A Comparative Study of KMCG Segmentation Based on YCbCr, RGB, and HSV Color Spaces

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Abstract:

Kekre Median Codebook Generation (KMCG) is a vector quantization algorithm. It is used for several purposes like image compression and segmentation. It has been applied by several application and shows its efficiency. This paper presents a comparison study of applying KMCG with three color models: RGB, YCbCr, and HSV for image segmentation. The experiments applied on five images, three of them are benchmarks. Two numerical metrics are utilized: E measure and Peak Signal to Noise Ratio (PSNR), in addition to the visual results. The final results show that KMCG conducts better segments when it is applied with the RGB color model. It returns more homogenes segments than using KMCG with YCbCr or HSV.
Introduction

Image segmentation is one of the most important steps in the analysis of processed image data. The main goal of segmentation is obtaining parts that have a strong correlation with objects areas of the real world in the image.

Segmentation accuracy is an important factor in determining the success or failure of computerized analysis procedures. For this reason, considerable care should be taken to improve the probability of accurate segmentation [1] [2]. Many methods of image segmentation have been proposed could be categorized generally as:

- **Edge-based** image segmentation like Active Contour
- **Region** base as Seed filling algorithm and clustering algorithms.
- **Thresholding** based image segmentation such as Otsu method.
- **Clustering** based image segmentation such as KMCG and K-mean
- **Combined** between the above category like watershed.

Literature Review

Generally, KMCG is a clustering algorithm found by Kekre in 2008 for data compression purpose. However; this algorithm enforces efficiency in several areas like segmentation and clustering. It summarized by the following steps [3]:

1. Distribute the data in equal size vectors.
2. Arrange vectors based on the first value.
3. Set the median of the array of vectors in the CB.
4. Repeat step 2 & 3 on the other vectors values until obtaining the desired codebook size as shown in Fig. (1).

![Figure 1: KMCG General Steps [5]](image)

KMCG is applied to an image by dividing it’s data to equal nonoverlapped windows. Each window color data is represented in a vector. As in gray level, the window size is four yields a vector length of 4 [4].

KMCG algorithm had been augmented, to decrease the required time in the clustering process of a gray image. In this method, vector size is increased to 6 columns, in which the last four columns are used to store original gray levels, which obtained from 2 x 2 blocks of the image. Further, averages of each of these blocks are done separately and stored in the second column in the respective vectors. The sequence number of the respective vectors has been stored in the first column [5].

KMCG used by different applications due to its homogeneity and efficiency of its segmentation. One of these applications is image cartooning. As in [6] shows that the consumed time of the cartoon production is less by using KMCG in comparison with other vector quantization methods. Also, it presents a better quality of segmentation of KMCG than the other methods.

Another application designed based on KMCG, which is fingerprint classification. It was observed that the method effectively improves the computation speed and provides high accuracy [7].

KMCG literature shows its importance and efficiency. Thus, this paper is to study and find the best color model to be applied with KMCG.
Color Models

Color models in image processing provide valuable tools for objects recognition and extraction from the scene. It also enables the extension of the domain space compared with gray images. Color spaces are used for different applications such as; computer graphics, image processing, TV broadcasting, and computer vision. Several models had been introduced. YCbCr and HSV are two samples of them. All of the models are extracted from the original model of RGB. [8].

YCbCr Color model used for digital video. It defined in the ITU-R BT.601 standards of ITU (International Telecommunication Union) represents the encoding form of non-RGB signal. The transformation from RGB to YCbCr color model is given in the following equation [8]:

\[
\begin{bmatrix}
Y \\
Cb \\
Cr
\end{bmatrix} = \begin{bmatrix}
0.299 & 0.587 & 0.114 \\
-0.169 & -0.331 & 0.500 \\
0.500 & -0.419 & -0.081
\end{bmatrix} \begin{bmatrix}
R \\
G \\
B
\end{bmatrix}
\]  

(1)

The HSV color model based on the idea of the human visual system. It belongs to the HSI family of color models uses cylindrical coordinates for the representation of RGB points as shown in Fig. 2. Hue (H) and saturation (S) which are the chrominance components. V is the maximum value of RGB.

HSV is used mainly for computer vision, and image analysis of the segmentation process. The conversion from RGB to HSV is summarized by the following steps [8].

1. Find the maximum and minimum values as in the following equation:

\[M = \max(R,G,B), m = \min(R,G,B)\]  

(2)

2. Normalized the RGB values to be in the range [0, 1].

\[r = \frac{M-R}{M-m}, g = \frac{M-G}{M-m}, and \ b = \frac{M-B}{M-m}\]  

(3)

3. Find V value.

\[V = \max(R,G,B)\]  

(4)

4. Calculate S value.

\[S = \frac{M - m}{M}\]  

(5)

However, if \(M = 0\) then \(S = 0\) and \(H = 180\).

5. Calculate H value as in equation (2.26)

\[H = H - 360 when H \geq 360, H = H + 360 when H < 0\]  

(6)

6. Normalize H to be in the range [0,360] as in the following:

\[H = 60(b - g) when R = M,\]

\[H = 60(2 + r - b) when G = M,\]

\[or H = 60(4 + g - r) when B = M\]  

(7)

7. Return HSV

KMCG Algorithm

The detailed steps of KMCG are demonstrated by algorithm 1. The window represents the data that needed to be clustered. For instance, if the vector is of RGB image data, and the window size is 4, then the length of the vector is 12. As shown in Fig. 3.

Figure 3 KMCG Vector Example
L is the length of the vector to be clustered. If the length is equal to 6, then the no. of clustering iterations is six, and the Codebook (CB) size is 64. Each iteration concludes sorting the vector of the whole image data based on one value of the vectors. For example: in the first iteration of the RGB image the vectors are sorted based on R1, which its position clarified by Fig. 3. Then after sorting the whole vectors, the data each cluster is separated into two clustered based on the median position of the vectors. Finally, the median vector is added into CB. This process is continued until the required length of the codebook is satisfied

**Experiments and Results**

The experiment is applied by testing KMCG with the three-color models: RGB, YCbCr, and HSV. Five samples of images that used. Three of them are standard images: Lena, Baboon, and the image of man is from a standard dataset called VidTIMIT [9].

The specification of the used computer and programming language is listed as the following:

- 12 G RAM, 512 SSD
- Intel ® Core™ i7_6500U CPU @ 2.50GHz
- System: Windows 10 64
- The programming language: C#

The size of the KMCG codebook which used by our experiment is 64.

| Algorithm (1): Original KMCG |
|-------------------------------|
| **Input** | A bitmap Im of size M*N, W (window size), L (required) |
| **Output** | CI (Cartooned Image) |
| **Begin** | //Initialization |
| **Step1** | Set lstVectors ← FillVectors(Im,W) |
| **Step2** | Set lstClusters ← InitializeClusters(lstVectors) |
| **Step3** | //Clustering and Codebook Construction |
| **Step4** | for j =1 to L do /* L is the required size of vectors values */ |
| **Step5** | foreach cluster C in lstClusters do |
| **Step6** | SortAscending(C,j) /* Sorting theCluster C based on value sequence j*/ |
| **Step7** | AddMediantoCB(C) |
| **Step8** | SplitClusterAndAdd(lstTempClusters,C) |
| **Step9** | end foreach |
| **Step10** | end for |
| **Step11** | //Constructing Cartooned Image |
| **Step12** | foreach cluster in lstClusters do |
| **Step13** | Set newRGB ←CalculateAverage(cluster) |
| **Step14** | SetValueInImage(C,newRGB,CI) |
| **End** | |

**Results**

**Table 1:** PSNR of KMCG with RGB, YCbCr, and HSV

| Image | KMCG RGB | KMCG YCbCr | KMCG HSV |
|-------|----------|-------------|----------|
| Baboon | 36.66 | 36.07 | 35.71 |
| Lena | 38.67 | 37.97 | 37.44 |
| Man | 42.85 | 39.21 | 40.18 |
| Woman | 42.02 | 38.33 | 38.08 |
| Girl | 42.78 | 38.39 | 38.8 |

**Table 2:** E measure of KMCG with RGB, YCbCr, and HSV

| Image | KMCG RGB | KMCG YCbCr | KMCG HSV |
|-------|----------|-------------|----------|
| Baboon | 3.61 | 3.68 | 3.71 |
| Lena | 3.26 | 3.4 | 3.4 |
| Man | 2.8 | 2.9 | 2.94 |
| Woman | 2.95 | 3.15 | 3.14 |
| Girl | 2.92 | 3.2 | 3.2 |
Discussion

The visual results are shown by Figs. 4, 5, 6. They reflect clearly that using KMCG with RGB color model conducts a better likeness and quality. While Applying KMCG with HSV shows the worst case. This remark is proved by utilizing the Peak Signal to Noise Ratio (PSNR) to evaluate and compare the precision of the KMCG with each color model as in Table 1.

PSNR is a good method to evaluate discrepancies between images. A high PSNR indicates an image of good quality. However, PSNR is not adequate for evaluating region homogeneity [10]. Thus, E measure is used to confirm PSNR results.

\[ E \] is better at selecting images that agree with human evaluators. \( E \) balances region uniformity and the number of regions. A low \( E \) value indicates good internal uniformity of regions [11], [12]. Table 2 shows a functional impact of \( E \) measurement of the comparison between the three-color models. \( E \) indicates a good behavior balance of the KMCG with RGB. As shown by Table 2 the \( E \) measure is the least in applying KMCG with RGB color model.

There is a slight difference between the results of using YCbCr and HSV. However, they don’t reach the quality of using RGB with KMCG.

Conclusion

The paper studied the best color model, which gives better segmentation results when it used with KMCG. The results show that KMCG gives a better visual and analytical results when it is used with RGB. We conclude that whatever the image is or the metrics used, using RGB with KMCG returns the best result. We recommend in the future work to compare KMCG with RGB segmentation with other clustering segmentation methods.
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مقارنة تقسيم الصورة بواسطة خوارزمية الـ KMCG بالاعتماد على HSV و YCbCr، RGB

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الخلاص:

هي أحد أنواع خوارزميات الـ KMCG المستخدمة لاغراض الضغط وتقسيم الصورة. استخدام الكمية في العديد من التطبيقات مثل كفاءتها وسرعتها. هذه الورقة البحثية تعرض مقارنة بين KMCG وتطبيق خوارزمية الـ Color Models و YCbCr، RGB المتضمنة مع ثلاثة أنواع من HSV. تم تطبيق تجربة المقارنة على خمسة صور، ثلاثة منها هي صور معيبية (Standard) وعدد المقاييس المستخدمة اثنين: E measure و PSNR، بالإضافة إلى الصور الناتجة المرئية. جميع المقاييس أثبتت ان استخدام الـ KMCG مع الـ RGB يعطي نتائج أفضل في تقسيم الصور.