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A Novel Approach to Extract Color Image Features Using Image Thinning

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Abstract: Color digital image recognition systems require discrimination processes that have high efficiency and speed to make the appropriate decision. Since the size of most digital color images is large, which may negatively affect the efficiency of the discrimination system, it is necessary to represent the digital image with a small set of values called the features vector. These feature vectors can be used instead of the image to identify the person using his image. In this research paper, we present a simplified and easy-to-implement method for extracting the features vector of any colored digital image. We use some morphological operations to thin the digital image and then calculate the thinning ratio as a feature of the colored digital image. The results of this paper show that the number of feature vectors depends on the number of structuring elements used in the digital image thinning operations. These structuring elements are replaced to form new image features. For efficiency comparisons, the results are compared with the K-means clustering method to show the speedup provided by the proposed method.

Keywords: Anding, complement, Erosion, features vector, Structural Element (SE), thinning, Thinning Ratio (TR).

1 Introduction

The digital image contains several rows and columns of pixels. Pixels are the smallest individual element in an image and represent the brightness of a given color at any particular point. Digital color images [1-3] include different types, such as a face image [2-7], an eye image, or a fingerprint image. Face images are used in many essential applications to identify or distinguish the person with the image, and these applications require high speed [8-14]. Since the image size is large, using it directly in the recognition process will reduce the efficiency of the recognition system, which calls for the need to represent the image with a small set of values called the features vector, as shown in Figure 1.

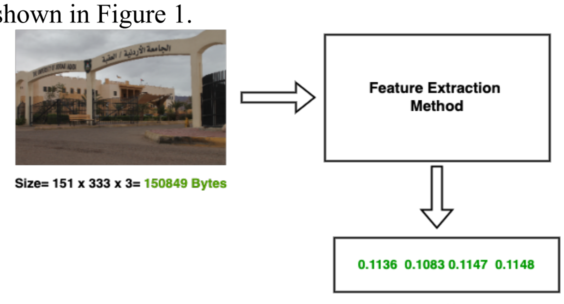

Fig.1. Features to represent a color image

Features values should satisfy the following requirements [15-19]. First, it should be unique for each image and not repeated for other photos so that it is used as an identifier to retrieve or identify the image. Second, the number of values in the features vector is small. Third, the number of values in the features vector is fixed and constant, does not change from one form to another, and is easy to handle.

The digital color image usually has a high resolution and thus leads to increasing image size; Table 1 shows descriptions of the selected images used in this paper.

Table 1. Selected image example

Image number	Dimension	Size(byte)
1	151x333x3	150849
2	152x171x3	77976
3	360x480x3	518400
4	1071x1600x3	5140800
5	981x1470x3	4326210
6	165x247x3	122265
7	360x480x3	518400
8	183x275x3	150975
9	183x275x3	150975
10	201x251x3	151353
11	600x1050x3	1890000
12	1144x1783x3	6119256

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The digital image is represented by a three-dimensional matrix, as shown in Figure 2, where one dimension is assigned to each of the three colors (red, green, and blue). The triple matrix facilitates the processing of the image, as the digital image is processed in multiple ways. What concerns us in this research paper are the following processing methods. This paper introduces a novel approach to extracting colors through implementing image complement, image anding, and image eroding.

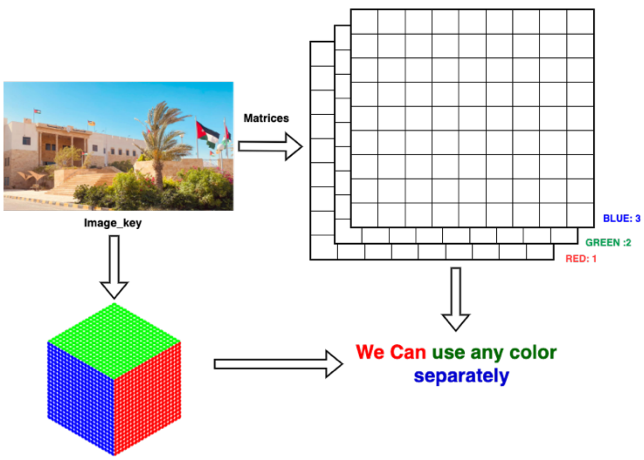

Fig.2. color image representation

1.1. Image complement

Image complement is the negative of the image. Image complement is a pixel operation, and it is applied for each pixel by subtracting the pixel value from the maximum gray value (255), as shown in Figure 3. Moreover, Figure 4 shows an image with its complement.

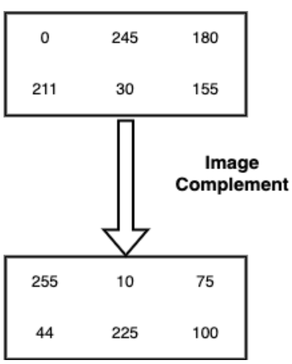

Fig. 3. Image complement example

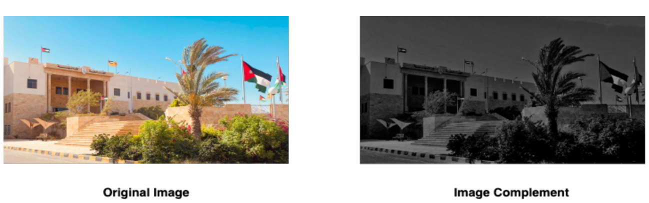

Fig. 4. Image and its complement

1.2. Image Anding

Image ANDing is also a pixel operation; this operation is executed on the bit level as shown in Figure 5; the two input images must have the same size; the example illustrated in Figure 5 shows how to implement this operation. It shows how to add the anding between the bits as given.

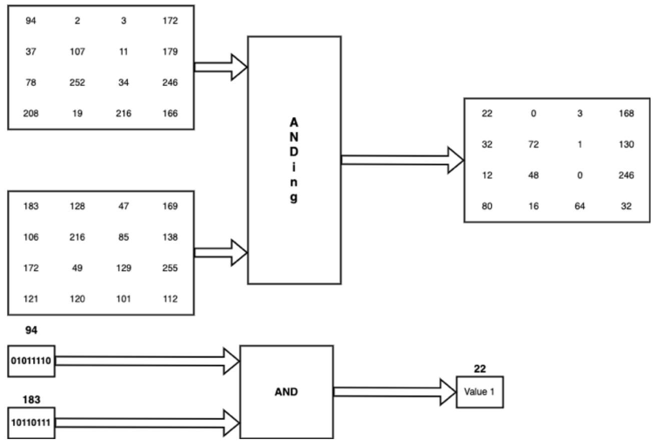

Fig. 5. Images anding example

1.3. Image Eroding

Image erosion is one of the basic morphological operations [20-22]. Erosion is applied using a structuring element of ones and zeros. One means that the associated pixel in the set of pixel neighbors covered by the structuring element (SE) is included in the process of eroding. In contrast, zero means that the associated pixel is excluded. Pixel erosion returns the minimum value from the pixel neighbors, which SE covers. The example illustrated in Figure 6 shows how to implement the erosion operation.

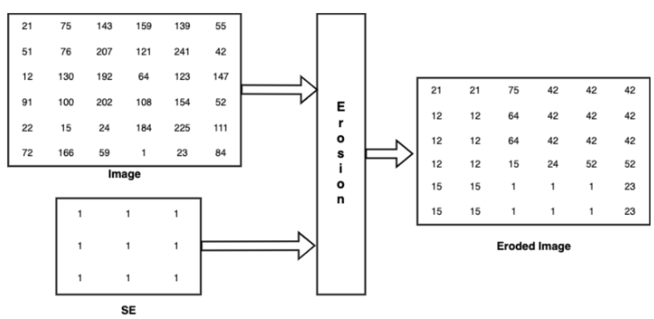

Fig. 6. Image eroding calculated example

The organization of this paper is as follows. Section 2 presents related work. Section 3 demonstrates the proposed methodology. Experimental results have been conducted in Section 4, followed by the result analysis in Section 5. Section 6 provides the conclusions of this research paper.

2 Related Work

The data K-means clustering method [23-30] is one of the most widely used methods for extracting the features of the colors in an image. Data clustering means grouping pixels (see Figure 7) values into a defined number of clusters, the centroids of the clusters or the within clusters sums can be used to form the image features, and the selected number of clusters will define the number of elements in the features vector. This study used the K-means method to compare their outcomes with the results obtained by the proposed methodology.

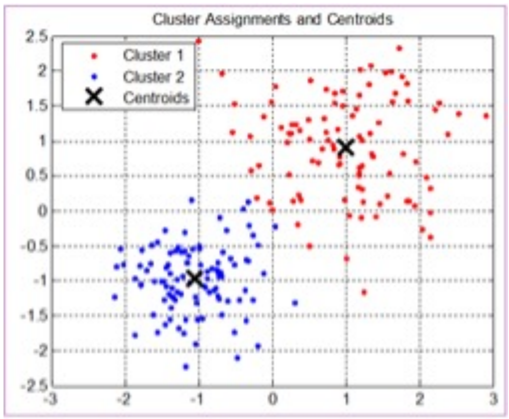

Fig.7. K-means clustering example

K-means clustering method manipulated in passes after initializing the number of clusters and the value of each cluster centroid. Each pass is used to perform the following operations: 1) Calculate the absolute value of the distance between each centroid and the data point (pixel), 2) Append the pixel to the cluster depending on the minimum distance, 3) Calculate the average points of each pixel, 4) Replace the centroids with the averages, and 5) If there is any change in the value of the centroid execute another pass, otherwise stop. Table 2, Table 3, Table 4, and Table 5 show phase 1, phase 2, phase 3, and phase 4, respectively. The phases represent the calculated steps for the K-means data clustering.

Table 2. Phase 1

Input data set	Distance D1	Distance D2	Belongs to cluster	New clusters centroids
12	8	4	2	C1=5
5	1	3	1	
7	3	1	2	
8	4	0	2	
40	36	32	2	
9	5	1	2	C2=15.89
6	2	2	2	
10	6	2	2	
30	26	22	2	
21	17	13	2	

Table 3. Phase 2

Input data set	Distance D1	Distance D2	Belongs to cluster	New clusters centroids
7	3.8900	2	7	C1=7.5
0	10.8900	1	0	
2	8.8900	1	2	
3	7.8900	1	3	
35	24.1100	2	35	
4	6.8900	1	4	C2=25.75
1	9.8900	1	1	
5	5.8900	1	5	
25	14.1100	2	25	
16	5.1100	2	16	

Table 4. Phase 3

Input data set	Distance D1	Distance D2	Belong sto cluster	New clusters centroids
12	4.5000	13.7500	1	C1=8.14
5	2.5000	20.7500	1	
7	0.5000	18.7500	1	
8	0.5000	17.7500	1	
40	32.5000	14.2500	2	
9	1.5000	16.7500	1	C2=30.33
6	1.5000	19.7500	1	
10	2.5000	15.7500	1	
30	22.5000	4.2500	2	
21	13.5000	4.7500	2	

Table 5. Phase 4

Input data set	Distance D1	Distance D2	Belongs to cluster	New clusters centroids
3.8600	18.3300	1	3.8600	C1=8.14
3.1400	25.3300	1	3.1400	No
1.1400	23.3300	1	1.1400	changes
0.1400	22.3300	1	0.1400	so stop
31.8600	9.6700	2	31.8600	
0.8600	21.3300	1	0.8600	C2=30.33
2.1400	24.3300	1	2.1400	No
1.8600	20.3300	1	1.8600	changes
21.8600	0.3300	2	21.8600	so stop
12.8600	9.3300	2	12.8600	

3 The Proposed Methodology

For a color image thinning and thinned image features extraction, the structuring elements shown in Figure 8 are required to thin a color image. The following steps are executed. The pseudocode for the proposed approach is described below. In addition, Figures 8, 9, and 10 illustrate an example of extracting one image feature using the SE.

For each of the structuring elements
Do
{
1) Erode the image using SE; the result is image (a).
2) Get the complement of the original image (b).
3) Erode b with the complement of SE (c).
4) Apply anding (a) and (c) to get the thinned image.
5) Find the summation of the original image matrix s1.
6) Find the summation of the thinned image s2.
7) Calculate the thinning ratio (TR=s2/s1).
8) Use TR as one image feature (F1, F2, F3, F4).
9) Add the calculated feature to the features vector.
}

End

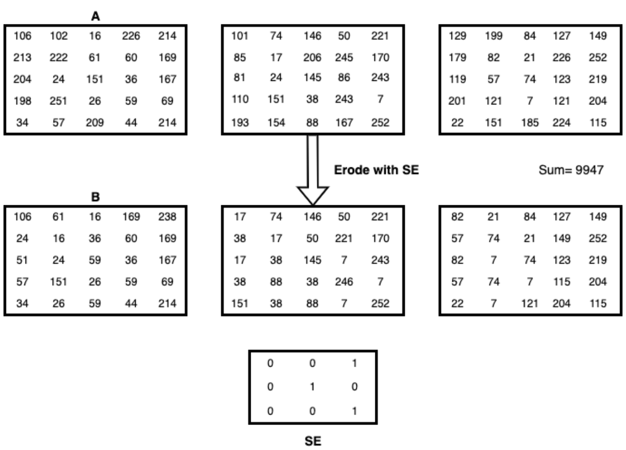

Fig.8. Color image eroding example

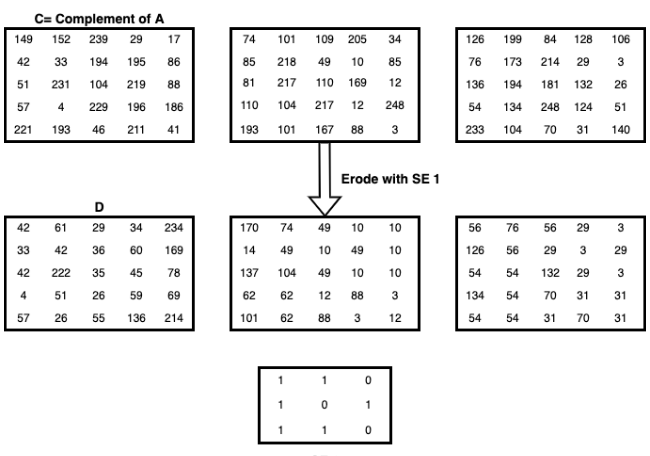

Fig.9. Eroding color image complement

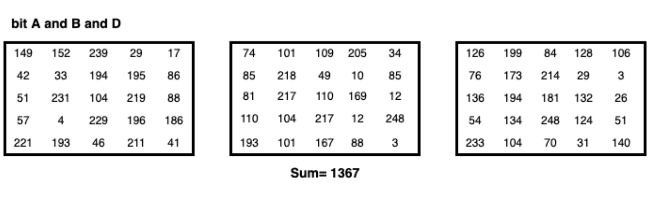

Fig.10. Getting the thinned image

4 The Experimental Results

A Matlab code was written for the proposed method, the images listed in Table 1 were selected, and the programs were executed using an I5 processor with 8 G bytes RAM. Table 6 shows the obtained features by implementing the proposed approach. The structuring element is to be selected by the user. The structuring element one will be used as a shape to be found in the image; the result of thinning is an image containing this shape and omitting all other profiles.

Table 6. Results using SE

Image number	**Thinning ratio (Features)**				**Extraction time (second)**
	F1	**F2**	**F3**	**F4**	
1	0.1136	0.1083	0.1147	0.1148	0.168000
2	0.0346	0.0394	0.0342	0.0352	0.090000
3	0.2472	0.2563	0.2489	0.2519	0.404000
4	0.1962	0.2040	0.1967	0.1978	3.808000
5	0.1523	0.1561	0.1518	0.1549	3.198000
6	0.1745	0.1724	0.1752	0.1737	0.129000
7	0.1586	0.1600	0.1588	0.1587	0.409000
8	0.1088	0.1127	0.1075	0.1092	0.158000
9	0.2042	0.2039	0.2054	0.2033	0.260000
10	0.1921	0.1832	0.1972	0.1922	0.144000
11	0.1002	0.1093	0.1008	0.1041	1.393000
12	0.0909	0.0956	0.0890	0.0916	4.521000

It is easy to select different SEs, changing the features and keeping them unique for each color image.

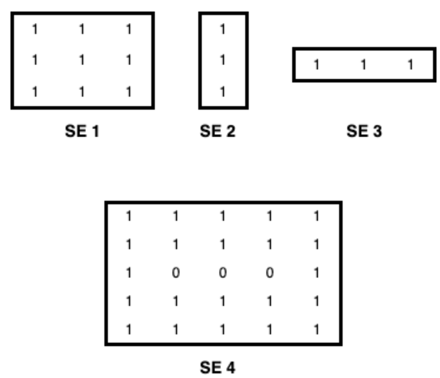

Fig.11. another selected SEs

Table 7 shows the obtained image features using structural elements, whereas Table 8 shows the results obtained by applying the K-means clustering method. Obliviously, for all the examined images, the tinning ratio and extraction time using the proposed approach are less costly and time consumed than the K-clustering method.
Such interesting findings reflect the strong points of the proposed methodology compared with the currently used ones.

Table 7. Results using SEs shown in Figure 1

Image no.	Thinning ratio (Features)				Extraction time (second)
	F1	F2	F3	F4	
1	0.7363	0.8642	0.8565	0.0841	0.157000
2	0.8727	0.9438	0.9338	0.0469	0.090000
3	0.7914	0.8982	0.8871	0.2487	0.431000
4	0.8652	0.9379	0.9224	0.2093	4.013000
5	0.8944	0.9495	0.9434	0.1482	3.420000
6	0.8488	0.9265	0.9110	0.1584	0.123000
7	0.8278	0.9158	0.9017	0.1596	0.430000
8	0.9334	0.9675	0.9638	0.1220	0.283000
9	0.8329	0.9275	0.8964	0.1868	0.160000
10	0.6777	0.8537	0.8032	0.1518	0.149000
11	0.9242	0.9584	0.9648	0.1231	1.491000
12	0.9638	0.9819	0.9797	0.1058	4.705000

Table 8. K-means clustering method results

Image no.	Thinning ratio (Features)				Extraction time (second)
	F1	F2	F3	F4	
1	230.7880	162.6748	88.6582	24.7795	1.238000
2	57.9272	205.8391	150.1751	238.7813	0.524000
3	191.0810	12.1478	66.4743	125.6163	3.499000
4	80.2933	28.4347	199.0978	134.3051	22.166000
5	55.4946	230.0808	107.0364	169.6816	17.403000
6	33.0259	83.5358	169.7968	122.5739	0.680000
7	6.2029	140.5972	226.1570	81.2838	1.416000
8	97.1373	155.0356	36.9657	235.6717	1.520000
9	83.9734	32.0082	201.8854	135.8075	0.822000
10	151.1589	80.2431	19.3801	218.0935	1.826000
11	111.8570	237.6980	55.6583	177.7467	8.563000
12	131.2108	157.1767	230.9996	92.9264	24.494000

K_means clustering method is a suitable method of color image features extraction because of the following reasons:

1. The method is flexible and provides various options to form the image features; we can use the centers of the clusters, within clusters sums, or the number of points in each cluster as a feature.
2. The length of the obtained features vector is fixed, the user can determine the number of elements in the features vector, and it will equal the number of selected clusters.
3. The obtained features vector is unique for each color image.
4. The method is not sensitive to image rotation; the features will remain the same even if we rotate the image, regardless of other forms of feature extraction. It is better than wavelet packet tree decomposition; here, it will be difficult to fix the number of elements in the features vector because image size is not fixed and usually not multiple of 2, so it is challenging to select the number of decomposition levels.
5. It is better than any method based on the local binary pattern; these methods are sensitive to image rotation. The rotated image will be treated as a new image, and an extra features vector will be added to the features database.

5 Results Analysis

This section describes the obtaining results and clarifies the essential points about the efficiency of the proposed image-thinning approach. For example, by considering the first image, the ratios for the features F1, F2, F3, and F4 were 0.7363, 0.8642, 0.8565, and 0.0841. On the other side, the K-means approach ratios were 230.7880, 162.6748, 88.6582, and 24.7795 for the same features in the same order. Further, the extraction time was 0.157000, 1.238000 seconds for both the proposed method and clustering correspondingly. From the method execution and the obtained experimental results, we can raise the following facts:

1. The proposed method of color image features extraction is a simple and effective method of feature extraction; it uses simple operations to apply image thinning and calculate the thinning ratio.
2. The structural elements are changed; changing SEs will change the image's features and keep the unique features of an image.
3. The extraction time in the proposed method depends on the image size, while the extraction time in K-means clustering depends on the image size and the required number of passes needed to calculate the centroids of the clusters.
4. The obtained features for the proposed method are normalized. All of them are below one, but the features extracted by the k-means method required data normalization. Consequently, the proposed method is more efficient and has a significant speedup (of average 6.5730) compared with the K-means method, as shown in Table 9.

Table 9. Speedup of the proposed method

Image size	Proposed Extraction Time (second) (t1)	K-means clustering Extraction Time (second) (t2)	Speedup proposed method (t2/t1)
150849	0.168000	1.238000	7.3690
77976	0.090000	0.524000	5.8222
518400	0.404000	3.499000	8.6609
5140800	3.808000	22.166000	5.8209
4326210	3.198000	17.403000	5.4418
122265	0.129000	0.680000	5.2713
518400	0.409000	1.416000	3.4621
150975	0.158000	1.520000	9.6203
150975	0.260000	0.822000	3.1615
151353	0.144000	1.826000	12.6806
Average	1.2235	7.0126	6.5730

6 Conclusion

This paper introduces a simple and efficient digital image feature extraction method containing image complement, anding, and eroding steps. The proposed method uses a simple and essential image processing operation to calculate the thinned image for any given image. Then the thinning ratio is calculated and used as an image feature. The proposed method uses various structuring elements to apply image thinning; these SEs can be easily changed and used to form unique features for any image. The extracted features of the color image are used to build a database for the color image of the recognition system, and the extracted features are small in numbers, fixed, unique, and normalized. The proposed method is efficient and speeds up the feature extraction process on average 6.2 times compared with the K-means clustering method, widely used in calculating image features.

Conflict of interest:

The authors declare that there is no conflict regarding the publication of this paper.

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