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Optimized Facial Features-based Age Classification

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Abstract**—**The evaluation and measurement of human body dimensions are achieved by physical anthropometry. This research was conducted in view of the importance of anthropometric indices of the face in forensic medicine, surgery, and medical imaging. The main goal of this research is to optimization of facial feature point by establishing a mathematical relationship among facial features and used optimize feature points for age classification. Since selected facial feature points are located to the area of mouth, nose, eyes and eyebrow on facial images, all desire facial feature points are extracted accurately. According this proposes method; sixteen Euclidean distances are calculated from the eighteen selected facial feature points vertically as well as horizontally. The mathematical relationships among horizontal and vertical distances are established. Moreover, it is also discovered that distances of the facial feature follows a constant ratio due to age progression. The distances between the specified features points increase with respect the age progression of a human from his or her childhood but the ratio of the distances does not change ($\delta = 1.618$). Finally, according to the proposed mathematical relationship four independent feature distances related to eight feature points are selected from sixteen distances and eighteen feature point's respectively. These four feature distances are used for classification of age using Support Vector Machine (SVM)-Sequential Minimal Optimization **(**SMO**)** algorithm and shown around 96 % accuracy. Experiment result shows the proposed system is effective and accurate for age classification.

Keywords**—**3D Face Model, Face Anthropometrics, Facial Features Extraction, Feature distances, SVM-SMO

I. INTRODUCTION

DETECTING and tracking facial feature points from video sequences has been attracted significantly increased interests in recent years [1-10]. Facial feature points are usually located on the corners, tips or mid points of the facial components. Identification of facial feature points plays an important role in many facial image applications like human computer interaction, video surveillance, face detection and recognition, age grouping, expression classification, face modeling and animation, face anthropometric, 2D and 3D face design, robotics and so on[3-5]. Many approaches have already been attempted towards addressing this problem, but complexities added by circumstances like inter-personal variation (i.e. gender, race), intra-personal changes (i.e. pose, expression) and inconsistency of acquisition conditions (i.e. lighting, image resolution) have made the task quite difficult and challenging.

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All the works that have addressed the problem of facial feature point detection so far can be grouped into several categories on the basis of their inherent techniques which will be discussed in section II. Since human faces provide a lot of information, and the subjects of human face are changed mainly due to three reasons viz. age, gender and ethnic group. As the age seems to be the main cause of the facial changes, it has come to the forefront. That is because the changes of the facial appearance due to the aging show some unique characteristics when compared with other reasons. It has founded that the facial changes can happen within four periods of a human's lifetime. That is during the period of infancy, childhood, youth hood and old age. It may be difficult to identify these people by examining their old photographs, because their facial appearance might have changed mainly due to the natural aging process. One goal of this research is to find out whether a conclusion can be arrived at as to how the appearance of a face changes subject to age levels. To achieve this goal, some objectives must be accomplished. One is to identify the facial features which are changing subject to time according to the age [2] [3].

There are a lot of researches have been done in the field of facial feature extraction and analysis by this time over the world. There are many techniques are applied to extract the features of the face during that time [1-10]. However, a little number of papers discussed or discovered how the features of a face are related to each other for a specific person. Although anthropometric measurement of face provides useful information about the location of facial features, it has already been used in their detection and localization. In this paper, we have explored the approach of using a mathematically developed, reusable anthropometric face model for localization of the facial features as well as the selection of the 18-most important facial feature points on the face. Euclidean feature distances are calculated from the selected features. Additionally, mathematical relationships are established among calculated feature distances. Finally, we used only four feature distances for age classification that almost related to eight feature points. The main concern of this paper is to optimize of facial feature points by establishing a mathematical relationship among facial features and used optimize feature points for age classification using support vector machine (SVM)-Sequential Minimal Optimization (SMO) algorithm.

The subsequent discussion has been organized into the following six sections: Section II presents related works, Section III explains the proposed method, Section IV discusses on age classification using optimized facial features, Section V shows experimental results of the propose system and discussion, and finally Section VI describes conclusions and future works of this study. The related works of this research are discussed in the next sections

II. RELATED WORKS

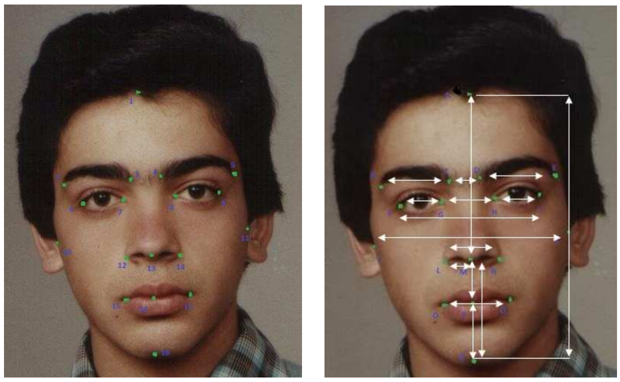
The related researches of the above mentioned concepts are as follows: In [1] presented the anthropometric face model base on 18-feature points. Also automatic extraction processes of their selecting facial features points and effectiveness of points to design a face anthropometric model have been discussed. The facial appearance might have change duo to the nature of aging process is discussed in [2]. There are different types of horizontal and one vertical distance distances between the selected features like height of face, width of lips, height of forehead etc as horizontal distance, the length of the cornea as vertical distance are considered in this paper. Moreover, the proposed system only conducted to synthesize the facial images of people whose age is beyond to 30 years. Twenty selected facial feature points based on expression recognition system are proposed in the paper [3]. Thirteen horizontal and vertical distances among the selected features are considered. In [4] an expression recognition system was proposed considering 26 automatic fiducial point of human face. It is also mentioned the fiducial points are considered to extract the facial salient points are usually located on the corners of the eye, corners of the eyebrows, outer corners of the lips, and so on. Adaboost classifier is considered as a classification tool in this paper. There are twenty selected facial feature points based facial action detection system using support vector machine is proposed in [5]. Ramanathan and Chellappa [6] proposed a modeling of age progression in young faces using 24 landmarks of facial images. This paper demonstrated on age separated face images of individual less than 24 years of age. In [7] proposed a face anthropometric model based on 57 landmarks of facial images.

Geometrical shapes of facial features have been adopted in several works for facial feature point localization and detection [8] [9]. Each feature is demonstrated as a geometrical shape; for example, the shape of the eyeball is a circle and the shape of an eyelid is ellipse. This method can detect facial features very well in neutral faces, but fails to show good performance in handling the large variation in face images occurred due to pose and expression [10]. Due to the inherent difficulties of detecting facial feature points using only a single image, spatio-temporal information captured from subsequent frames of video sequence has been used in some other work for detection and tracking facial feature points [11][12]. Some works have also used image intensity as the most important parameter for detection and localization of facial features [13][14].Finally, we have considered some other's reference related to the other's relevant topics like database and software of this research work. However, according to above discussion we found some papers are related to facial feature point's extraction and face anthropometrics model but there are no information of those reference papers on how the facial features of a person are related to each other's mathematically or statistically and how to change of facial features due to age progression of human. Most of the previous researcher used at least eighteen facial feature points for their proposed system model.

The research in age estimation (age determination or age classification) has increase significantly since 2002 [17, 18, 19, 20, and 21]. There huge numbers of research works are already done and still running on age classification field because of its dynamicity. In the next section we are going to represent our propose method in details.

III. PROPOSED METHOD

Firstly, according to this proposed method 18 facial feature points and 16 facial features distance between selected features points are calculated. Most of the selected feature points are related to the mouth, nose, eye, eye brow.



(a) (b)

Fig. 1 (a) 18 selected feature points (b) Example measurements of proposed model.

The Fig.1 (a) and Table.1 shows the selected 18 feature points and description of the feature points of the propose method respectively. The proposed distance measurement among the selected facial feature points is represented in Fig.1 (b).

TABLE I
DESCRIPTIONS OF SELECTED FEATURE POINTS

Point No.	Points Description
1	Top of the head
2	Left eyebrow outer corner
3	Left eyebrow inner corner
4	Right eyebrow inner corner
5	Right eyebrow outer corner
6	Left eye outer corner
7	Left eye inner corner
8	Right eye inner corner
9	Right eye outer corner
10	Left most point of face
11	Right most point of face
12	Left nose corner
13	Top of the nose
14	Right nose corner
15	Left corner of the mouth
16	Middle of the mouth
17	Right corner of the mouth
18	Tip of the chin

There are elevens distances respect to horizontal axis and five distances respect to vertical axis on the facial image are represented in this section. The descriptions on horizontal and vertical distances of selected feature points are shown in Table II and Table III respectively.

The selected 18 feature points of a facial image from A to R are shown in Fig.1 (b). According to Fig.1 (b), we have assigned alphabet horizontally and selected horizontal points to calculate horizontal distances for establishing relationship among the distances first. The horizontal distances and their relationship according to Fig.1 (b) as follows: BC, DE, FG, HI, FI, GH, CD, LN, LM, OQ and JK are distances of the horizontal selected points on a face. Respect to the calculated distances we establish relationship among these feature distances, where

$$BC = DF \text{ and } FG = HI$$

also,

$$BC / FG = 1.618 \text{ , } GH / CD = 1.618$$

$$FI / OQ = OQ / LN = LN / LM = 1.618$$

TABLE II
HORISONTAL DISTANCE BETWEEN THE FEATURES POINTS

Direction	No.	Features	Definition
Horizontal	1	Width of left eyebrow	$wleb = x_C - x_B$
	2	Width of right eyebrow	$wreb = x_E - x_D$
	3	Width of left eye	$wle = x_G - x_F$
	4	Width of right eye	$wre = x_I - x_H$
	5	Eye outer cornet distance	$eoc = x_I - x_F$
	6	Eye inner cornet distance	$eic = x_H - x_G$
	7	Eyebrow inner cornet distance	$ebc = x_D - x_C$
	8	Nose corner distance	$ncd = x_N - x_L$
	9	Nose corner and middle points distance	$ncmpd = x_M - x_L$
	10	Width of mouth	$wom = x_Q - x_O$
	11	Width of the face	$wof = x_K - x_J$

TABLE III
VERTICAL DISTANCE BETWEEN THE FEATURES POINTS

Direction	No.	Features	Definition
Vertical	1	Top of head and chin points distance	$thcd = y_R - y_A$
	2	Top of head and nose middle points distance	$thnmd = y_M - y_A$
	3	Nose and mouth middle points distance	$nmmd = y_P - y_M$
	4	Mouth middle and chin points distance	$mmcd = y_R - y_P$
	5	Nose middle and chin points distance	$nmcd = y_R - y_M$

According to these relationships Fig 2 shows the selected three horizontal distances like FG, GH, OQ are enough to calculate remained seven distances those are related to other's selected feature points. In this study we have considered OQ from LN or OQ.

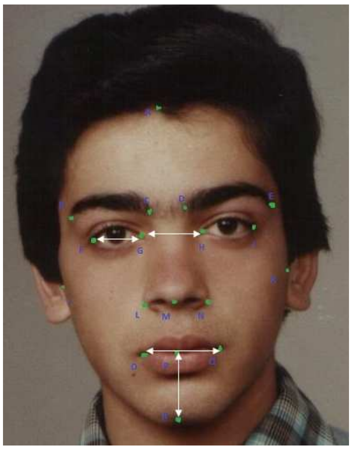
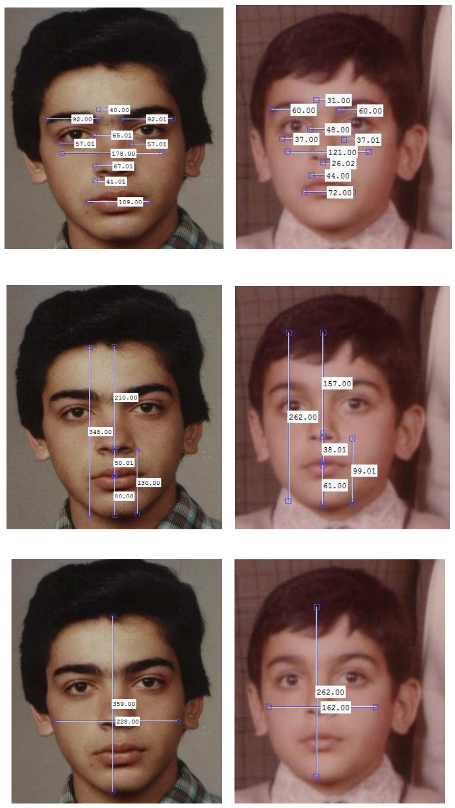


Fig. 2 Finally selected and used feature distances and points from intra-feature distances relationships

On the other hand there are five vertical distances calculated from the selected feature points and relationship among the distances as follows: AR, AM, MP, PR, and MR are distances between selected vertical feature points.



(a) (b)

Fig. 3 Measured Horizontal and Vertical distance, Height and width of face of a boy in (a) age 14 and (b) 9 years old

Where,

$$AR/AM = AM/MR = MR/PR = PR/MR = 1.618$$

Fig.2 shows that the final considered vertical desistance is PR, We have also discovered that the relationship between height and width of face exist as follows.

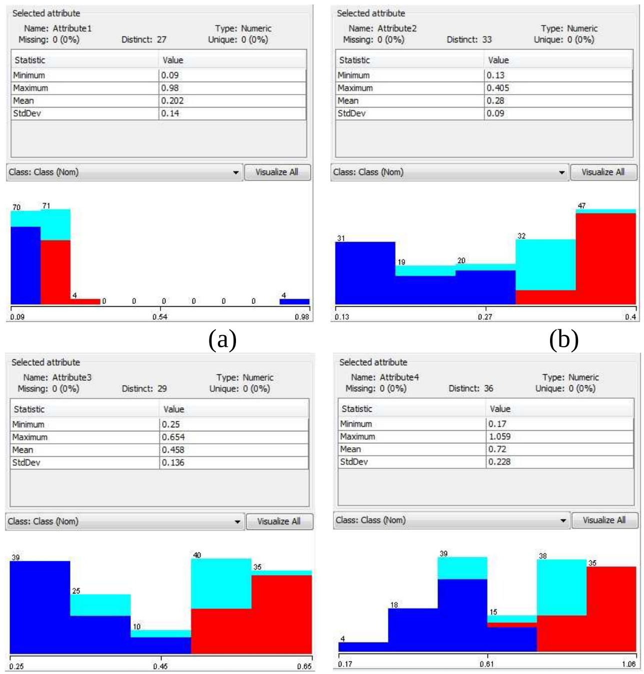
$$AR/JK = 1.618$$

Among the five vertical distances only one distance is calculated between middle mouth points to chin point. Other's distances are calculated from the represented mathematical relationships among the selected vertical feature points. Among the selected 16 distances and from established relationships among the selected feature points, we optimized feature points and finally used only eight points instead of 16 points. As the selected facial features distance are follows a mathematical relationship. Finally, only four feature distances FG, GH, OQ, and PR are used to classify of age in this study. In Fig 3 (a) and (b) shows horizontal, vertical distances and face height and width relationship of a person for 14 years and 9 years respectively.

According to the relationship mentioned above, it is clear that four feature distances are enough to calculate all the others distances for facial image to extract the desired features according to this proposed method. Finally, Instead of eighteen feature points we used only eight feature points in this study. The main concern of this paper is to optimization of facial feature point by establishing a mathematical relationship among facial feature and used optimize feature point for age classification. We have used only four feature distance for age classification that represented in Fig.2. The next paragraph represents effective experimental study of this proposed feature optimization method.

IV. Age Classification Using Optimized Facial Features

Matlab-7.9 and WEKA 3.6.3 are used in this study under Windows-7 environment on Intel® Core™ 2Duo CPU E7200 @ 2.53GHz (2CPUs) desktop with 4096MB RAM. In this section age classification method is discussed in details respect to above mathematical facial features relationship method as an effective application of this proposed optimize facial feature reduction system. We have collected final facial datasets from FG-NET Aging Database [22], which contains 1,002 face images from 82 subjects. For this case study, around 150 faces for 50 persons are considered, whose age ranges are from 3 to 45 years. Class 1 represents age range 1 – 10. Class 2 represents age range 11 – 23. And class 3 represents ages above 24.Firstly; selected 8 facial feature points are marked with green points in final facial image database. We have marked with selected eight green points with identity due to calculate the distances perfectly. Matlab-7.9 is used to calculate the Euclidean distance between the selected mark points. Secondly, calculated four feature distances for individual person are stored in a excel file as csv format. The excel file contains around 600 calculated facial feature distances. Individual distance is considered as an attributes of final excel file. Here we are representing attributes characteristics in the following Fig 4.



(a) (b) (c) (d)

Fig. 4 Individual four facial feature distance characteristics

Finally, SVM-SMO algorithm is applied to the final data set to classify data according to age using WEKA machine learning tools.

V. Results and Discussion

All experiments have been made using SVM-SMO algorithm from WEKA machine learning loots developed in the JAVA language. The results for age classification using WEKA of this propose system is as follows: number of instances: 149, Test mode: 10-fold cross-validation, Time taken to build model: 0.02 seconds.

```
=== Summary ===
Correctly Classified Instances         143               95.9732 %
Incorrectly Classified Instances         6                4.0268 %
Kappa statistic                          0.9384
Mean absolute error                      0.2312
Root mean squared error                  0.2881
Relative absolute error                 53.305  %
Root relative squared error             61.88   %
Total Number of Instances              149

=== Detailed Accuracy By Class ===
               TP Rate   FP Rate   Precision   Recall  F-Measure   ROC Area  Class
                 0.935     0         1          0.935     0.967      0.995    Class1
                 1         0.021     0.963      1         0.981      0.99     Class3
                 0.943     0.035     0.892      0.943     0.917      0.954    Class2
Wght Avg.        0.96      0.015     0.962      0.96      0.96       0.983

=== Confusion Matrix ===
  a  b  c   <-- classified as
 58  0  4 |  a = Class1
  0 52  0 |  b = Class3
  0  2 33 |  c = Class2
```

Fig. 5 WEKA outputs for age classification

According to the result it represents around 96% accuracy with correct classification and 4% incorrect classification. From the confusion matrix it can be seen that around 58 belongs to class1 and 4 miss classified. Around 52 classified as class2, 33 classified as class3 and miss-classified 2 shows in Fig 5. The main advantage of this proposed method is reduction of time complexity and also it is required less memory with respect to other proposed method.

VI. CONCLUSION AND FUTURE WORKS

In this paper, we have proposed optimized facial feature based age classification model by establishing mathematical relationships among selected feature points due to reduce the computational time. It is also discovered that four distances calculation among selected facial feature points is enough to calculate other twelve horizontal and vertical distances among 18 feature points. As selected features points are related to mouth, eye, eyebrow, and chin so it is easier to detect from facial images. The relationship between height and width of a face is also represented. The main goal of this research is find out whether a conclusion can be arrived at as to how the appearance of a face changes due to age progression of a human. Therefore, in order to accomplish this target, this research used an approach of classified the exacted facial feature distances using SVM- SMO algorithm and finally, classifier shown around 96 % accuracy. The experimental results shows that the propose system is robust and accurate to age classification. This research was conducted only for the FG-NET database for age classification. Furthermore, this methodology which happens in a similar way can be applied to draw conclusions on the aging process in the facial images for each and every ethnic group based on the different age, and various facial expressions. Automatic facial feature point's detection and extraction will be applied to make propose system more perfect and automatic in the future. Finally, we are going to apply this propose facial feature measurement system to design 2D or 3D facial model perfectly and robustly in the near future.

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