Dominant Color-Based Indexing Method for Fast Content-Based Image Retrieval

Ahmed Talib[1,2], Massudi Mahmuddin[1], Husniza Husni[1], and Loay E. George[3]

[1] Computer Science Dept., School of Computing,
University Utara Malaysia, 06010 Sintok, Kedah, Malaysia
s91707@student.uum.edu.my, {ady,husniza}@uum.edu.my
[2] IT Dept., Technical College of Management,
Foundation of Technical Education, 10047 Bab Al-Muadham, Baghdad, Iraq
[3] Computer Science Dept., College of Science,
Baghdad University, 10071 Al-Jadriya, Baghdad, Iraq
loayedwar57@yahoo.com

Abstract. Content-based image retrieval is an active research area in image processing and computer vision. Color represents an important feature in CBIR applications, thus many color descriptors were proposed. Sequential search is one of the common drawbacks of most color descriptors especially in large databases. In this paper, dominant colors of an image are indexed to avoid sequential search in the database. Dominant colors in query image are used independently to find images that containing similar colors to create reduced search space instead of the whole database search space. This will speed up the retrieval process in addition to improve the accuracy of color descriptors. Experimental results show effectiveness of the proposed color indexing method in reducing the search space to less than 25% without degradation the accuracy.

Keywords: Color indexing, Dominant colors, MPEG-7 descriptors, RGB color space, Database search space.

1 Introduction

Image retrieval become one of the most famous research directions nowadays because it uses to search an image in archive, domain-specific, personal and web image databases. For retrieving color images from multimedia database, low level features and especially color feature have been widely used in this regard. This is because color represents the most distinguishable feature compared with other visual features, such as texture and shape [1-2]. In this respect, MPEG-7 Committee proposed many color, texture and shape descriptors to be used in image and video retrieval [3]. Authors in [4-5] maintain that human visual system first identifies prominent colors in the image and second it processes any other details. The whole process resembles the way humans recognize image from its dominant colors without paying any attention to their distribution. MPEG-7's Dominant Color Descriptor (DCD) provides compact and effective representations for colors in the image [3]. Recently, compactness

S. Boonkrong et al. (eds.), *Recent Advances in Information and Communication Technology*, Advances in Intelligent Systems and Computing 265,
DOI: 10.1007/978-3-319-06538-0_14,

property of dominant colors representation becomes more attractive for many researchers to reduce size of color descriptors from several hundred bins (histogram-based methods) into few colors (8 colors in MPEG-7 DCD) such as the works that have been achieved in [6-8]. Additionally, this compactness property becomes mandatory in specific applications such as web-based image retrieval [1].

Searching a large images database imposes many challenges because the time required to retrieve the results of query image is high, consequently this will degrade performance of CBIR. Researchers address some issues that are related with image retrieval performance. These issues can be divided into two categories [9]. First category concerns with retrieval robustness (accuracy of image retrieval), it ignored the retrieval efficiency where most works in this category rely on sequential search [2],[10-11]. Second category concerns with retrieval efficiency, where the time of retrieval (retrieval speed) get more focus. In this paper, the second category is focused.

Color is a salient feature among the low level visual features [2],[7]. As a representative of color feature, color histogram and dominant color descriptors are the widely used features in content based image retrieval (CBIR) [5]. The high dimensionality of the histogram feature vector make it highly computational cost in similarity measure and inefficient in searching/indexing process. It is called "curse of dimensionality" problem that represent the first problem of color-based indexing methods. To solve this problem, many dimensions reduction approaches are used. Color quantization techniques are used in this context but fixed quantization techniques lead to accuracy degradation. Therefore, dynamic color quantization techniques were proposed, which are Dominant Colors (DCs) extraction methods. DCs consider as the most effective solutions in this context where few colors are extracted to represent the image. To index images' DCs, vector quantization methods are used but "color approximation" problem is emerged. Color approximation problem is occurred due to using clustering algorithms to find the representative (centroid) of the cluster. This color approximation degrades the retrieval accuracy because the matching process is performed with cluster centroid (which is obtained by averaging all cluster's colors) instead of actual color values. Therefore, color indexing method is proposed. It belongs to space partitioning methods, where RGB color space is divided into small partitions using uniform Octree color quantization method [12]. It combined with B+-tree method, which is used for representing the colors percentages, to filter irrelevant images out in early stage.

The paper is organized in the following way. Section 2 is concerned with explicating the general CBIR indexing methods and specifically color-based indexing methods because the color feature represent the scope of this paper. Section 3 is mainly concerned with the proposed RGB-based indexing method and the newly proposed color percentage filtering scheme that helps improve and speed up the retrieval process. Section 4 illustrates the extensive experiments that contain quantitative results. Finally comes the conclusion in Section 5.

2 Related Works

In large image database, indexing is urgent matter to reduce the search space of the retrieval process and in turn to speed up the process. Most color-based methods perform sequential search in their retrieval process; this will impose delay in the time of image retrieval process. Color histogram is one of the common color descriptors. Despite of the color histogram is characterized by simplicity in its implementation but it results large feature vector that is difficult to index, *"curse of dimensionality"* problem. Therefore, DCs can be used to avoid this problem. The benefits of DCDs over histogram-like methods is the former find image's representative colors from image itself instead of making it fixed in the color space as the latter. This will make accurate and compact descriptor. Therefore, DCD is selected to be the base of this paper to perform the image indexing.

For indexing the image features, there are two main approaches in general: *multi-dimensional indexing* and *vector quantization techniques*. Multi-dimensional indexing techniques are divided into two categories, Space Partitioning (SP) and Data-Partitioning (DP) methods. Both of them divide the space or data into small partitions but the difference lies in how the partitioning process is achieved. SP methods such as kd-tree divides the whole space into disjoint partitions without consideration of the data whereas in DP methods such as R-tree, feature space is divided depending on features (data) distribution in the database [13]. The advantage of SP method is it performs complete and disjoint partitions of the whole space that means there is no overlapping between these partitions.

In vector quantization techniques, there are many techniques that have been proposed, such as hierarchical K-means clustering. In these methods, there is no partitioning of space or data into small parts, instead grouping the data into clusters or groups is achieved. Each cluster (group) is represented by a single value called cluster's centroid. Cluster's centroid is computed by averaging all cluster members, thus the query point is compared with cluster's centroid instead of original value of the members. Disadvantages of these methods is comparing with clusters' centroids instead of original values lead to inaccurate results because some cluster's members are far from the query points in spite of having suitable distance from cluster's centroid. The latter problem is called "color approximation problem".

For 3-dimensional color indexing, several methods have been proposed in CBIR field. High dimensional histogram indexing method, that used by Deng et al. [14] for comparison, is considered as the simplest and most expensive indexing method. This method suffers from high dimensional problem, 1024-D of color histogram bins. Babu et al. [15] combine color clustering and spatial indexing method (R-Tree) for indexing colors of flags and trademarks databases. Sudhamani and Venugopal [16] also proposed a method for color clustering and indexing. They used mean shift algorithm for color clustering, R*-Tree for spatial indexing and perceptually uniform LUV color space instead of RGB. The above two methods depend on clustering that are suffered from aforementioned problems of clustering (one of VQ techniques). In general, color-based indexing methods depend on fixed range of colors in similarity measure. Therefore, spatial indexing methods such as R-Tree and R*-Tree are not necessary and fixed indexing structure is more efficient [14]. Accordingly, Lattice structure was proposed in [14] that is characterized by efficient finding the nearest neighbors of given point (color) in 3-dimensional LUV color space. Nevertheless, this efficiency depends on careful selection of radius in hexagonal lattice cell and this is not a straight forward process, hence there is no comparison (in the literature) has been made with this method. Additionally, it suffers from same problem of SP and clustering methods, which is the query point may locate at the border of lattice cell.

Recent research is proposed by Yildizer et al. [13] to solve this problem. The significant contribution of that research is introducing two threshold values C_G and Cs that can be considered as search space parameters. C_G represents the distance from query point that can be searched around it (in the closest cluster) to find similar images instead of considering all cluster members. Cs represents the distance from query point that can be considered to add other clusters to the similarity searching process.

As conclusion, all vector quantization indexing methods, which most color-based indexing methods are depended on, suffered from color approximation problem. Approximation process is carried out during vector quantization process, such as K-means clustering method, to produce color centroids. Therefore, this problem is addressed in this paper to discuss and solution is proposed.

3 Proposed Indexing Method

In this section, DC-based indexing method is proposed to reduce search space of color-based methods (i.e.: it dedicates to all methods, not only DC-based methods) to speed up retrieval process as well as preserve retrieval accuracy.

The proposed method motivated by the question, “where are we need to search exactly, to reduce search space rather than doing whole database search space?” The key answer is searching depends on fixed range queries. In other words, searching on images that only have colors of distance less than or equal the maximum distance to the query image colors. As mentioned before, using tree-like indexing in the fixed range queries is ineffective. Therefore, fixed space partitioning method is used in this research. Before building database index structure, similarity between two colors must be considered and maximum distance between these colors also needs to be determined because the index structure will depend upon them; this will be explained in the next section.

3.1 Maximum Distance between Similar Colors

The key of the proposed method is a similarity among colors within fixed range. The searching can be done only in a specific range within distance, which is the maximum distance between two colors to consider them as similar colors. The Euclidian distance between two 3-D colors to assume them similar was 10, 20 or 25 [17]. Therefore, the maximum difference value (MxDV) for each color channels (Red, Green and Blue in RGB color space) is set to 25.

3.2 Indexing Structure

In DC-based methods (e.g. MPEG-7 DCD), DCs are extracted using dynamic quantization method (GLA) and most likely the image is quantized to most significant 5-bits of color channels (bit3 to bit7). Since the maximum difference between two channels is 25, the changing of the two bits (bit3 and bit4) is within this range. This because the weights of these bits are 8 and 16 respectively; their summation is 24 that approximately equals to MxDV (25). In this regard, bit7, bit6 and bit5 are out of tolerance range of colors to be similar. Thus, these three bits are the first level of color similarity; they are used to differentiate among not similar colors. The other two bits (bit3 and bit4) are used separately to be second and third levels respectively of color similarity. Hence, first indexing dimension contains 512 cell. Second and third indexing dimensions contains 8 cells, as presented in Fig. 1.

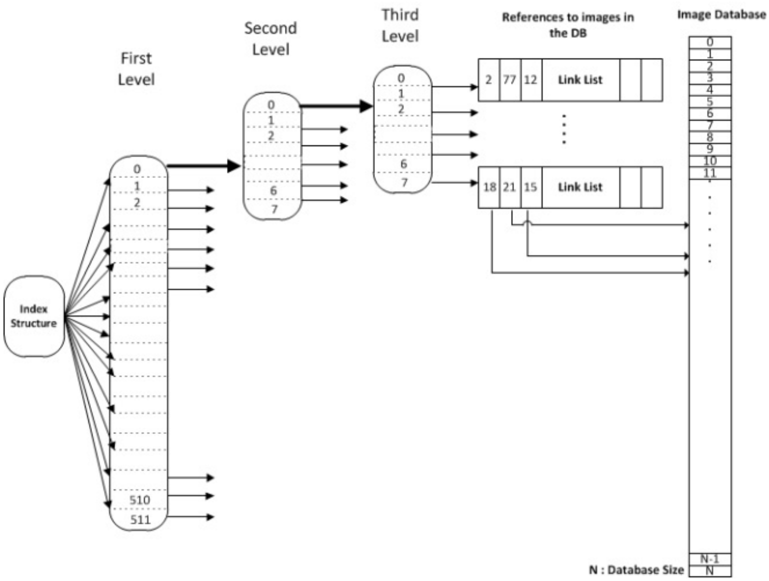

Fig. 1. Structure of Proposed RGB Indexing Method

Color percentage plays an important role in similarity measure of certain color with its corresponding color in other images where the similar colors consider as dissimilar if their percentages have large difference such as similarity measure of different color descriptors such as MPEG-7 DCD, Correlogram, and most color descriptors. Therefore, filtering images (that have large difference in percentage) out in early stage helps in reducing search space and speeding up the retrieval process. In Deng [14], filtering process is performed online during query processing. Filtering out the dissimilar images in terms of colors is achieved firstly; then percentages of colors are matched through pass by all images sequentially to perform second level of filtering. This online process is time consuming process in large database; thus, achieving it offline is mandatory in large size database. Therefore, the proposed indexing structure is extended to include partitions of color percentages. Single level B+-tree is used to represent color percentages. The unique node of B+-tree contains four pointers each pointer refers to the certain list as <0.25, 0.25-0.5, 0.5-0.75 and >0.75 respectively.

3.3 Searching Process

In this process, a query is required to find its similar images in the database. Searching process includes the following steps:

1. For each DC in the query image, find database images that are similar in both colors values and colors percentages; this is by reaching to suitable node(s) in index structure and in turn to the database images that associated with this node(s).

A. Reaching to the nodes in the third level of index structure, which are similar to the query color, is considered as the first level of similarity (it is called color-based similarity). In this level, all false matched images that don't contain colors similar to the query will be eliminated.

B. Second level of similarity is a percentage-based similarity. Each reached node in point (A) has B+-tree structure of color percentages. Two paths of B+-tree that nearest to the query color percentage will be selected to obtain the candidate images for comparison.

2. Merging images references that resulted from each DC of the query image to produce search space of the query, which is called as reduced search space (RSS).

3. Calculate dissimilarity distance between query and all images in the RSS, and then rank them accordingly.

In step 1, most false match images are removed according to different color tolerance value and color percentages. Three color tolerance values are used according to maximum distance value that extracted from Section 3.1. These color tolerance values (CTV) are 0, 8 and 24 regarding to 2-bits (bit3 and bit4) of color channels.

The difference of the proposed indexing scheme over space partitioning methods such as kd-tree structure lies in different aspects:

1. The fixed-size representation (array) is faster than dynamic-size representation (tree) of kd-tree.
2. The new design of the proposed RGB method exploits the range query in building the index structure (3-levels structure), instead of changing query parameters to perform range query as in kd-tree that have 8-levels structure to represent RGB color space. This new structure speeds up the search mechanism.
3. Embedding B+-tree representation in the last level of the proposed representation makes the search result more accurate and fast. This is because, the color percentage is used as fourth level of filtering to exclude the images that have different color percentage than query's colors percentages.

4 Experimental Evaluation

Performance of the proposed technique is evaluated based on the following:

1. **Number of Indexed Colors:** Indexing of images database can be performed with different numbers of colors (8, 5, 3 or 1) to measure the effect of each one on the retrieval performance. It is noteworthy to mention here that DCs is sorted in descending order according to their color percentage before indexing process.
2. **Evaluation Metrics:** Two types of metrics are used in this research:
   - *Efficiency Metrics:* The main goal of indexing is to reduce search time compared to sequential search by reducing database images that can matched the query image. The reduced time needed for searching in the RSS can be computed by the percentage RSS/WSS, WSS denoted to the Whole Search

Space. The percentage RSS/WSS% can be called as Search Space Ratio (SSR) that represents ratio of images that are actually searched to the all images in the database. An Overhead Ratio (OHR) of the proposed indexing is also necessary to be computed. This ratio represents the time needed to create RSS.

- *Accuracy Metrics:* Three quantitative performance metrics are utilized to measure the accuracy of different color descriptors that are used in the proposed indexing method. These metrics are ARR, ANMRR and P(10).

3. **Evaluation Datasets:** Evaluating the proposed indexing techniques will be conducted on two datasets, newly introduced Cartoon-11K (11,120 images) and well-known Corel-10K (10,800 images). These datasets are different in terms of image content (color and variety) as well as their sizes are large enough to fit the objective of designing the indexing methods. The main dataset in this research is cartoon dataset that is used to evaluate color descriptors. This is because the characteristic of the most cartoon characters is appearing with the same colors in all or most images [18].
4. **Competing Indexing Methods:** Indexing methods that are selected to compete with the proposed method are sequential search, k-Means (KM), and recent k-Means with B+-tree methods (KMB) [13]. Sequential search is a conventional method in CBIR for searching in the database. The accuracy resulted from sequential search is considered as optimal accuracy because searching in this method include whole database. Therefore, all competing indexing methods accuracies are compared with it to check the degradation that can be obtained from these methods due to the reduction of search space.
5. **Evaluation Color Descriptors:** the color descriptors that can be used to test the proposed indexing method are MPEG-7 DCD and Color Correlogram (ColGrm). MPEG-7 DCD is used because it contains dominant colors whereas the Correlogram is complicated color descriptor and it is general color descriptor (it does not have dominant colors). This is to prove that the proposed indexing method can be generalized for all color descriptors not just for DCDs.

Table 1. Accuracy and Efficiency metrics for Color Correlogram Descriptor using sequential search and competing indexing methods applied on Cartoon-11K Dataset

Color ColGrm	**Indexed color=8**		**Indexed color=5**		**Indexed color=3**		**Indexed color=1**	
	P(10)/ ARR/ ANMRR	**SSR+ OHR**	**ARR/ ANMRR/ P(10)**	**SSR+ OHR**	**ARR/ ANMRR/ P(10)**	**SSR+ OHR**	**ARR/ ANMRR/ P(10)**	**SSR+ OHR**
Sequential Search	0.35/ 0.118/ 0.852				100%			
K-Means Clustering	0.31/ 0.100/ 0.874	45.8% + 0.7%	0.32/ 0.102/ 0.872	40.8%+ 0.4%	0.27/ 0.089/ 0.889	24.1%+0 .1%	0.22/ 0.076/ 0.905	14.5%+0 .06%
K-Means with B+Tree	**0.35**/ 0.115/ 0.856	76.6% + 1.3%	**0.35**/ 0.116/ 0.856	71%+1. 1%	0.31/ 0.104/ 0.870	39.8%+0 .6%	0.23/ 0.080/ 0.899	26.7%+0 .4%

Table 1. (*continued*)

Proposed Octree CTV =24	**0.36/ 0.122/ 0.848**	**57.3 %+ 0.9%**	**0.36/ 0.122/ 0.848**	**49.8%+ 0.08%**	**0.36/ 0.120/ 0.850**	**40.5%+. 007**	0.32/ 0.097/ 0.879	24.5%+ .0008%
Proposed Octree CTV=8	**0.35/** 0.115/ 0.857	**27%+ .075 %**	**0.35/** 0.113/ 0.859	**25%+ 0.02%**	**0.35/** 0.108/ 0.866	**22.1%+ .004%**	0.31/ 0.087/ 0.890	16.3%+ .0005%
Proposed Octree CTV=0	0.34/ 0.100/ 0.875	14%+ 0.003 5%	0.34/ 0.099/ 0.877	13.6%+. 0005	0.32/ 0.093/ 0.884	12.8%+ .0002%	0.27/ 0.081/ 0.898	10.8%+ .00001%
Proposed Octree+CPF CTV =24	**0.36/ 0.122/ 0.848**	**47.2 %+ 0.8%**	**0.35/ 0.122/ 0.848**	**39.2%+ .07%**	**0.35/ 0.121/ 0.850**	**29.7%+ 0.005**	0.31/ 0.093/ 0.883	15.1%+ .0006%
Proposed Octree+CPF CTV=8	**0.36/** 0.115/ 0.857	**18.9 %+ .065 %**	**0.35/** 0.113/ 0.859	**17.2%+ .015%**	**0.35/** 0.108/ 0.865	**14.8%+ .003%**	0.31/ 0.084/ 0.892	10.5%+ .0004%
Proposed Octree+CPF CTV=0	0.34/ 0.100/ 0.874	9.3%+ .0003 %	0.34/ 0.099/ 0.876	9%+ 0.004	0.32/ 0.092/ 0.884	8.5%+ .00015%	0.27/ 0.079/ 0.900	7.4%+ 0.0003%

Analysis the results of all competing indexing methods that shown in Table 1 can be summarized in the following points:

- KM reduces search space (that mean, the time) to the half (and more) according to number of indexed colors; but the accuracy is degraded. This is because; the comparison of query DCs is performed with the cluster centroids instead of actual colors inside the clusters. Cluster centroid represents an approximation to all cluster members, thus comparison with it will produce some errors.
- KMB outperforms the KM in enhancing the retrieval accuracy but with increasing the space that have been searched. This is because; some missing nearest images to the query that located in the other clusters are reached in this method. Additionally, the colors in the suitable range inside one cluster are selected only instead of all cluster members; this helps to avoid searching in the whole space. Therefore, this method succeeds in obtaining good accuracy (compared with K-means) with reasonable search space.
- The Proposed Octree indexing and Octree with Color Percentage Filter (CPF) methods have different settings involve four different number of indexed colors (8, 5, 3, and 1) and three color tolerance values (24, 8 and 0). The accuracy value of the proposed indexing scheme is increased in some settings (that presented in the bold font) than sequential search method. This is due to the following reasons; first one, the query's DC is reached to the exact corresponding color value in the index structure and some colors around it (according to tolerance value). This will lead to the query will be compared with images that have similar colors only. In this case, no need to approximate color value (as in KM that have some errors and leads to compare with some images of not similar colors). Second reason for increasing the accuracy is narrowing the search space to include images of similar colors only and in turn the rank of some relevant images will be enhanced. As depicted in Table 1, search space is significantly reduced into 22% without degradation to the accuracy

that measured by P(10), which represent the accuracy of the first page of retrieval results of CBIRs. P(10) is very important in web-based application [1]. On the other hand, KM could not maintain the retrieval accuracy whereas KMB could, in the 8 and 5 indexed colors but with significantly increasing to the search space. Moreover, the accuracy of the proposed Octree method (in most settings) is better than the accuracy of KM and KMB with outperforming in reducing search space, the Octree has SSR lower than KM and KMB.

– Color Percentage-based Filtering (CPF) method using B+-tree is proposed to speed up the retrieval process by considering only the images that have similar colors as well as similar color percentage. The result showed that this filtering process succeed in reducing SSR of the proposed indexing method by 10% (in average) without degradation to the accuracy.

Experiments on MPEG-7 DCD also show similar accuracy to the ColGrm descriptor but limitation of space in this paper led to exclude it here. Additionally, the results of Corel-10K dataset is also excluded due to the same reason.

5 Conclusions

In this paper, indexing methods of CBIR are presented. Specifically, the problems of color-based indexing methods such as high-dimensional problem for histogram-based methods and color approximation problem of DC-based methods are addressed. Both problems are tackled in this paper by proposing DC-based indexing method, where uniform RGB color space is used. The superiority features of the proposed RGB indexing method over the existing methods lies in utilization of dominant color for indexing images using Octree quantization method where this indexing method can be used for different color descriptors. Moreover, the proposed method characterized by using static representation for index structure that allow speed retrieval as well as it has color percentage filtering scheme (using B+-tree) to filter irrelevant images out in early stage.

References

1. Penatti, O.A.B., Valle, E., Torres, R.D.S.: Comparative Study of Global Color and Texture Descriptors for Web Image Retrieval. Journal of Visual Communication and Image Representation (2012)
2. Talib, A., Mahmuddin, M., Husni, H., George, L.E.: A weighted dominant color descriptor for content-based image retrieval. Journal of Visual Communication and Image Representation 24, 345–360 (2013)
3. Yamada, A., Pickering, M., Jeannin, S., Jens, L.C.: MPEG-7 Visual Part of Experimentation Model Version 9.0-Part 3 Dominant Color. ISO/IEC JTC1/SC29/WG11/N3914, Pisa (2001)
4. Yang, N.-C., Chang, W.-H., Kuo, C.-M., Li, T.-H.: A fast MPEG-7 dominant color extraction with new similarity measure for image retrieval. Journal of Visual Communication and Image Representation 19(2008), 92–105 (2008)

5. Kiranyaz, S., Birinci, M., Gabbouj, M.: Perceptual color descriptor based on spatial distribution: A top-down approach. Journal of Image and Vision Computing 28(2010), 1309–1326 (2010)
6. Kiranyaz, S., Birinci, M., Gabbouj, M.: Perceptual Color Descriptors. Foveon, Inc., Sigma Corp., San Jose, California, USA (2012)
7. Talib, A., Mahmuddin, M., Husni, H., George, L.E.: Efficient, Compact, and Dominant Color Correlogram Descriptors for Content-based Image Retrieval. Presented at the MMEDIA 2013: Fifth International Conference on Advances in Multimedia, Venice, Italy, April 22-26 (2013)
8. Wong, K.M., Po, L.M., Cheung, K.W.: A compact and efficient color descriptor for image retrieval. In: Proceedings of IEEE International Conference on Multimedia and Expo (ICME 2007), Beijing, China, pp. 611–614 (2007)
9. Jouili, S., Tabbone, S.: Hypergraph-based image retrieval for graph-based representation. Pattern Recognition 45, 4054–4068 (2012)
10. Kunttu, I., Lepistö, L., Rauhamaa, J., Visa, A.: Image correlogram in image database indexing and retrieval. In: Proceedings of 4th European Workshop on Image Analysis for Multimedia Interactive Services, London, UK, April 9-11, pp. 88–91 (2003)
11. Hou, A.L., Zhao, L.-Q., Shi, D.-C.: Garment image retrieval based on multi-features. In: International Conference on Computer, Mechatronics, Control and Electronic Engineering (CMCE), pp. 194–197 (2010)
12. Gervautz, M., Purgathofer, W.: A simple method for color quantization: Octree quantization. In: New Trends in Computer Graphics, pp. 219–231. Springer (1988)
13. Yildizer, E., Balci, A.M., Jarada, T.N., Alhajj, R.: Integrating wavelets with clustering and indexing for effective content-based image retrieval. Knowledge-Based Systems 31, 55–66 (2012)
14. Deng, Y., Manjunath, B.S., Kenney, C., Moore, M.S., Shin, H.: An efficient color representation for image retrieval. IEEE Trans. Image Process 10(1), 140–147 (2001)
15. Babu, G.P., Mehtre, B.M., Kankanhalli, M.S.: Color indexing for efficient image retrieval. Multimedia Tools and Applications 1, 327–348 (1995)
16. Sudhamani, M., Venugopal, C.: Grouping and indexing color features for efficient image retrieval. International Journal of Applied Mathematics and Computer Sciences i3, 150–155 (2007)
17. Stehling, R.D.O., Nascimento, M.A., Falcão, A.X.: Cell histograms versus color histograms for image representation and retrieval. Knowledge and Information Systems 5(3), 315–336 (2003)
18. Khan, F.S., Rao, M.A., van de Weijer, J., Bagdanov, A.D., Vanrell, M., Lopez, A.: Color Attributes for Object Detection. In: Twenty-Fifth IEEE Conference on Computer Vision and Pattern Recognition, CVPR 2012 (2012)