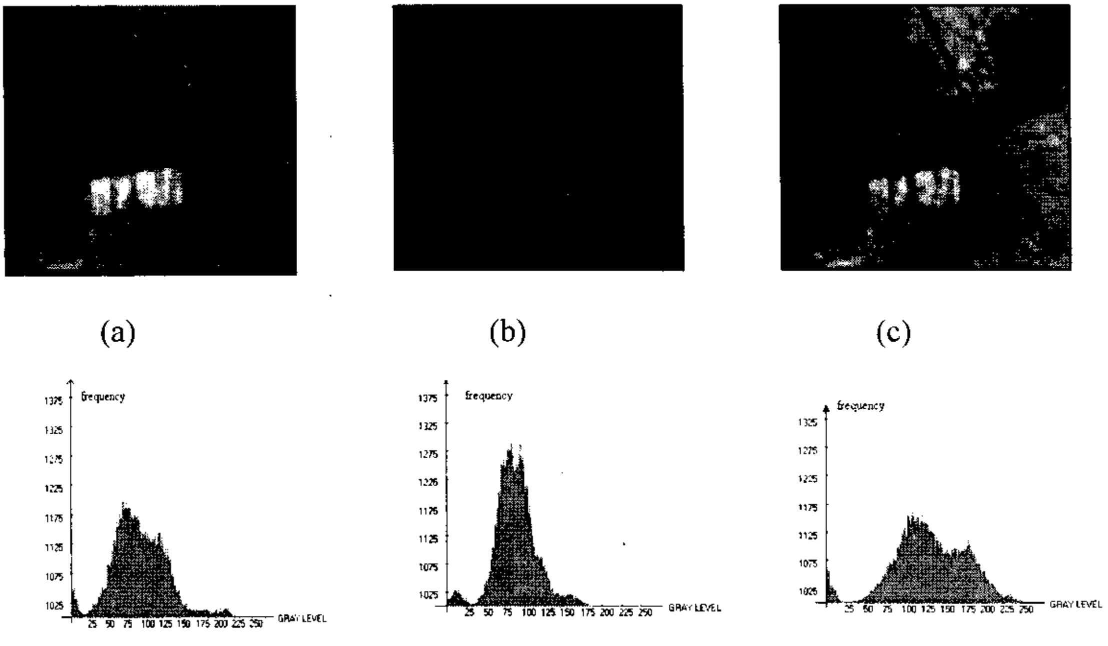


Fig. 11: The relation ship between RGB and CMY coordinate systems

Principal Components Transform (PCT): Many image processing operations work on several or all bands of an image. If there are many bands, it becomes difficult to visualize as well as expensive to process all the bands. To perform principal component analysis, the axes of the spectral space are rotated, changing the coordinates of each pixel in spectral space, and the data file values as well. The new axes are parallel to the axes of the ellipse, major (longest) axis of the ellipse, is called the first principal component of the data (Sultanny, 2000). A new axis of he spectral space is defined by this first principal component (Sultanny, 2000) .



(a) (b) (c)

(d) (e) (f)

Fig. 12: the principal component transformation

Fig. (12 a, b, c) shows PC1, PC2, PC3 components to the RGB image shown in figure (2). Fig. (12 d, e, and f) shows the histograms of the PCs.

a-The first principal component(PC1)
b-The second component(PC2)
c-The third component(PC3)

d-The histogram of PC1 component
e-The histogram of PC2 component
f-The histogram of PC3 component

Discussion

The satellite images, which are used in remote sensing for different applications such as the **Spot** images with its three bands and the **Landsat** images with its seven bands can be processed by using different types of color coordinates.

The algorithms were developed for converting colored images from one color model to another that is more suited for image processing, in the satellite images for remote sensing applications. The algorithms converted the color images from RGB model to HIS, LHS, HSV, YIQ, and principal component and visa versa. Since displays are most often provided output. image with direct RGB model. Images in any other color models (such as HSV, HSI, and YIQ) must be transformed back to the RGB model after handling the processed components in these models (such as V in HSV model, L in LHS model and so on). The operation of transforming the image from RGB model to other models and processing the image in this model and transforming the image back to RGB model take a time different from one model to another. Figure (13) shows the time needed for processing the images in different sizes (any types of images) with different color models after applying smoothing filter. The figure shows that the YIQ model take the smallest time than the other models, the RGB model take long time and becomes not practical for big images size. Therefore processing images in any another color models better than processing them in direct RGB model. In spite of the principal component model take approximately the same processing time of RGB model, but it is more effective in multiband images (satellite images with more than three bands). Since any process is applied to PC1 only, not to all image bands, i.e. this model can be work well to reduce the processing image bands.

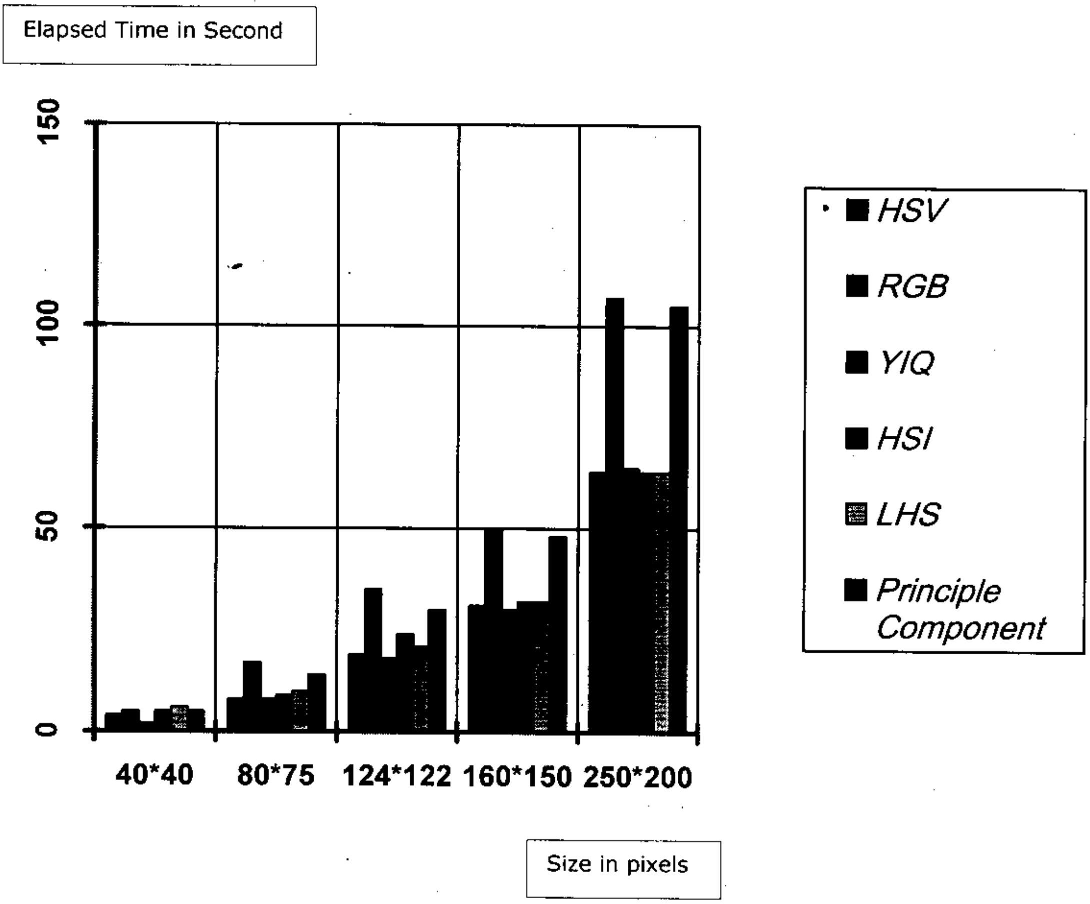


Fig. 13: Histogram of color models elapse time

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