

***Clustering of Human Face images with
different rotation angles***

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Abstract

The aim of this paper is to classify the different human face images in specific clusters such that the different face images for any given person will be compiled in one cluster, whereas the different face images of other persons will be set in other clusters. For each person at least five different face images are taken by choosing different rotation angles. We proposed three algorithms, the first algorithm used to determine the adaptive neighborhood for each individual, the second one used to prepare the data of the studied population before the implementations, and the third is an automatic clustering algorithm. Our proposed algorithms were applied on different face images of many persons which were taken from the Iraqi population and the ORL database of many persons. We obtained a good classification results with small rate of error. This research is implemented by using Pentium (4) PC and MATLAB 6.5.

1-Introduction

In our real life, we can recognize different human beings by looking at their faces. To identify an individual, we look at the external faces characteristics. We recognize many faces after several years of separation by comparing their faces outlines characteristics [1,2,3].

The evolution in computer sciences aided the researchers to recognize human beings from their faces by using different techniques in the fields of image processing, face recognition, and clustering [4,5,6,7]. For example, If we put many face images with different rotation angles for a certain person with hundreds face images of other persons, we can recognize these images from the other face images easily, that is because the face images of any person will still preserve his common characteristics in spite of the variation in these images which are caused from the horizontally and vertically rotation by a specific degree. This process caused the clustering of the images of any person in one cluster with small probability of an error ratio.

2- Digital Image processing (DIP)

DIP is one of the important fields in computer science that is concerned with the computer processing of images. These images come from many different sources such as digital cameras, scanners and satellite sensors. They are stored as a file of a specific format. In general, the purpose of digital image processing is to enhance or improve the image in some ways, or to extract information from it [4].

Different approaches are used to represent the image on computer systems such as binary images, gray-level images or color images; we will apply the gray-level images in this paper.

The 2-D continuous image may be divided in N rows, and M columns. The intersection of a row and column is called a pixel. The value assigned to every pixel is the average of the brightness in that pixel rounded to the nearest value. The process of representing the amplitude of 2-D signal at a given pixel determines the gray-level of that pixel.

3- Face recognition

Face recognition is an example of advanced recognition. The process is influenced by several features such as shape, reflectance, pose, occlusion and illumination which make it difficult. A human face is an extremely complex object with features that vary over time, especially the skin which cover human face which determines the important features of the face. It should be quite clear that human face is more difficult to model, and recognize than most industrial parts, but integration of features in recognition of faces has a beneficial effect on robust classification [7].

Human faces are very interesting as objects of picture analysis for several reasons [3]:

- They are not artificial and not simple as the geometrical shapes such as cubes, or pyramids which have been used in the visual sense analysis of hand-eye projects.

- A face has many component substructures such as: eyes, nose, mouth, chin, and so on, which are proper for "context of the face ". These components are distributed with a certain permissible range, whose cultural relations can be correctly grasped by the concepts of picture structure.
- Lines in the face are very difficult to define, difficult to extract and are not always straight.
- The variety of human face images is as large as the human family.

The purpose of this research is to have a good probability to create a special cluster for the different face images of each of the given persons and this cluster determines the common features of his real face.

4-1 Clustering Techniques

Clustering is a popular unsupervised pattern recognition technique which partitions the input population of size N into M clusters (regions) based on some similarity or dissimilarity metrics [8,9,10] .

The classification technique had been applied for the first time in 1753 by Adanson [11] in the biological field in order to classify the animals and plants. In 1963 Sokal and Sneath [12] had studied this technique in the field of the numerical taxonomy.

After the evolution in the hardware and software of the computer sciences, the clustering analysis has been applied in different fields such as image classification, pattern recognition, image segmentation and classification of animals and plants [12-17].

4-2 Mathematical properties of clusters

Let POP be a population (space) of N individuals. We can represent POP as follows:

$POP = \{ ind^{(1)}, ind^{(2)}, \dots, ind^{(N)} \}$, where $ind^{(i)}$ is any individual of POP.

Let POP is partitioned into M clusters C_1, C_2, \dots, C_M such that any individual $ind^{(i)} \in POP$ must be assigned to one cluster of C_1, C_2, \dots, C_M , where $i \in \{1, \dots, N\}$

These clusters have the following properties:

1. $\forall i \in \{1, 2, \dots, M\}, C_i \neq \phi$.
2. $C_i \cap C_j = \phi$, Where $i, j \in \{1, \dots, M\}$, and $i \neq j$.

3. $\cup_{i=1}^M C_i = \text{POP}$.

5- Neighborhoods

Neighborhood operation plays a key role in modern digital image processing and clustering techniques. In this paper we have used different types of neighborhoods for given images such as the K_nearest, the R and the adaptive neighbors.

5-1 The K-nearest neighbors

We can recognize the 4_ connected neighbors and the 8_ connected neighbors in the rectangular sampling and the 6_ connected neighbors in the hexagonal sampling [5]. In general, the K_nearest neighbors means that for each individual in the studied population we must determine the K individuals that must be the nearest with respect to the tested individual [22]. In the K_nearest neighbors, the number of neighborhood elements for each individual in the studied space is an integer constant.

5-2 The R-neighbors

From the literature review, we found that there exists another type of neighborhood which has not always constant number of neighbors [18,19].

In this case, the number of neighbors for each individual of the studied population depends on the real location of this individual with respect to the other individuals. So the real structure of the studied individuals has influence upon the determination of the number of neighbors for each one. To determine the neighborhood for each individual, we can choose a threshold (R), and each individual whose distance is less than R must be put in the neighborhood of the tested individual. Let X be any individual of studied population, we take a circle (sphere) whose center is X and radius is R. Therefore the neighborhoods of X in R_level will contain all the individuals in that population that are laying only in the interior region of that circle (sphere), we usually call this type of neighboring is *R_neighborhood*. Mathematically, let R be the value of the threshold, and X be any individual in the studied population, we can define the R_neighborhood of X as follows:

$R_neighborhood(X) = \{Y \in \text{POP} \mid d(X,Y) < R\}$ where d is a distance measure.

5-3 The adaptive-neighborhood

From our experiments, we notice that if we take a constant threshold for all the studied individuals, we may get good results, but these results may not be the best. This is especially in the case where the real structure of the studied data contains many groups, where the individuals of some groups are distributed in small region while the individuals of the other groups are located in a large region.

In order to solve this problem, we proposed an adaptive threshold such that each individual of the studied population has its special threshold value. We applied hybrid technique which uses the notions of K_nearest neighbors and R_neighborhood. The following algorithm was used to determine the adaptive_ neighborhood of each individual of the studied population.

5-4 Algorithm-1: Determination of the adaptive_ neighborhood

For each face image X of the studied population do the following:

Step [1]: Compute its Euclidean_differences with the other population

individuals by using the template matching approach.

Step [2]: Sort the Euclidean_difference of X with respect to the other

individuals in ascending order.

Step [3]: Choose a positive integer K which determine the K_nearest

individuals for X.

Step [4]: Compute the K_Euclidean_ differences average of X as follows:

$$\text{Average Difference}(X) = \sum_{i=1}^k d(X, Y_i) / k$$

In this paper we used the adaptive_eighborhood which gave us an optimal classification in comparison with the types which used a constant threshold R.

6- Types of clustering methods

There are many types of clustering methods. The most famous are:

6-1 Clustering methods in which the number of clusters is given priori

These methods use some types of dissimilarity or similarity measures in order to construct the desired cluster. If the user gives an initial number of clusters which doesn't correspond with the real structure of the given data, then he (she) obtains not optimal classification. Many researchers who applied these methods assert this fact [14,15,20].

6-2 Automatic classification methods

In this type of clustering methods, the number of clusters is not given a priori by the user. The number of clusters is determined automatically through the execution of these methods and this number depends on the real structure of studied data [8,9,15,20 ,21] .The practical application of these methods shows that the best methods of this type are those which applied R_neighborhood or adaptive neighborhood concepts. The number of the obtained clusters depends on the choice of threshold R, or on the choice of each K and R in using the adaptive neighborhood concept. When we apply the R_neighborhood in the clustering method, we noticed that choosing a very large value to the threshold R led to get one and only one cluster, while choosing a very small value R led to get clusters such that each individual on the studied population will construct one cluster with one element. Therefore choosing an optimal value of R will give an optimal classification. The optimal value of R can be determined either experimentally or by using some approaches of computation. We proposed an automatic clustering algorithm by using the adaptive neighborhood concept, where the results of our algorithm depend on the chosen values of K and R.

7 Data preparation

7-1 Samples of the processed images:

In this paper we applied the proposed algorithms on the following face images:-

- 1-Human face images which are taken from the ORL (Olivetti Research Laboratory) database for 10 persons and each one has (5) images with different orientations and with different simple facial expressions.
- 2- Human face images which are taken from the Iraqi persons for 10 persons and for each one we took 5 face images with different rotation angle.
- 3-Merging the images of (1) and (2), and process them by using our algorithms.

The following algorithm is used for the preparation human face images of Iraqi persons.

7-2 Algorithm-2 : preparation of human face images

This algorithm concerned with the preparation of the face images of the real data which are taken from Iraqi population. We studied the human face images for (10) persons, and for each one we took (5) face images with different rotation angles. Before the implementations of these face images by using our clustering algorithm, we must do the following for each face image (X).

Step [1] Use the same camera with the same resolution and zooming, the same fixed distance between the camera and the person, and the same fixed location level (height) for the camera with the respect to the person face.

Step [2] Use the same format. In this research the studied images are of type JPEG.

Step[3] Convert each studied face image into the Gray-level.

8-The proposed clustering algorithm

We propose the following automatic clustering algorithm in which we apply the techniques of template matching of images, and the adaptive-neighborhood .It consists of the following steps:

Algorithm-3: Automatic clustering algorithm

Step [1] Use algorithm-2 in order to prepare the real data.

Step [2] Use algorithm-1 to determine the number of the neighborhood for each face image (X) by using the adaptive neighborhood concept and put these numbers in the vector DEN where the values of DEN for each element X is defined as follows:

$$DEN(X) = \text{cardinal} [\text{Adaptive_ neighborhood}(X)]$$

Step [3] Sort the elements of the vector DEN in descending order, and remove all

individuals for which $DEN(X) = 1$.

Step [4] *Clustering initialization, $i = 0$.*

Step [5] *Let W be the first element in sorted vector DEN . Delete W from studied population POP .*

Step [6] *Creating new cluster, $i=i+1$.*

Create new cluster named cluster (i) and assign the individual W with its adaptive_ neighborhood to the cluster (i).

Step [7] *Test the stopping of the algorithm as followings:*

If $POP = \emptyset$ Then

Output the elements in each cluster (i). Go to Step[9]

Else

Let Z be the first element of the remained elements of POP in

DEN . Delete Z from POP .

Step [8] *Test the assignment of Z to the created clusters as follows*

Let $j \in \{1, 2, \dots, i\}$

If $Z \in \text{cluster}(j)$ Then

Assign the non classified element in the adaptive_ neighborhood (Z) in the cluster(j), and go to step [7]

Else

Let $W = Z$, and go to step [6].

Step [9] *End.*

9- Practical results and discussions

This section contains three experiments and the discussion of their results.

9-1 Experiments

Experiment_1:

In this experiment, we applied our algorithms on the standard face images taken from the ORL database. We randomly chose (10) presences, and for each one there are (5) face images with different horizontally and vertically rotation angles.

The following figure shows a sample of the results of this experiment:

Cluster (1)



Cluster (2)



Cluster (3)



Cluster (4)



Cluster (5)

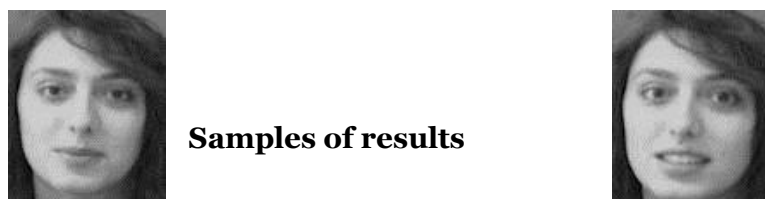


Figure (1):

Samples of results

obtained from experiment_1.

Experiment_2:

In this experiment we processed (10) persons from the Iraqi population. We took five face images for each person with different horizontally and vertically rotation angles, and apply algorithm-2 to prepare each face image in order to decrease the percentage error which may occurred as a result of bad preparation. The studied data contains face images of females and males with different orientation and simple facial expressions. Some of them are with glasses. The following figure shows a sample of the results of this experiment:

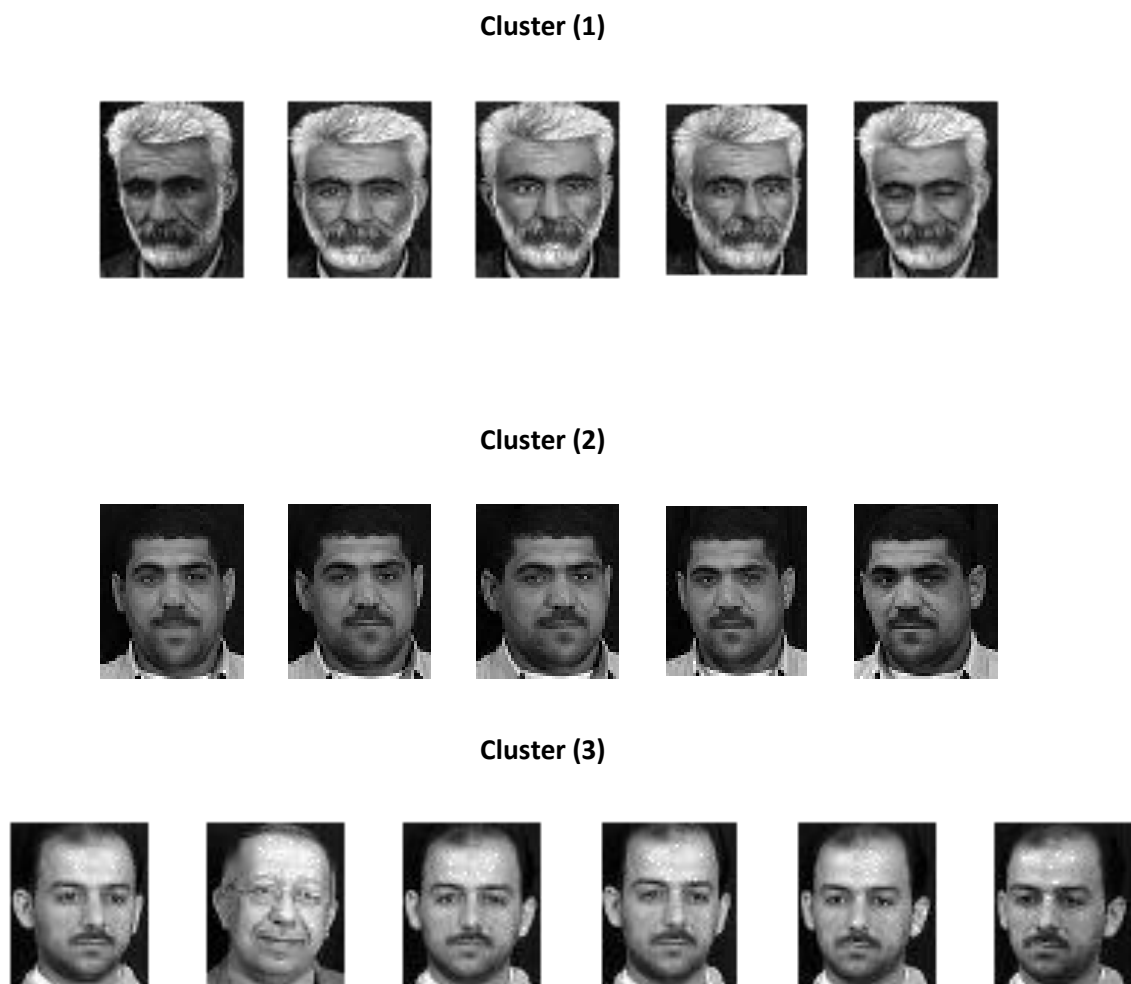


Figure (2): Samples of results obtained from experiment_2.

Experiment_3:

In this experiment, we merge the data of experiment_1 with the data of the experiment_2. Figure (3) shows a sample of the results obtained from this experiment.

Cluster (1)



Cluster (2)



Cluster (3)



Cluster (4)



Cluster (5)



Cluster (6)



Cluster (7)



Figure (3): Samples of results obtained from experiment_3

9-2 Discussion

- 1- For all three experiments, we chose K=5.
- 2- For all our experiments, we firstly implemented the clustering algorithm (algorithm-3) by using a constant value for the threshold R. Secondly, we used adaptive threshold for each tested face image. We noticed that the optimal results which are presented in figures (1,2,3) are obtained by using the adaptive threshold values.
- 3- The following table contains the initial values intervals of the threshold R to get optimal results and the percentage rate intervals of each successes and errors.

Experiment number	POP size	Number of clusters	Execution time	Intervals of threshold R	Intervals of success percentage	Intervals of error percentage
Experiment-1	50	[14-17]	40 sec	[0.9 – 1.05]	[86% - 92%]	[8%-14%]
Experiment-2	50	[13- 15]	40 sec	[0.9 – 1.05]	[78%- 100%]	[0% -22%]
Experiment-3	100	[29 – 31]	92 sec	[0.95 – 1.5]	[79% - 93%]	[7% - 21%]

Table (1): Results of the three experiments.

- 4- For all experiments, we noticed two types of errors:
 - i- In few cases, face images for more than one person lied in one cluster. Cluster-3 of experiment_1 is an example of this error since the last face image belonged to no its real cluster. This type of error occurred as a result of a large variations in the tested face images such as using glasses or making large facial expressions. We compute the percentage error in our experiments according to this type of error.
 - ii- The face images of some persons were partitioned into two clusters with or without common face image. Cluster (5) and cluster (6) of experiment_3 are examples on a common individual (the second

image) and these two clusters concern one person. We notice that the frontal face image comes as a common image between these clusters. Cluster (4) and cluster (5) of experiment_1 are examples to partition the face image of a person into two clusters without common individual. This type of error is obtained as a result of not choosing optimal values for K and R.

5- It is normal that the results of experiment_3 has errors more than experiment_1 and experiment_2. Since the face images of this experiment came from two sources (the ORL database and the Iraqi population).

10- Conclusions

From the obtained results we conclude the following:

- 1-The automatic clustering methods are better than the clustering methods in which the number of clusters is given priori.
- 2-We used an adaptive_neighborhood which merges between the concepts of K_nearest neighbors and the R_neighbors. We assert that the application of the adaptive_neighborhood gives optimal results, because this technique takes the real structure of the studied data into account.
- 3- From the three experiments, we noticed that the different face images of any studied person are often belonging to the same cluster. This means that the face preserves common features in spite of the variation which is caused by different rotation and different facial expressions.
- 4- The optimal results depend on the value of each K and R which are chosen at the beginning of the clustering algorithm. We obtained optimal results in the experiments when K = 5, and R as listed in the table (1).
- 5- From the obtained results, we noticed two types of errors, either more than one person face images lied in the same cluster or the face images of one person partitioned into two clusters with or without common face image.

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