DOI: 10.24996/ijs.2019.60.3.24

ISSN: 0067-2904

Enhanced Cartooning System Based on Dynamic Augmented KMCG and LIP

Fatin Sadiq Alkinani*[1], Abdul Monem Salih Rahma[2]
[1]Department of Computer Science, University of Baghdad, Baghdad, Iraq
[2]Department of Computer Science, University of Technology, Baghdad, Iraq

Abstract
The Non-Photorealistic Rendering (NPR) demands are increased with the development of electronic devices. This paper presents a new model for a cartooning system, as an essential category of the NPR. It is used the concept of vector quantization and Logarithmic Image Processing (LIP). An enhancement of Kekre Median Codebook Generation (KMCG) algorithm has been proposed and used by the system. Several metrics utilized to evaluate the time and quality of the system. The results showed that the proposed system reduced the time of cartoon production. Additionally, it enhanced the quality of several aspects like smoothing, color reduction, and brightness.

Keywords: KMCG, Cartoon, Vector Quantitation, LIP

تحسين نظام كارتوني باستخدام خوارزمية Dynamic Augmented KMCG و LIP

فاتن صادق خزعل*، عبد المنعم صالح رحمة
[1]قسم علوم الحاسوب، جامعة بغداد، بغداد، العراق
[2]قسم علوم الحاسوب، جامعة التكنولوجيه، بغداد، العراق

الخلاصه
التغير السريع في التطور التكنولوجي للاجهزة الالكترونية ادى الى تولد متطلبات جديدة لنمط الحياة الحديث. من هذه المتطلبات هي تحويل الصورة الى انماط اخرى تدعى Non-Photorealistic)) Rendering (NPR هذه الورقة البحثية تقترح تحديث على نظام كارتوني يستخدم خوارزمية (KMCG) التي تعتبر احدى خوارزميات الـ .(Vector Quantization) و لذلك تم تطوير خوارزمية (KMCG) لتصبح اسرع و بصور متجانسة المناطق. كذلك تم استخدام LIP لتحسين الصورة. و اخيرا مجموعة من المقاييس تم توضيفها لتقييم المقترح منها PSNR و .E Measure و تم الاستنتاج و من خلال التقييم ان الطريقة المقترحة للتحسين ذات نتائج افضل من الطريقة الاصلية من حيث السرعة، النوعية، و الالوان

Introduction

The rapid change of human electronic lifestyle yields new demand for keeping privacy and having fun applications. The path that used mainly for this purpose is by converting the image to a category Non-Photorealistic Rendering (NPR) such as cartoons. Cartoon as concerned has a few colors with higher region contrast. As well as, it has firm edges [1]. Many methods used to satisfy cartooning systems produced and each one has its impact. Those methods are categorized depending on its purposes. One of those purposes is converting image to cartoon image. Processes that used mainly for

*Email: fatin.alkinani@sc.uobaghdad.edu.iq

this purpose have two directions, cartooning using filters and vector quantization [2]. Some filters have a clearable cartooning effect such as Bilateral Filtering (BF) and Kuwahara Anisotropic. BF filter is a smoothing filter used to eliminate noise. It also gives a cartoon effect after several iterations [3]. However, BF is not useful in excluding high-contrast details. It leaves numerous noisy and small regions untouched. This problem fulfilled by Anisotropic Kuwahara, which could be added to its other cons like generating a painting-like flattening effect [4]. The second path by using vector quantization methods, which yield an acceptable cartoon effect. In 2014, researchers applied Linde Buzo Gray (LBG) and Kekre's Proportionate Error (KPE) for cartoon production. The results compared with BF filtering. It shows that both of LBG and KPE produces images with cartoon effects in a lesser time comparable with BF [5].In 2016, a study applied Anisotropic Filter, BF, LBG, KPE, and Kekre Median Codebook Generation (KMCG). The conclusion shows that KMCG produces a better cartooning effect in the least time [2].

In this paper, a modified fast and dynamic KMCG proposed and used for reducing the cartooning production time without needing to specify the codebook size. Additionally, Logarithmic Image Processing (LIP) technique is used for image light and shadow enhancement.

Vector quantization

Vector Quantization (VQ) is simply a mapping function, which maps n dimensional vector space to a finite set CB = {C1, C2, C3, ..…., CK}. The set CB is called Codebook consisting of K number of code vectors and each codevector Ci = {ci1, ci2, ci3, ……, cin} is of dimension m. The key to VQ is the good codebook [6]. KMCG is one example of vector quantization algorithms.

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

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 Figure-1.

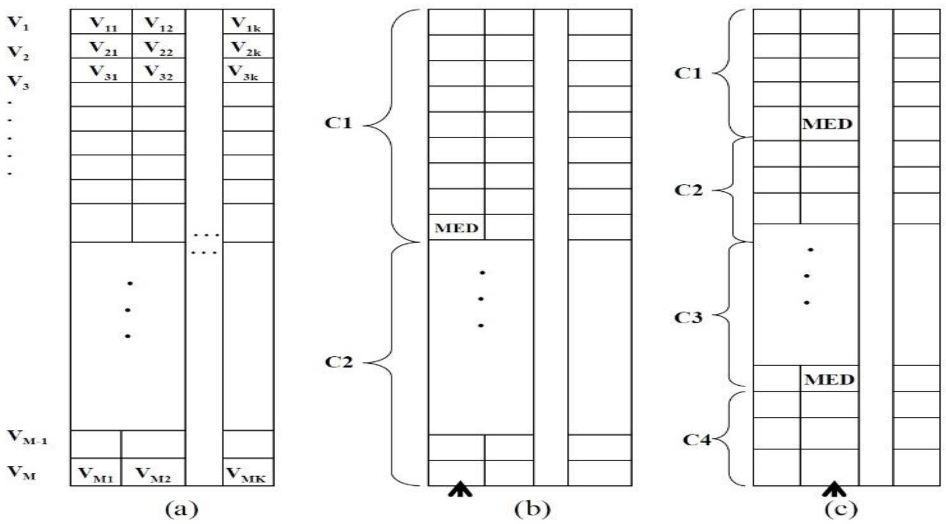


Figure 1-KMCG General Steps [7]

KMCG is applied to an image by dividing it into equal nonoverlapped windows. Each window color data represented in a vector. As in gray level, the window size is four yields a vector length will be 4 [6]. KMCG algorithm is augmented for decreasing the required time of the clustering process in a gray image. The vector size is increased to 6 columns, as the last four columns are used to store original gray levels 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 first column contains the sequence number of the respective vectors [7].

KMCG Cartooning System [2]

Original KMCG cartoon system is mainly used KMCG algorithm as the primary step in cartooning procedure. KMCG gives with the other enhancement and edge detection techniques a cartooning effect.

To sum up the steps, the input image is smoothed by using image enhancement techniques. Then KMCG is applied to reduces the colors in the obtained image. Finally, the output of edge abstraction and KMCG are integrated together for producing a complete painterly effect on images.

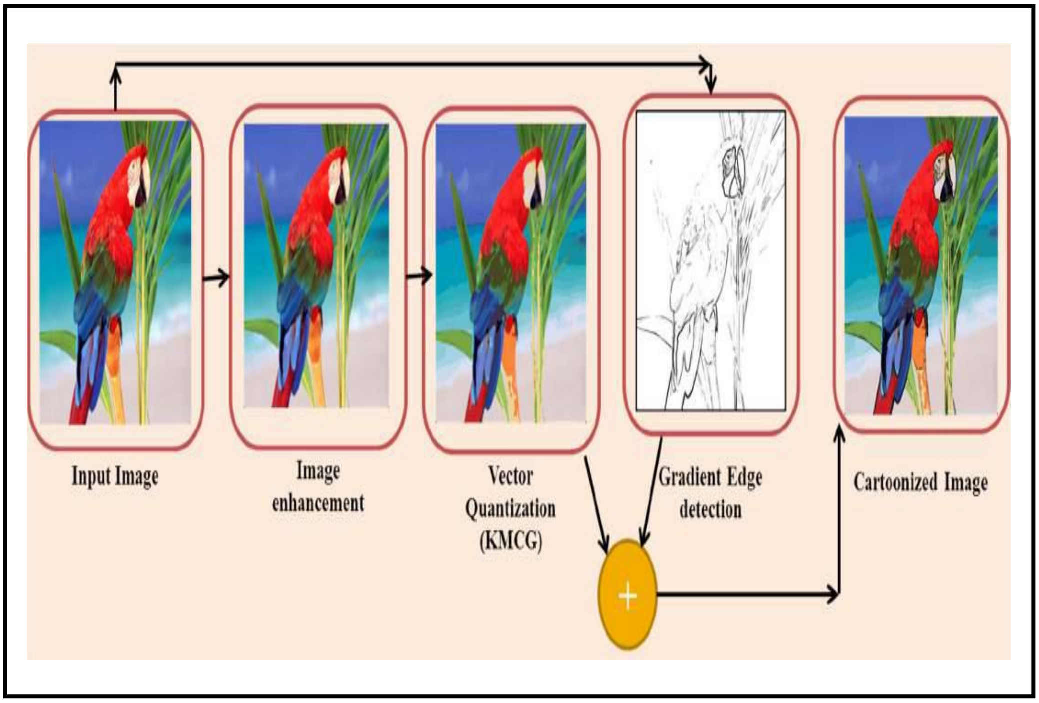


Figure 2-Original KMCG System

The experiments showed that 64 codebook size is appropriate for producing a good cartooning effect.

Dynamic Augmented KMCG

For fast dynamic homogeneous clustering, we proposed modification on the original KMCG using the idea of augmentation mentioned in the Vector Quantization section and thresholding. Firstly, the vector constructed using means of values belong to the same feature. Such as in the RGB image the obtained values will be average for each red, green, and blue. The size of each vector is 4. The first value is the data sequence, stored in the vectors in addition to the other three values. Thus, the vectors will be sorted only three times.

Secondly, by assuming that all vector values at the same scale as in RGB image, the hieratical clustering will be based on comparing the difference between the first and the last value of the arranged column in each cluster with a threshold. If it is larger than the threshold, then the median vector of that cluster obtained to be in CB. The step is repeated until no cluster divided based on the arranged column. Consequently, the other column of the vectors arranged in each cluster to be divided as in the first column. This procedure will be continued for all vector values. Algorithm (1) shows in detail all the mentioned steps.

```
Algorithm 1: Dynamic Augmented KMCG
Input       A bitmap Im of size w_l; Threshold
Output      lstClusters(List of Clusters)
Begin
Step1       ///Initialization
            Set lstVectors← FillVectors(Im) /* First Value of each Vector is index and other three values
            are means of the RGB channels in each window */
            Set lstClusters ←InitializeClutsers(lstVectors)
Step2       //Vector Sorting and Codebook Construction
            for j =2 to L do
                foreach cluster C in lstClusters do
                    SortAscending(C,j) /* Sorting theCluster C based on value sequence j*/
                end foreach
                while flag = true do
                    Set flag ←false
                    foreach cluster C in lstClusters do
                        Set first ←First Column in C
                        Set last ←last Column in C
                        Set Dif ←GetDiff(first,last)
                        if Dif>Threshold then
                            AddMediantoCB(C)
                            SplitClusterAndAdd(lstTempClusters,C)
                            Set flag ←true
                        end if
                    end foreach
                end while
                Set lstClusters ←lstTempClusters
            end for
End
```

Proposed Enhanced system

The proposed system used mainly the Dynamic Augmented KMCG instead of smoothing and clustering steps of the original system in KMCG Cartooning System section. This step is to reduce the colors and smoothe image without losing its details. Then, Logarithmic Image Processing (LIP) model is applied specially for enhancing light of the image.

The LIP models include a set of mathematical equations based on algebraic and functional operations. It could be applied to the intensity processing of an image within a limited range. Also, it is known as physically justified by simulating human visual system laws. One of those mathematical is dynamic range expansions proposed Jorlin. It uses LIP multiplicated law for low light image enhancement. This enhancement approach used firstly equation (1) to find the multiplication scalar [8].

$$\boldsymbol{\lambda} = \frac{\ln\left[\frac{\ln 1-\frac{f(a)}{M}}{\ln 1-\frac{f(b)}{M}}\right]}{\ln\left[\frac{\left(1-\frac{f(b)}{M}\right)}{1-\left(\frac{f(a)}{M}\right)}\right]} \text{------Eq} \qquad (1)$$

Where f(a) is the darker color band in a darker value of RGB pixels. Contrarily, f(b) is the brighter value of all brighter band of RGB pixels. M is the maximum value in the range; here it equals 256. Then the scaler is used in applying equation 2.

$$\boldsymbol{\lambda} \ll\times\gg \boldsymbol{f} = \boldsymbol{M} - \boldsymbol{M}\left(\mathbf{1} - \frac{\boldsymbol{f}}{\boldsymbol{M}}\right)^{\boldsymbol{\lambda}} \text{-----Eq} \qquad (2)$$

Finally, detected canny edge is added to the cartooned image [9]. The mean of the darker surrounded pixels is substituted instead of edge point to avoid the effect of false edges. Figure-3 clarifies the flowing and the sequence of the steps of the proposed system.

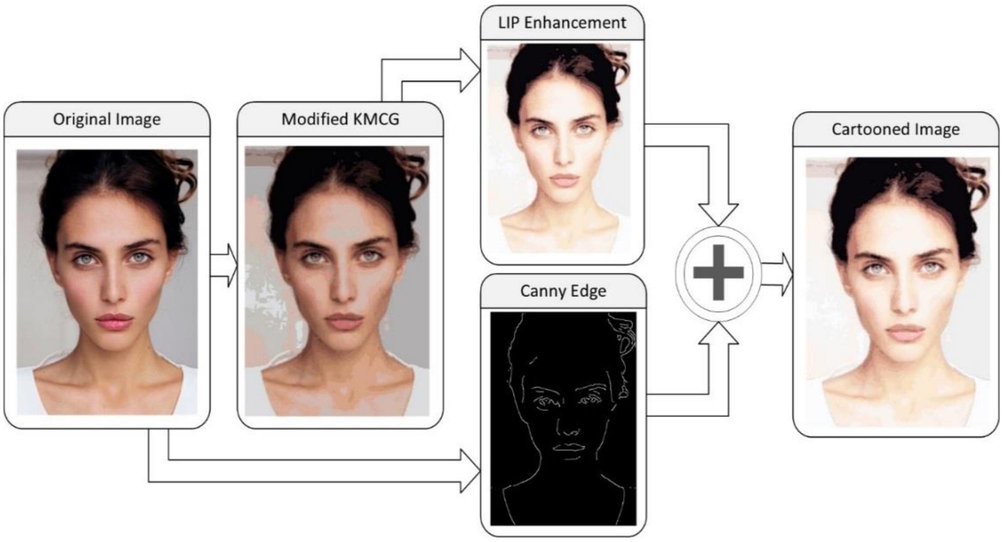


Figure 3-Dynamic Augmented KMCG System

Experiments and Analytical Results

The proposed system is applied on six samples, one of them is a benchmark image (Lena), and the others are obtained from the web. The specifications of the used computer listed as the following:

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

Several metrics applied to evaluate the system and the algorithm. Firstly, time in seconds, measured for the speed. Precisely, the system is limited to be applied on one core with a property of real-time [10]. It will eliminate switching and interrupt time. Table-1 shows the time for both algorithms. The CB size of KMCG taken twice, 32 and 64. The threshold of Dynamic Augmented KMCG is 60, which detected to be the best value that gives a better cartooning look and metrics after several trials. Total time for both systems is also calculated with an assumption that the smoothing method used of the old system is mean filter. As shown, in Table-1 the time in the proposed modified system and the algorithm is lesser than the original. As the execution time of the modified algorithm decreased slightly from the time of the original algorithm. However, when the modified algorithm applied with in the cartooning system the smoothing step is ignored because of its ability to do smoothing without needing to apply another technique. Thus, the time of the proposed cartooning system by using the modified KMCG is decreased tremendously than the old KMCG that needs smoothing technique to be applied within the cartooning system.

Table 1-Time comparison of KMCG, Modified KMCG, and Original System with the proposed system Size

Image	**Size**	**KMCG Cb32 (s)**	**KMCG Cb64 (s)**	**Modified KMCG (s)**	**Total KMCG System (s)**	**Total ProposedK MCG System (s)**
French Woman	400 x 530	0.41	0.44	0.40	6	1.5

Girl	650 x 648	0.85	0.88	0.79	10.5	1.9
Jack	848 x 480	0.85	0.88	0.74	11	2.5
Rose	848 x 480	0.77	0.86	0.75	11	2.5
office	259 x 194	0.11	0.12	0.1	0.3	1.3
Lena	512 x512	0.54	0.56	0.49	7	1.7

PSNR used as a good method to evaluate discrepancies between images. The highest PSNR, the best quality of an image, However, it should not consider as an adequate evaluation of region homogeneity [11]. As shown in Table-2 the difference between the PSNR of the output of the two algorithms is small, and there is no real indication about the better system.

E measure is a segmentation metric. It does a better job of selecting images that agreed with human evaluators than the other methods. It balances between the uniformity of the regions and the number of regions. The lower value of E the better internal uniformity of regions [12], [13], Table-3 shows a functional impact of E measurement of the proposed system. Since, in Dynamic Augmented KMCG, the size of CB is allocated dynamically, and the cluster generation is based on the threshold, the E measures indicate a good behavior balance of the modified KMCG. As it satisfied the minimum cluster with better uniformity

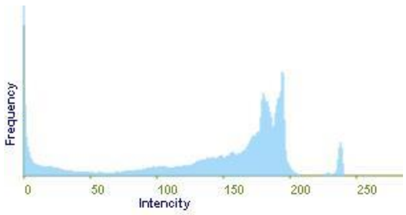
Table 2-PSNR Measures of the Original and Modified Algorithm

Image	PSNR KMCG Cb32	PSNR KMCG	PSNR Modified KMCG
Woman	41.84	43.04	40.98
Girl	42.5	43.78	41.35
jack	41.85	44.07	41.46
Rose	42.52	44.12	42.27
office	38.73	39.29	39.46
Lena	41.52	42.53	41.51

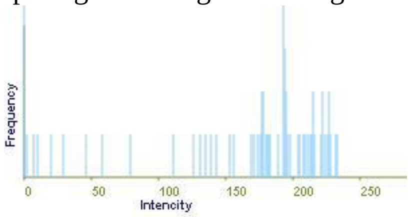
Table 3- E Measures of the Original and Modified Algorithm

Image	E KMCG Cb32	E KMCG Cb 64	E Modified KMCG	Cluster No.
Woman	2.6	1.8	1.2	32
Girl	2.6	1.815	1.043	18
jack	2.4	1.815	1.008	22
Rose	2.49	1.815	1.096	17
office	3	1.826	1.514	58
Lena	2.8	1.817	1.326	29

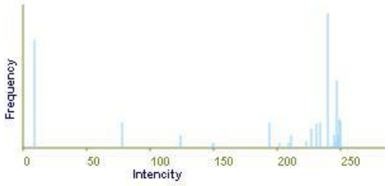
Colors are reduced tremendously in the proposed system. It also varied depending on the image. This could be shown clearly by comparing the histograms in Figure-4.



a



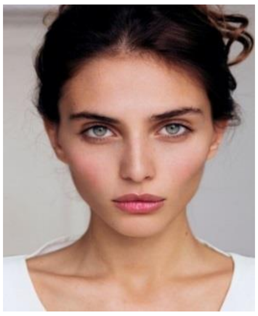
b



c

Figure 4-Histogram of a. Original Image b. original KMCG System c. proposed

Another advantage should not be neglected, is the quality of smoothing. As shown in Figures-(5-8) the hair texture is faded in the proposed system, and the details are preserved well.



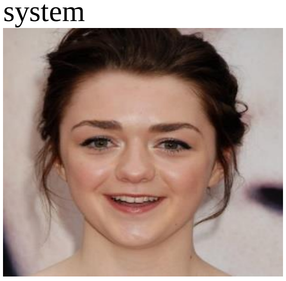
a

b

c

d

Figure 5-Women Image a. Original Image b. KMCG CB size 32 c. KMCG CB size 64 d. Modified system



a

b

c

d

Figure 6-Girl a.Original Image b. KMCG CB size 32 c. KMCG CB size 64 d. Modified system

a

b

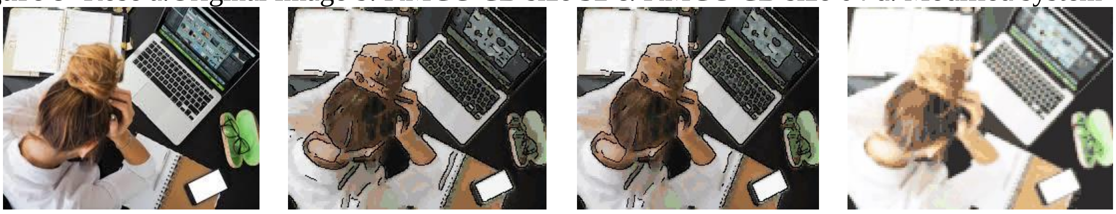
c

d

Figure 7-Rose a.Original Image b. KMCG CB size 32 c. KMCG CB size 64 d. Modified system

a b c d

Figure 8- Rose a.Original Image b. KMCG CB size 32 c. KMCG CB size 64 d. Modified system



a *b* *c* *d*

Figure 9- Office a. Original Image b. KMCG CB size 32 c. KMCG CB size 64 d. Modified system

Finally, the distribution of the light and shadow is enhanced to give the image more painting look. It could be shown clearly in Figures-(5-7).

To assure that the system techniques is to obtain cartooned images, we presented the results to two specialists in digital art for ranking from 1 to 5. As 1, is nearest to reality, 3 has a neutral look between reality and kind of art. And 5 referred images look painted by a professional artist. Figure-10 summaries specialists' evaluation.

Figure 10-Artists Evaluation

Conclusion

The proposed Dynamic Augmented KMCG algorithm gives an advantageous enhancement over the original KMCG algorithm. Its execution time reduced slightly. Also, it functions image smoothing over its ability to do segmentation homogeneously. These advantages of the proposed modification of the original KMCG enhance the quality of proposed cartooning system over the original KMCG cartooning system with respect to smoothing, color reduction. As the smoothing is done by the proposed modification of the dynamic augmented KMCG, which reduces the execution time of the smoothing technique usage of the old cartooning system. Also, the color redacted dynamically based on the threshold of the Dynamic augmented KMCG and the amount of the colors of the image. LIP dynamic range expansion technique is used in the proposed cartooning system to enhance the light dynamically based on the amount of the light of the image. Also, it simulates human eyes in the light enhancement.

These cons are supported with three numerical metrics: time, PSNR, and E measure for the modified. The time of the modified algorithm is less than the time of the original KMCG. Also, the time of the proposed cartooning system is lesser than the original system. As using the proposed Dynamic Augmented KMCG in the proposed system merge the two steps of the smoothing and segmentation in one step and reduces the time intensively regarding the comparison of the all applied samples. PSNR doesn't give a clear remark about the better algorithm. The difference between the PSNR is very low between the output of both algorithms. Thus, to provide a good segmentation and visual metric an E measure is used to evaluate the original and the modified proposed KMCG. E measures of all samples show a better result of Dynamic Augmented KMCG segmentation than the original KMCG.

Additionally, both of the results of the cartooning system presented to the two specialists of the digital art. The percentage of the samples that give a better cartooning look of the proposed system than the original cartooning system is 83%. The rest of the samples' votes show an equal quality of the art visuality.

Dynamic augmented KMCG conducts inspired feedback when it is used with a cartooning system. Thus, in the future works, it will be tested with other applications and examine its behavior.

Acknowledgment

We would like to express our great appreciation, for the two specialists in digital art, Dr. Sundus Hatem Majeed, College of Fine Arts, Baghdad University, and Sanaa Mohsin Adhab, University of Information Technology and Communication.

References

1. M. M. A. Zaid., L. E. **2015.** Goarge and G. Al-Khafaji, "Distinguishing Cartoons Images from Real-Life Images," *International Journal of Advanced Research in Computer Science and Software Engineering,* **5**(4).
2. P. A. K. A. K. Archana B. Patankar, **2016.** "Image Cartoonization Methods Using LBG, KPE, KMCG quantization," in International Conference on Computing Communication Control and automation (ICCUBEA), Pune, India.
3. T. C and M. M. **1998.** "Bilateral Filtering for Gray and Color Images," in Proceedings of the 1998 IEEE International, Bombay,India.
4. Döllner, J.E.H.K.J. **2009.** "Image and Video Abstraction by Anisotropic Kuwahara Filtering," *Pacific Graphics*, **28**(7).
5. DArchana, P.T. and Patankar, B. **2014.** "Cartoonization Using LBG And KPE Vector Quantization," *Int. Journal of Engineering Research and Applications*, **4**(5).
6. Kekre, T.K.S.H.B**. 2008.** "An Efficient Fast Algorithm to Generate Codebook for Vector Quantization," in International Conference on Emerging Trends in Engineering and Technology, IEEE Computer Society.
7. kekre, P.S.H.B. **2013.** "Segmentation of Ultrasound Breast Images using Vector Neighborhood with Vector Sequencing on KMCG and augmented KMCG algorithms," *International Journal of Advanced Computer Science and Applications*, **4**(2).
8. Jourlin, M. **2016**. *Advances In Imaging And Electron Physics*, 1st Ed., Elsevier, 2016.
9. Umbaugh, S. E. **2010.** *Digital Image Processing And Analysis*, 2nd ed., CRC Press, 2010.
10. Nakov, S. and Kolev, V. **2013.** *Fundamentals Of Computer Programming With C#,* 1st ed., Svetlin Nakov & Co.
11. Fardo, F., Conforto, V. and Francisco, **2016.** "A Formal Evaluation of PSNR as Quality Measurement Parameter for Image Segmentation Algorithms," Computer Vision and Pattern Recognition, 2016.
12. Zhang, H., Fritts, J. and Goldman, S**. 2003.** "An Entropy-based Objective Evaluation Method for Image Segmentation," Proceedings of the SPIE, vol. 5307, pp. 38-49.
13. Giuliana Ramella, G.S.D.B. **2013**."*Image Segmentation Based on Representative Colors Detection and Region*," in Mexican Conference on Pattern Recognition, Springer.