The Design and Implementation of Digital Image Segmentation in HSV Color Space

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ABSTRACT
Segmentation subdivides an image into its constituent parts or objects[4]. The purpose of segmentation is to simplify or change from a digital image to the more meaningful and easier to analyze. Most of the segmentation process is done in RGB representation. In this paper, the segmentation process is done in HSV representation. The process consist several steps: changing the representation from RGB to HSV, search the centroid points using maximin algorithm, clustering by K-Means, and post processing of the results of clustering to eliminate noise and unnecessary detail. This application was created with C #. net with Microsoft Visual Studio 2005 as its IDE. The result indicates that the segmentation results are influenced by the centroid points. With determining the exact number of centroids, it gives clear segmentation result. Factors that can affect the centroid are intensity light and color range on the digital image.

Keywords
HSV, K-Means, Clustering, Image Segmentation.

1. INTRODUCTION
Segmentation is the process of digital image distribution into several parts. The segmentation function method of this feature is how to simplify or change the form of a digital image into meaningful and easier condition, so it can be analyzed faster depend on its application. The problems are how to recognize the objects or foreground image with the background setting and the fix parametric object segmentation as its real form.

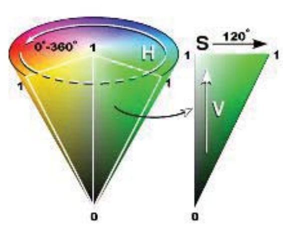


Figure 1. HSV Cone

Digital imaging is the group of color pixel that set on specific position and color to present a form or object. The pixel itself is well known as group of digital imaging represented by the value of RGB (*Red, Green,* dan *Blue*). The disadvantage of RGB representation itself can't to recognize the detail of highlights, shadows, and shading from a digital image. To complete the RGB method, the HVS digital image segmentation is added for excellent and perfect integration. HSV is a cylindrical coordinate representation function that used to rearrange RGB geometrical structure with relevant value, shown in Figure.1. This method is divided into few major topics that will be discussed bellow. Specific words may be known as the information follows.

Hue, is the basic color element to be used. Saturation is the perspective of lighting and the human sensitivity of color gradation variety depend on hue. Value is the intensity of color level or color brightness. HSV representation method provides the detail of color information for the human perspective about color and how the human use the color like an artist create a painting works.

The HSV per-pixel method use the technique of degenerate color that divided into two major function called color and gray histogram. The number of this method is set in a variety of description such as hue will set on [0^o,360^o], Saturation [0,1], and Value [0,1], so the quantization process for each dimension normalization can be counted as example bellow:

Quantization for Hue = 12^o, Saturation = 0.125, and Value = 0.125 it will be 30x8x8=1920 bin. If the amount of Hue Saturation is close to the gray color, the amount should be separated by the color and gray histogram for the perfect presentation. The detail of this function can be read as the table below.

Table 1. Correspondence of Histogram Bins and HSV Indices

Histogram bin	Range Parameter	Correspondence of Index
	v' = 0	
G(v)	atau	v = v'
	v' ∈ [1, 7] dan s' = 0	
	h' ∈ [0, 29]	h = h'
B(h,s,v)	*s'* ∈ [1, 7]	s = s'
	v' ∈ [1, 7]	v = v'

G(v) is represented the amount of pixel on gray histogram bin with the parametric described by (v) and B (h,s,v) represented the amount of pixel in color histogram bin with the parametric (h,s,v). So the total bin can be count 30 x 7 x 7 = 1470 bins.

Thus, the next step will continued with the process of clustering by the histogram value, labeling them on each pixel. The clustering processes use the K-Means method to analyst all part of n clusters parts to “k” clusters observation based on mean or average value on close level. The value of “k” is counted by random method, commonly replacing with maximum heuristic algorithm histogram.

The clustering result is also describes as digital image segmentation, but it is need final process to eliminate the image noise and unnecessary pixel label. This process called post processing. The final result of all this process provides a new digital image that can be used for other application or processing and analyze as needed. The other function of this method (HSV segmentation) can be used also for object searching based on blob segmentation area. The widest and dominant blob will be describe as figure of background and the left blob (which has a different value of segmentation with the background) will be describe as foreground figure.

2. DESIGN AND IMPLEMENTATION

This Digital Image Segmentation in HSV Color Space contains 3 sections.

- Color space transformation.
  The function for transform RGB color space to HSV color space is defined by a set of equation number 1.

$$H1 = \cos^{-1}\left\{\frac{0.5[(R-G)+(R-B)]}{\sqrt{(R-G)^2+(R-B)(G-B)}}\right\}$$

$$H = H1 \quad \textit{if} \quad B \le G$$

$$H = 360° - H1 \quad \textit{if} \quad B > G$$

$$S = \frac{Max(R,G,B) - Min(R,G,B)}{Max(R,G,B)}$$

$$V = \frac{Max(R,G,B)}{255} \tag{1}$$

- Histogram HSV generation.
  Since the ranges of three dimensions in HSV color space are not the same (Hue: [0, 360◦], saturation: [0, 1], and value: [0, 1]), a quantization process is needed, shown in Figure.2. Quantization for Hue = 12^o, Saturation = 0.125, and Value = 0.125. For correspondence of histogram bins, follow the Table 1.

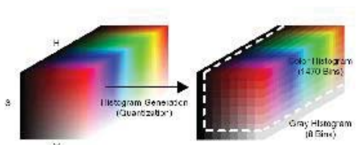


Figure 2. Histogram HSV *Generation* dan *Quantization*

- K-Means clustering and segmentation.
  K-Means clustering is a method for cluster analysis to observe many parts of *n* into *k* clusters or centroids where observations are based on the mean or average of the nearest neighbors. To find number of centroid from generated histogram, Maximin algorithm is used. From color and gray histogram bins, find the bin which has the maximum number of pixels to be the first centroid. For the remaining bins, calculate the minimum distance between it and its closest centroid. Bin which has a maximum value of the minimum distance is selected as the next centroid. Function for calculate the distance, is defined by

$$D_h^2(h_i, h_j^{(t)}) = \begin{cases} \left(\frac{360^0}{h_Q} - \left|h_i, h_j^{(t)}\right|\right)^2, if \left|h_i, h_j^{(t)}\right| > \frac{180^0}{h_Q} \\ \left(\left|h_i, h_j^{(t)}\right|\right)^2, otherwise \end{cases}, \tag{2}$$

Repeat the process until the number of centroid equals to KMax or the maximum value of the distance is smaller than a predefined threshold ThM. The KMax by default set by 10, based on the assumption that there should be no more than 10 dominant color in one image for highlevel image segmentation, and ThM = 25 is set empirically according to the human perceptions of different color in HSV color space.

After find the centroid, the next process is clustering the rest bins which not the centroid itself. The color and gray histogram will be clustered together. For color histogram, since Hue dimension is angle, the distance measurement between a color histogram bin vector $\mathbf{B}_i = (h_i, s_i, v_i)$ with a cluster centroid vector $C_j^{(t)} = (h_j^{(t)}, s_j^{(t)}, v_j^{(t)})$ in the current iteration t is defined in the form of the Euclidean distance.

$$D^2(B_i, C_j^{(t)}) = D_h^2(h_i, h_j^{(t)})^2 + (s_i - s_j^{(t)})^2 + (v_i - v_j^{(t)})^2 \tag{3}$$

Each color histogram bin clustered to nearest centroid by the distance measurement.

$$\phi_{(j|B_i)}^{(t)} = \begin{cases} 1, \ if \ \ j = \arg\min_k D^2(B_i, C_k^{(t)}) \\ 0, otherwise \end{cases} \tag{4}$$

For the gray histogram bins since no Hue value information, the distance measurement between a gray histogram bin $\mathbf{G}_i = (v_i)$ with a cluster centroid vector Cj(t) = (hj(t),sj(t),vj(t))

$$D^2(G_i, C_j^{(t)}) = (s_j^{(t)})^2 + (v_i - v_j^{(t)})^2 \tag{5}$$

After all color and gray histogram bins clustered to nearest centroid then update centroid. Again, since the hue dimension is circular, the indices in the hue dimension should be considered not absolutely but relatively. The method to calculate the relative value of the original Hue index h_i to the centroid $C_j^{(t)} = (h_j^{(t)}, s_j^{(t)}, v_j^{(t)})$

$$\overline{h}_{i,j}^{(t)} = \begin{cases} h_i - \frac{360^0}{h_Q}, & if \left|h_i - h_j^{(t)}\right| > \frac{180^0}{h_Q} and \ h_j^{(t)} < \frac{180^0}{h_Q} \\ h_i + \frac{360^0}{h_Q}, & if \left|h_i - h_j^{(t)}\right| > \frac{180^0}{h_Q} and \ h_j^{(t)} > \frac{180^0}{h_Q} \\ h_i, & otherwise \end{cases} \tag{6}$$

Then update all dimension of centroid according to the following equations. Where $B(B_i)$ is the number of pixels in the color histogram bins for histogram bin vector B_i and $G(G_i)$ is the number of pixels in the gray histogram bins for histogram bin vector G_i.

$$h_j^{(t+1)} = \frac{\sum_{i=1}^{N_B} \widetilde{h}_{i,j}^{(t)} \, \phi_{(j|B_i)}^{(t)} \, B(B_i)}{\sum_{i=1}^{N_B} \phi_{(j|B_i)}^{(t)} \, B(B_i)},$$

$$s_j^{(t+1)} = \frac{\sum_{i=1}^{N_B} s_i \, \phi_{(j|B_i)}^{(t)} \, B(B_i)}{\sum_{i=1}^{N_B} \phi_{(j|B_i)}^{(t)} \, B(B_i) + \sum_{i=1}^{N_G} \phi_{(j|G_i)}^{(t)} \, G(G_i)},$$

$$v_j^{(t+1)} = \frac{\sum_{i=1}^{N_B} v_i \, \phi_{(j|B_i)}^{(t)} \, B(B_i) + \sum_{i=1}^{N_G} v_i \, \phi_{(j|G_i)}^{(t)} \, G(G_i)}{\sum_{i=1}^{N_B} \phi_{(j|B_i)}^{(t)} \, B(B_i) + \sum_{i=1}^{N_G} \phi_{(j|G_i)}^{(t)} \, G(G_i)},$$

After all centroid has been updated, check whether the clustering process is converged according the summation of distances between each histogram bin to nearest cluster centroid.

$$\Delta^{(t)} = \sum_{i=1}^{N_B} \sum_{j=1}^{K} \phi_{(j|B_i)}^{(t)} \, D^2(B_i, C_j^{(t)}) \, B(B_i) + \sum_{i=1}^{N_G} \sum_{j=1}^{K} \phi_{(j|G_i)}^{(t)} \, D^2(G_i, C_j^{(t)}) \, G(G_i) \quad (8)$$

If the difference of total distortion $|\Delta(t+1) - \Delta(t)|$ is less than predefined threshold. If not converged then repeat the clustering process until converged or when maximum iteration is reached. After the clustering process is completed then the digital image has been labeled or segmented in the HSV representation.

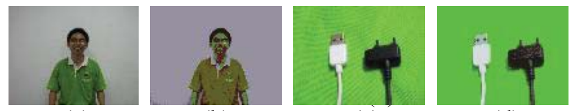
In addition, a filter for post-processing is introduced to effectively eliminate noise (small labeled). And also suggest the candidate of object from the segmentation result, background or foreground.

- Post processing.
  To remove the noise, common Spatial Filters like Median and Mean Filter are applied to labeled image.
- Suggest the candidate of object.
  The first step on seeking object candidate is starting with the label image of the background candidate. The initial process starting with counting the roving image, the label which has the maximum amount will be set as background. Wide of the initially process depend on the user input where the minimal wide per pixel will be affected through initial system. When the process is finished by the background labeling, the seeking object process will be continued as further step.
  In assumption, the left labeled image exclude the background will be initialed as foreground image. This process starts by the verification loop that allows the system to count the process with valid value. The group of the left labeled image will be set partly as blob. This blob will be categorized into few threshold images, then selecting by user input. When the large of the blob is low from the threshold, it will be vice versa and will be used as object candidate.

3. EXPERIMENTS

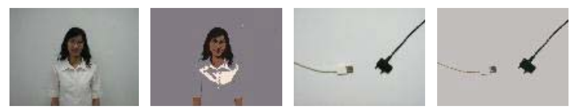
The experiments are performed in Intel® Core i5™ 430M 2 core @ 2.8 GHz, RAM 4 GB, and graphic card ATI Mobility Radeon HD 5470 1 GB VRAM. Digital images are captured by pocket digital camera Canon PowerShot™ A430 4.0 Megapixels.

- Digital image background experimental factors.
  The process of testing is done by giving the input image with a background color must be contrast and had a different color contrast with the object itself. In this test, a resolution of 1024x768 pixels is selected and the parametric segmentation mode is set by default.



(a) (b) (c) (d)

Figure 3. Background contrast with the object: (a) Original 1, (b) Segmentation result of (a) (k=10, time=6029 ms), (c) Original 2, (d) Segmentation result of (c) (k=9, time=2465 ms)



(a) (b) (c) (d)

Figure 4. Background not contrast with the object: (a) Original 1, (b) Segmentation result of (a) (k=10, time=5647 ms), (c) Original 2, (d) Segmentation result of (c) (k=14, time=9172 ms)

Image which has a contrast background, give more clearly segmentation result. Centroid searching parametric testing.

The testing process of the centroid searching parametric is done by giving the value of the parameter range K-Max which limit the number of centroid and the threshold parameters that limit the calculation. The experiments also distinguished between the maximin algorithm automatically searches and manually from users inputs where the choice is limited by human perception about colors and objects. In this test, a resolution of 1024x768 pixels is selected and the parametric segmentation mode is set by default except for the centroid search, shown in Figure.5 and Figure.6.

(a) (b) (c) (d)

Figure 5. Maximin algorithm: (a) Source Digital Image, Segmentation result: (b) K-Max default (100, (c) K-Max set 6 (d) K-Max default (100)

(a) (b) (c)

Figure 6. Manually user inputs: (a) Source Digital Image, Segmentation result: (b) Try I: K-Max set 7 (candle, spidol, rubber, bottle cap, lighter, razor blade, and

background, (c) Try II: K-Max set 7 (candle, spidol, rubber, bottle cap, lighter, razor blade, and background)

It can be seen that finding centroid using maximin algorithm with various range K-Max and Threshold give different number of centroid found. Meanwhile, user manual input may affected a different segmentation results, though the selecting object testing process had been used twice. This may be happened because the value of the chosen centriod HSV may be different in the same object, for example the gradation looks like the same but actually has different value.

- Flux testing factors.

The Flux testing factor process is accomplished by providing a digital image that has a range of composition and same object but different in flux. Flux settings not from digital image reprocessing, but from exposure settings on the camera, is raised, lowered, or normal. In this test, a resolution of 1024x768 pixels is selected and the parametric segmentation mode is set by default.

Figure 7. (a) Exposure normal. (b) Segmentation result (12 centroid finded)

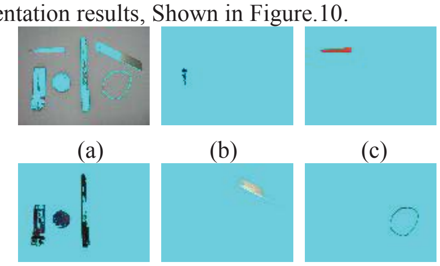
Figure 8. (a) Exposure -2. (b) Segmentation result (11 centroid finded)

Figure 9. (a) Exposure +2. (b) Segmentation result (13 centroid finded)

It can be seen that lower or more exposure make digital images loose of color information. Lower exposure makes color fades to dark and more exposure makes color fades to white. Various flux not affected the segmentation process, but affected the segmentation result because the finded centroid are different.

- Testing the segmentation result to find candidate object

  The testing process to find candidate object from segmentation result are performed by providing different kinds of segmentation results, Shown in Figure.10.



(a) (b) (c)

(d) (e) (f)

Figure 10. Source image Fig. 10 (a) with 6 centroid, (a) candidate background, (b) candidate foreground 1, (c) candidate foreground 2, (d) candidate foreground 3, (e) candidate foreground 4, (f) candidate foreground 5

(a) (b) (c) (d)

Figure 11. Source image Fig. 5 (a) with 4 centroid, (a) candidate background, (b) candidate foreground 1, (c) candidate foreground 2, (d) candidate foreground 3

It can be seen that segmentation result affected the process to finding the candidate object. When the results of the segmentation equal to the expectation, the search of object candidate will be valid.

4. CONCLUSION

Based on the test results, it can be inferred conclusions as follows:

- Segmentation results is only affected by the centroid values and number of centroid that is used in the K-Means clustering process. The amount processing depends on the centroid size.
- Within searching process, the number of objects in the centroid digital image does not affect to the found of centroid. The process itself will only be affected by the HSV values information on various objects in the digital image.
- Light intensity/flux is affected to the clarity information on digital image where this information would be a reference in the selection process of centroid. The image that gets a high light intensity, will be resulting to digital image tends towards white color when compared with normal intensity. So do the opposite conditions, when the image gets a low intensity, the digital images tend to black. This is similar to the subject of human eyes to see objects. When the light intensity is too high or low, then the information can be captured by eyes is reduced or absent.
- The contrast background with the object on the digital images will produce a clear segmentation between the background and the object. Meanwhile, not contrast background makes some or all of the segmentation on the object into one cluster with a digital image background.
- The right determination of the exact amount of centroid, resulting clear and fixed segmentation. The large number of the centroid makes the segmentation became scattered and produce some noise.
- The lowest number of centroid, will only make the segmentation results looks like forced.

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