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Comparative Analysis of RGB and HSV Color Models in Extracting Color Features of Green Dye Solutions

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Abstract: RGB (Red, Green, Blue) and HSV (Hue, Saturation, Value) color models were compared with respect to their effectivity in color feature extraction. Varying concentration levels of green dye solutions were prepared, and their digital images were obtained in a controlled environment. The green dye was chosen to mimic the color of algae. Matlab® was utilized for color feature extraction and analysis. The result showed that it is easier to observe and classify colors given clustered data points in *HSV* color model than in *RGB* color model. And there is a direct correlation between the concentration level and digital colors in both color models.

1. INTRODUCTION

Color plays a role on how we perceive and analyze things around us. It is a result of the interaction between the electromagnetic radiation (visible light), and the object's surface properties (i.e. reflectance and transmittance) (Waldman, 2002).

In the human eye, there are photoreceptors that respond to the incident light for color perception. These are the cones. Cones are sensitive to any of the three primary colors (Red, Green or Blue) (Chudler, 2013). Based on this aspect, a lot of color models were established to quantitatively measure color. Quantitative color measurement is one of the key components in color science, scene analysis, detection and tracking.

RGB and HSV color models are one of the simple color models that are widely used today in detection and tracking (Tathe and Narote, 2012, Ong, Mascardo, and Pobre, 2010; Dutta and Chaudhuri, 2009).

In the present work, comparison between the RGB color model and HSV color model was made with respect to varying concentration levels of green dye solutions. Green dye solution was selected to mimic the color appearance of algae. In a previous study (Punzalan, Ong, Carandang, Santos, 2013), only the RGB color model was utilized in validating the correlation between dye solution and concentration level.

2. METHODOLOGY

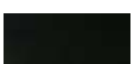
Stock solutions of 14 varying concentration levels following the serial dilution method were prepared using a commercial green dye powder (see Table 1). Each solution was placed in a clear-matte rectangular container, as shown in Fig. 1.

Sony Cybershot DSC-TX5 camera, mounted on a tripod, was used to capture still images of the stock solutions. The camera sensor was about 51cm above the surface of the solution, just enough height for the container to fit the field of view of the camera. The camera settings was set to automatic mode, and set to capture a 2-megapixel resolution image. Each still image was captured given an ambient lighting condition in a controlled environment.

Fig. 1.Experiment Setup.

A 500x200 region of interest was identified in every still image of each stock solution. The cropped image was then rendered in RGB color space and HSV color space for the collection of color features in Matlab®. Graphical representation of each image was then observed and analyzed in both color spaces.

Table 1. Green dye solution in varying concentration levels with their image counterpart arranged in decreasing concentration level (C1 to C14).

Solution	*C1*	*C2*	*C3*	*C4*	*C5*	*C6*	*C7*
Concentration ($x10^{-3}$ M)	**7.68**	**6.92**	**6.22**	**5.60**	**5.04**	**4.54**	**4.08**
Image							
Solution	*C8*	*C9*	*C10*	*C11*	*C12*	*C13*	*C14*
Concentration ($x10^{-3}$ M)	**3.67**	**3.31**	**2.98**	**2.68**	**2.41**	**2.17**	**1.95**
Image							

3. RESULTS AND DISCUSSION

Fourteen green dye solutions of varying concentration levels were redered in RGB color space and HSV color space using Matlab®. The concentration level together with its counterpart image is labeled from C1 to C14 as shown in Table 1, and arranged in decreasing concentration level.

Figures 2 and 4 are the graphical representation of the cluster/spread of RGB values and HSV values, respectively, of specific concentration level (C1 to C14) with respect to the number of pixels in each image. The colormap on the side of each graph represents the pixel count.

The cluster/spread in each graph could be associated with how homogenous the region of interest is, in terms of the color it reflects towards the camera sensor. Wider spread could be due to the unavoidable glare, total internal reflection of light, and shadows, which are visible in some of the images in Table 1.

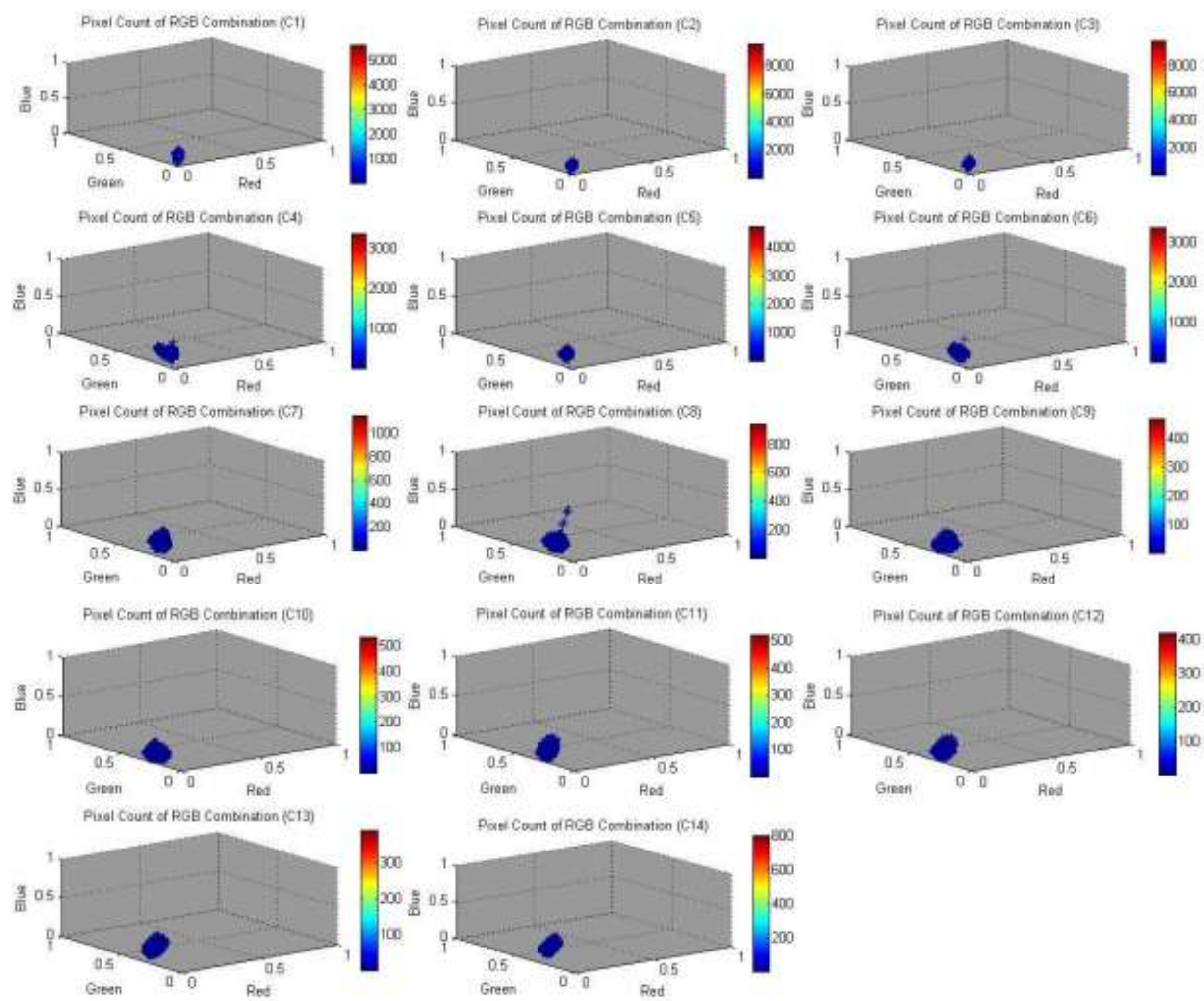


Fig. 2. Graphical representation of the cluster of RGB combination given their pixel count in every concentration level (C1 to C14). The colormap on the side of each graph represents the pixel count.

In RGB color model, a (0.00,0.00,0.00) combination represents a black color and (1.00,1.00,1.00) combination represents a white color. The values in between are the shades of gray of each RGB combination, from darker shades (0.01,0.01,0.01) to lighter shades (0.99,0.99,0.99). In HSV color model, the hue represents the color, the saturation is attributed to the different shades of that color, and value/brightness describes the intensity of lightness/darkness. Figure 3 shows a circular hue spread, which has a range of value from 0.00 to 1.00. It can be seen from this representation that a green hue has a range of approximately 0.20 to 0.40.

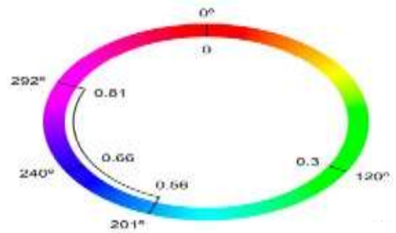


Fig. 3. Hue representation in a circular spread from 0.00 to 1.00 or 0^o to 360^o (Capitan-Vallvey).

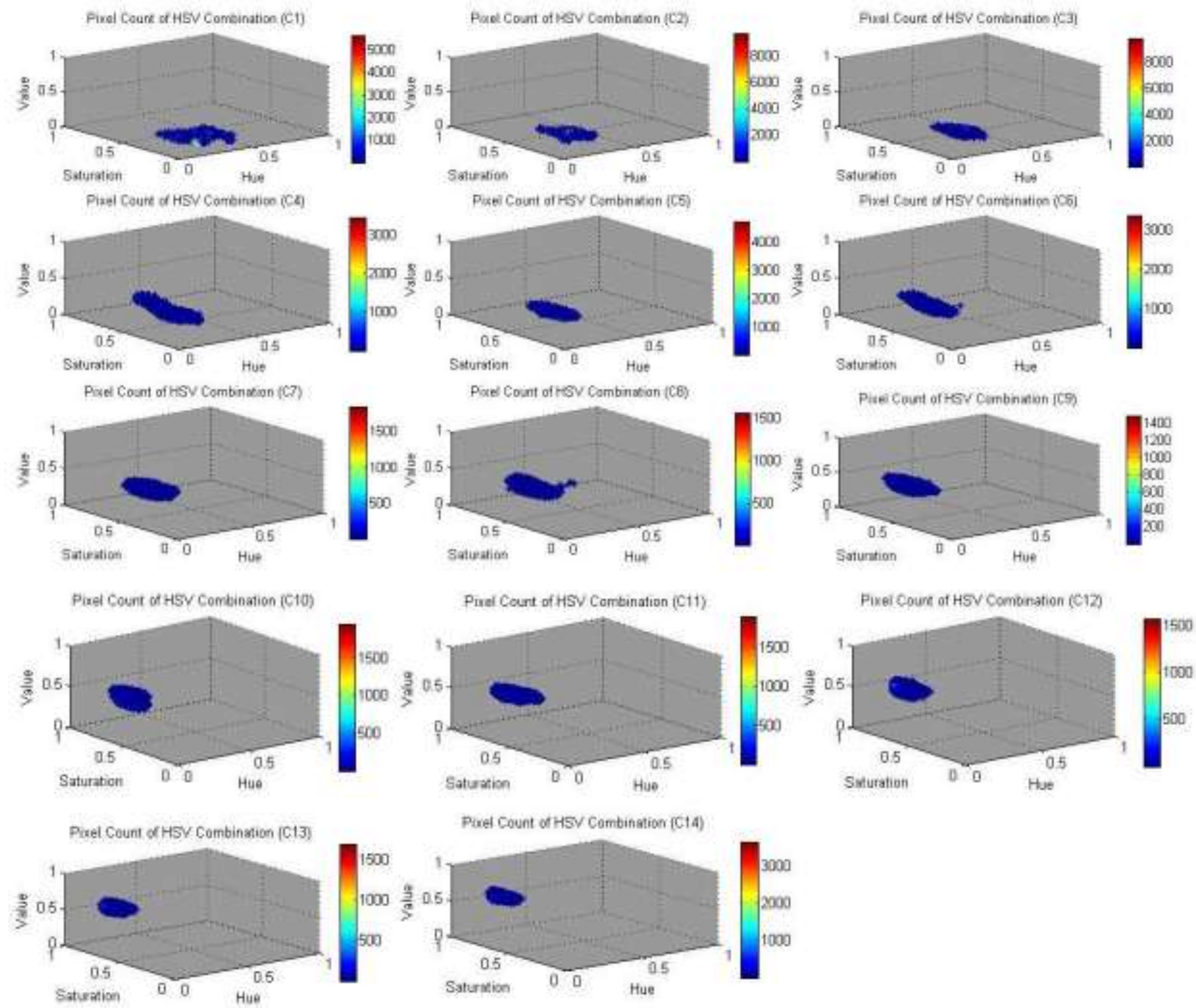


Fig. 4. Graphical representation of the cluster of HSV combination given their pixel count in every concentration level (C1 to C14). The colormap on the side of each graph represents the pixel count.

It is apparent in all the graphs in Fig. 4 that the data points in the hue-axis did not deviate much from one concentration to the next, and it fits the numerical range of "green" given in Fig 3; and only in the saturation-axis that the movement of the cluster of data points is apparent. As the level of concentration decreases, the color information in the saturation-axis increases.

Based from the two sets of graph (Fig. 2 and Fig. 4), it can be seen that it is easier to perceive the color information in the HSV representation than that of the RGB representation. It might also be due to the fact that in RGB color space, it follows an additive color mixing of the primary colors. Different combination could produce a different color. And it is not perceivable given the above representation.

From the cluster/spread of each RGB and HSV pixel combinations, their mean were computed. To see the relationship between the concentration levels and their color features in both RGB and HSV space, another plot was done and can be seen in Fig. 5a and 5b, respectively.

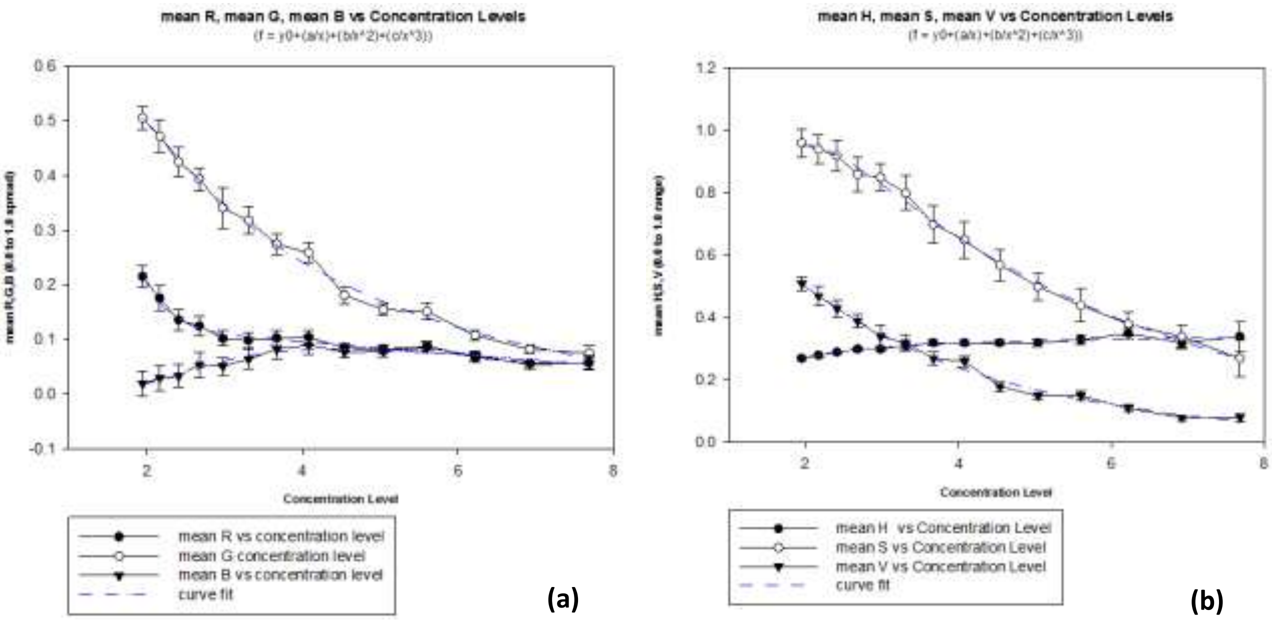


Fig. 5: (a) mean *R*, mean *G*, mean *V* vs concentration levels, and (b) mean *H*, mean *S*, mean *V vs* concentration levels.

Table 2: Statistical result based on the best curve fit of the mean *R,G,B* and mean *H,S,V* with respect to their concentration levels. This result is generated using the SigmaPlot ver. 12.5 (Systat Software, Inc. 2014).

	Global Goodness of Fit				Statistical Tests		
	R	Rsqr	Adj Rsqr	Standard Error of Estimate	PRESS	Normality Test (Shapiro-Wilk)	Constant Variance Test
RGB	0.9980	0.9959	0.9944	0.0093	0.0055	P = 0.4996	P = 0.5358
HSV	0.9989	0.9978	0.9970	0.0129	0.0108	P = 0.1828	P = 0.4619

The *y*-coordinate represents the mean value of each Red, Green, Blue, and Hue, Saturation, Value with respect to the concentration level it represents. For each graph, vertical error bars were also included, with maximum standard deviation: for mean R = 0.022859, for mean G = 0.03727, for mean B = 0.023597; for mean H = 0.047844, for mean S = 0.06022, and for mean V = 0.037296. This error bars takes into account the fact that even if the dye solution is homogenous, some natural stimuli, such as glare, total internal reflection and shadows, could influence the color information that the camera sensor captures.

In Table 2, the color information in both color models with respect to the concentration levels passed the Normality Test using the Shapiro-Wilk and the Constant Variance Test. Also, the statistical results showed that the best curve fit for each color models has R-squared = 0.09959 for the mean *RGB* values and R-squared = 0.9978 for the mean *HSV* values. This only shows that the color features with respect to the concentration values are close to the best curve fit in both color models.

4. CONCLUSION

This paper showed that graphical cluster/spread representation of color features in both color models could quantify the "homogeneity" of each solution as perceived by the camera sensor. As for the representation and interpretation of clustered data points with respect to color classification, *HSV* color model gives more perceivable information than in the *RGB* color model. The result further showed in both color models that the concentration has a direct correlation with digital colors given a polynomial equation.

5. REFERENCES

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