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Face Shape Classification based on Modified Relative Improved Differential Box Count Method

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Abstract

The application of Fractal Dimension (FD) is not limited to a single domain; rather its usefulness can be extended to fields like segmentation, classification of shapes and analysis. Through this paper, the idea of classification of face shapes is presented using our proposed method -Modified Relative Improved Differential Box Counting (DBC) method. The method has been compared with the current existing FD calculation method, Improved DBC. The face data set is matched with popular geometric shapes, ellipse, rectangle, oval and triangle and classified according to the minimum FD difference between the face image and the given geometrical shapes. The experiments conducted with face sketch data sets have provided promising results and has also demonstrated that our proposed method can perform better in the field of classification, thus in general indicating that fractal dimension method is effective for classification of face shapes.

Keywords: *Fractal Dimension, Segmentation, Classification, Differential Box Count, Improved DBC*

1. Introduction

Human Perception depends on the facial features of an individual. The face can be divided into numerous physical features consisting of shape of teeth, jaw, ears, eyes, etc. These physical features in aggregation produce the shape of human face. The distinguishing attributes of human face are colour, texture, and shape. Here, we are working on classification of faces based on the shape of face.

Shape is defined as the form, or external boundary, or outline that represents an object. In a two-dimensional plane shapes are classified as circle, oval, polygon, triangle, rectangle, square and ellipse. Similarly, in a three-dimensional plane classification takes place as polyhedral, ellipsoid etc.

Human face classification to different shapes like circle, oval, ellipse, etc. is important to scientific, medical and law enforcement agencies. Many computer systems have been designed that are consistently being used in facial surgery planning. Various methods such as Region Based Similarity, Correlation and Fractal Dimension are present to classify human face with objects.

The application of fractal analysis is in many fields since the introduction of fractal geometry in the year 1967 by Benoit Mandelbrot [1]. The basic parameter of fractal analysis is fractal dimension. Fractals are natural objects or structures that possess the property of self- similarity. Fractals cannot be described in Euclidean dimension as a line is in one-dimension, a plane is in two-dimension and a cube is in three-dimension. The non-integer dimension is also one of the important properties of fractals which is known as fractal dimension.

The methods for estimation of fractal dimension are box-count method, Fractional Brownian Motion, Power Spectrum method, Hybrid Method, lacunarity analysis and multi-fractal analysis, e.t.c. We have used the box-count method for calculation of FD. Gagnepain and Roques-Carmes [2] proposed the reticular cell counting method in 1986, which was then improved by Keller [3] in 1989 by improvising the calculation of box-number step. DBC (Differential Box-count Method) was proposed by Sarkar and Chaudhari [4] in 1994. DBC method used minimum and maximum gray levels of the corresponding grid in the image for calculation of FD instead of using the process of cell counting to count the number of boxes. There were further improvements to DBC method by Jin [5] in 1995 as RDBC (Relative Differential Box Count Method) and Chen[6] in 2003 as SDBC (Shift Differential Box Count Method). Liu and Chen [7] proposed an Improved DBC method in 2013 eliminating the drawbacks in the box-number and box-height problem of existing Box-Counting methods.

The Fractal dimension estimation using box-count method or the box-counting dimension is

$$D = \frac{\log N_r}{\log r} \quad (1)$$

Where D = Fractal Dimension

N_r = Number of Boxes of side length r

r = Scale of the Box

In this paper, we have classified the face images into Ellipse, Rectangle, Triangle and Oval using the Fractal dimension method. Estimation of fractal dimension is performed using a proposed box-count method for better accuracy, its simplicity and easy computability.

This paper is organised as follows. In Section 2, we have presented some of the works carried out in the field of Face Shape classification in the past. Section 3 describes Face Shape classification using two methods based on fractal dimension calculation. Section 4 gives the experimental Results. Required conclusions have been made in Section 5. The paper ends with Necessary Acknowledgement, References and Appendices.

2. Related Works

Luning Li and Jaehyun So[8] proposed an AAM (Active Appearance model) based face shape classification method using Support Vector machines. The best representative samples were used to build AAM model from selected images. Then a three class SVM model was trained for classification of face shapes. Sarakon [9] proposed a classification method from three-dimensional human data. The complete body data was used as an input to the system. First step comprises of segmentation of head. In the next step, the face plane is identified. The third step is classification of face shape using SVM. The face was classified into four shapes - ellipse, long, round and square. Sunhem [10] proposed a face classification method that classified into five shapes namely round, oval, oblong, square, heart. This method was based on AAM and face segmentation to derive a set of features that can be easily evaluated by Machine Learning algorithms. Bansode and Sinha [11] classified faces based on three attributes. In region based similarity the image is divided into unique regions and each corresponding region is assigned an Identification number. In correlation method, the correlation co-efficient is the measure for classification of face shapes. In Fractal dimension method, the minimum difference between FD of human face and the object is calculated for classification.

Li and Sun[12] improved the drawbacks of DBC method. The Box-Height, Box-Number and Image Intensity Partition problems were improved. The over-counting and under-counting problems were eliminated by Modified box-count mechanism in the Improved DBC[7]. Shifting of blocks was also properly carried out in the method by Liu and Chen.

3. Methods

Classifying objects based on their shapes has a lot of applications in the robotics industry. Different methods are present for classifying the objects based on their shapes. They include region based similarity method, correlation method, etc. Fractal Dimension (FD) method is a newer method of classifying the object shapes and is much suitable for irregular objects. Fractal dimension method uses the box counting techniques to calculate the FD. Several techniques are developed on fractal dimension calculation. But only the box count method is applied for face shape classification till date. Hence to improve the efficiency of the procedure, we have proposed a new technique -Modified Relative Improved Differential Box Counting Method. The classification is compared among the recent existing Improved Differential Box Count method (DBC) [12] and the proposed method, modified relative improved version of the (DBC).

3.1. Improved Differential Box Count Method [12]

The Improved Differential Box Count method uses standard deviation and mean to calculate the FD of a gray scale image. The detailed algorithm is summarized below:

1) Divide the input image into blocks of size l x l. Any two blocks adjacent to each other should overlap by one row (or column) of pixels at the boundary.

2) Assign a column of boxes with a scale of r x r x r’ starting from the pixel with the minimum gray level. r’ is calculated using the equation

$$r' = \frac{r}{1+2a\sigma} \tag{2}$$

Where r = scale of the box and r=l-1.

2aσ = image roughness

3) Determine the n_r for each block using the formula

$$n_r(i,j) = \begin{cases} \frac{ceil(l-k)}{r'}, & l \neq k \\ 1, & l = k \end{cases} \tag{3}$$

Where n_r (i,j) = number of boxes in (i,j) block

l = minimum gray level in (i,j) block

k = maximum gray level in (i,j) block

4) For different values of scale r, N_r is calculated using the equation

$$N_r = \sum_{(i,j)} n_r(i,j) \quad (4)$$

Where N_r = Total boxes covering the image for scale r

5) Plot a graph of log (N_r) versus log(r) and compute the slope of the best fit line that gives the FD of the input image.

3.2. Proposed Methodology

The proposed method, Modified Relative Improved Differential Box Counting Method, removes the limitations of improved DBC method that are caused because of box number calculation and box height calculation. New formulae are derived for box height and number of box estimation. The algorithm for this method is described in detail below:

1) Divide the given image of size M x M into blocks of size l x l.
2) Assign the column of boxes with a scale of l x l x l' . l'is calculated according to the formula

$$l' = l \times G/M \quad (5)$$

Where G = Gray level of the image

3) Calculate n_r for each block using the formula

$$n_r = ceil(\frac{MI}{l'}) \quad (6)$$

Where MI = Maximum gray level intensity in each block

4) Calculate N_r for different values of r using Eq. (4).
5) Plot log(N_r)versus log(r)graph and determine the slope of the best fit line giving FD of the given image.

4. Results and Discussions

The FD calculation of the image is done according to the algorithms described in sub-section 3.1 and 3.2. The FD of geometrical shapes- ellipse, rectangle, oval and triangle are calculated according to the algorithm described above.

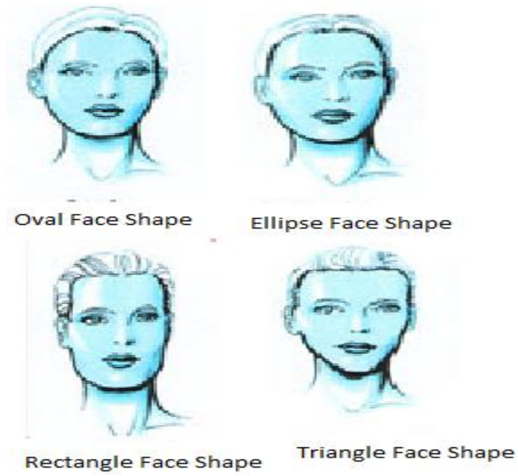

Figure 1. Different Face Shapes

The difference in FD between face image and the different geometrical structures taken are calculated. The minimum difference of FD is considered and the corresponding geometrical structure classifies the face image. There are different types of face shapes. Fig. 1. shows a few different types of face shapes that are taken into consideration for face classification in this paper.

In this paper, both improved DBC and modified relative improved DBC methods are implemented to get the FD difference between face and the geometrical objects. In table 1, we have shown the estimated FD for the geometrical structure using these two methods. This paper shows the classification using the fractal dimension methods only. The experiment is conducted by using the CUHK [13] face sketch data sets. A total of 606 images from this data set are used and face classification is done accordingly. The sample results are shown in Tables 2, 3. Here, we have categorized the faces into four face shapes, elliptical, rectangle, oval and triangle and have done the face classification for the data sets accordingly. All the implementation and operation on images of the data sets are carried out by taking the image size of 256 x 256.The results from implementation of CUHK testing sketch of 100 faces using both the methods show that the maximum number of faces are of ellipse shape followed by the triangle shape. Fig. 2. shows the comparison between the results obtained from both FD methods using the sketch of 100 faces. For the implementation of CUHK training sketch of 88 faces, Fig. 3. shows the comparison between the two methods using those faces as input. The results indicate that maximum number of faces are of ellipse type followed by oval and triangle shape faces. Fig. 4. shows the result comparison between the two methods for the implementation of AR sketch of 123 faces. The results show that the maximum number of faces are of ellipse shape only. Fig. 5. shows the implementation and comparison between the methods for XM2VTS sketch of 295 faces. Here too, the maximum face shapes belong to ellipse category. A total of 606 sketch faces were used to get the result sets. The data sets have a high percentage of ellipse shape face sketches. The percentage of ellipse face shape in Modified Relative Improved DBC method is 93.39 %, followed by 2.97 % of triangle face shape, 2.47 % of oval face shape and 1.15 % of rectangle face shape. The percentage of ellipse face shape in the Improved DBC method is 79.37 %, triangle face shape is 17.49 %, oval face shape is 2.47 % and rectangle face shape is 0.66 %. The Table 4 shows the average face classification for the 4 data sets of CUHK used and the two methods that is used for the face classification. The sample images that are used to get the results in Tables 2 and 3, are shown in Fig. 6. at the Appendix section. All the images have been labelled with face shapes explicitly by looking at the images with naked eye. Such labels help in easy verification of the results obtained through our method.

The results obtained for the face shape classification using fractal dimension method were compared with face shape classification results obtained using Region – based similarity and the correlation method presented by N.K. Bansode, P. K. Sinha [11]. Such comparisons would help in stating that the results obtained using the fractal dimension method is correct and better.

Table 1. Fractal Dimension of geometrical shapes

Sr. No.	Method	Ellipse	Rectangle	Oval	Triangle
1.	Improved DBC	1.6575	1.4667	1.4999	1.5698
2.	Modified Relative Improved DBC	2.6632	2.5735	2.5949	2.6103

Table 2. Improved DBC Method results

Sr. No.	Face	Ellipse	Rectangle	Oval	Triangle	Remark
1	1.6882	0.0307	0.2215	0.1883	0.1184	Ellipse
2	1.6360	0.02147	0.1693	0.1361	0.0662	Ellipse
3	1.6268	0.0307	0.1600	0.1269	0.5696	Ellipse
4	1.4979	0.1595	0.0312	0.0019	0.0719	Oval
5	1.5736	0.0838	0.1069	0.0737	0.0038	Triangle
6	1.7299	0.0724	0.2632	0.2300	0.1601	Ellipse
7	1.6918	0.0342	0.2250	0.1918	0.1219	Ellipse
8	1.7083	0.0508	0.2417	0.2084	0.1385	Ellipse
9	1.7203	0.0628	0.2536	0.2204	0.1505	Ellipse
10	1.7181	0.0606	0.2514	0.2182	0.1484	Ellipse
11	1.7338	0.0762	0.2670	0.2338	0.1639	Ellipse
12	1.6368	0.0206	0.1701	0.1369	0.6701	Ellipse
13	1.7181	0.0607	0.2515	0.2183	0.1484	Ellipse
14	1.6763	0.0188	0.2096	0.1764	0.1065	Ellipse
15	1.7238	0.0663	0.2571	0.2239	0.1540	Ellipse
16	1.7015	0.0440	0.2348	0.2016	0.1317	Ellipse

Table 3. Modified Relative Improved DBC Method results

Sr. No.	Face	Ellipse	Rectangle	Oval	Triangle	Remark
1	2.6414	0.0217	0.0679	0.0465	0.0311	Ellipse
2	2.6576	0.0056	0.0841	0.0627	0.0473	Ellipse
3	2.5826	0.0806	0.0091	0.0123	0.0276	Rectangle
4	2.5584	0.1047	0.0150	0.0364	0.0518	Rectangle
5	2.8933	0.2301	0.3198	0.2984	0.2830	Ellipse
6	2.9535	0.2903	0.3800	0.3586	0.3432	Ellipse
7	2.9482	0.2850	0.3748	0.3534	0.3799	Ellipse
8	2.9550	0.2918	0.3815	0.3601	0.3447	Ellipse
9	2.9501	0.2869	0.3766	0.3552	0.3398	Ellipse
10	2.9254	0.2621	0.3519	0.3305	0.3151	Ellipse
11	2.9552	0.2920	0.3817	0.3603	0.3449	Ellipse
12	2.9553	0.2920	0.3817	0.3604	0.3449	Ellipse
13	2.9433	0.2800	0.3697	0.3484	0.3329	Ellipse
14	2.9504	0.2872	0.3769	0.3556	0.3401	Ellipse
15	2.9339	0.2706	0.3603	0.3389	0.3236	Ellipse
16	2.9388	0.2756	0.3653	0.3439	0.3285	Ellipse

Table 4 Face Shape Classification Average (%)

Sr. No.	Method	Ellipse	Rectangle	Oval	Triangle
1	Improved DBC	79.37	0.66	2.47	17.49
2	Modified Relative Improved DBC	93.39	1.15	2.47	2.97

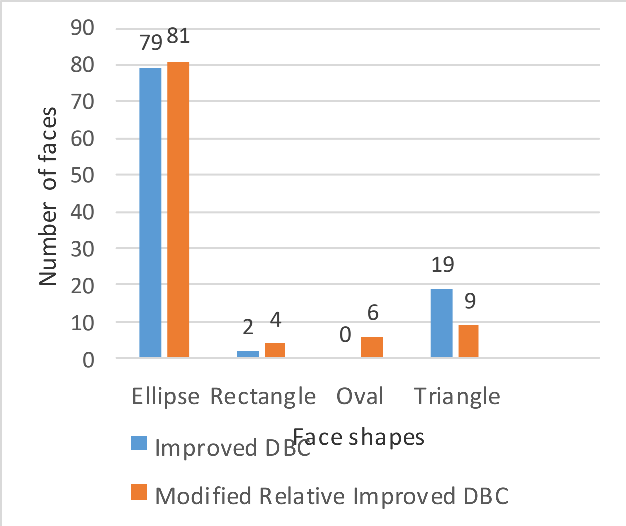

Figure 2. Face Shape Classification (CUHK Testing Sketch)

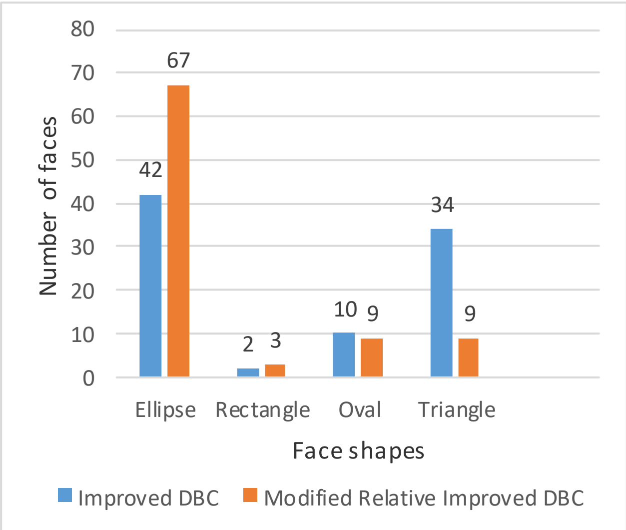

Figure 3. Face Shape Classification (CUHK Training Sketch)

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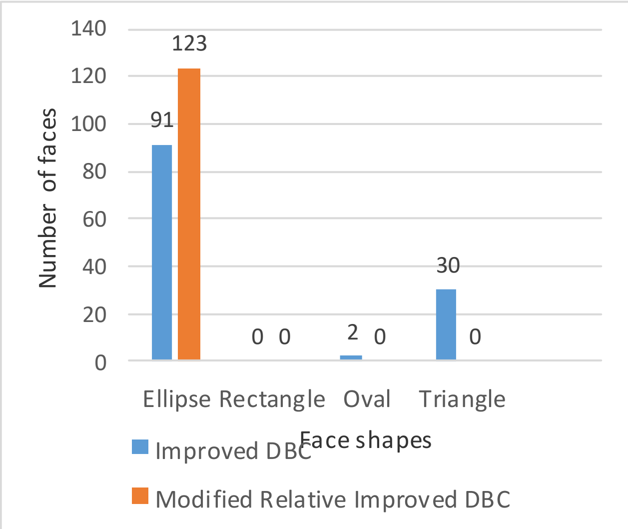

Figure 4. Face Shape Classification (AR Sketch)

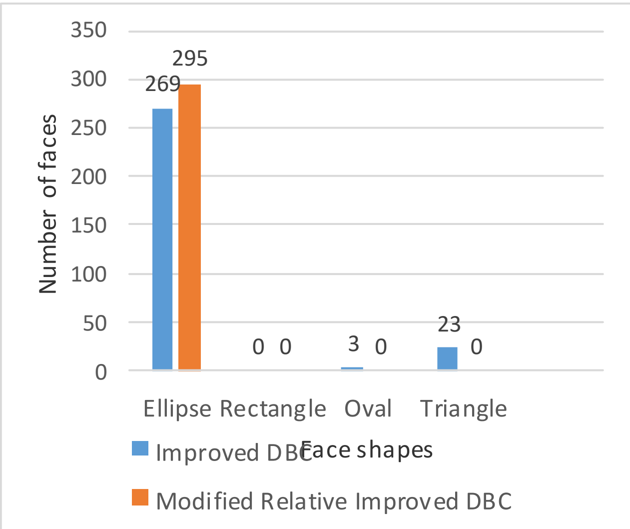

Figure 5. Face Shape Classification (XM2VTS Sketch)

5. Conclusion

In this research paper, we have presented a way to classify the face based on fractal dimension method. We have implemented the existing fractal dimension algorithm, Improved Differential Box Count method, to classify the faces from the CUHK face data set and have used 606 sketched images for the same. We have also implemented our proposed algorithm of gray scale image fractal dimension and made the classification on the same face data sets. The experimental result shows that the proposed method is effective in classification of face images. The results of the proposed method are well verified against the labelled database of face images which were used as input to the method. The results show that the fractal dimension is an effective method to classify the face shape as a whole.

The face classification is done using the four face data sets of CUHK face database. The results show that 90 % of the face sketches present in the database are of elliptical type. Very few number of faces present are of oval, rectangle and triangular type. Same statistics were obtained while labelling the CUHK face database.

The results obtained using the fractal dimension method is very similar to the statistics obtained through Region based similarity and correlation method [11].

Such results indicate that fractal dimension technique is promising in the field of classification and further research on this can be conducted where classification can be done based on more varied geometrical shapes, colour images and extend its application further to a new domain.

Appendix

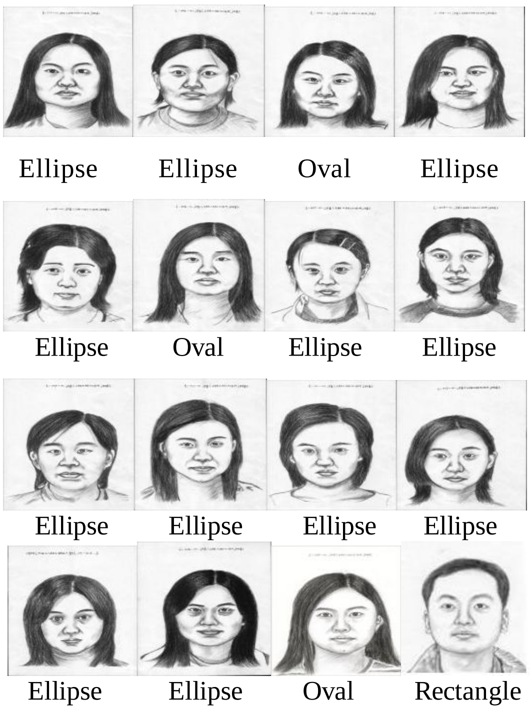

Figure 6. Sample Images

1. http://mmlab.ie.cuhk.edu.hk/facesketch.html.

(a)

(b)

(c)

Figure 7. Sample face sketches from (a) the CUHK student database, (b) the XM2VTS database. and (c) the AR database

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