Institute of Advanced Engineering and Science

IAES International Journal of Artificial Intelligence (IJ-AI)
Vol. 1, No. 4, Dec 2012, pp. 161~170
ISSN: 2252-8938

Face Recognition Using Two Dimensional Discrete Cosine Transform, Linear Discriminant Analysis And K Nearest Neighbor Classifier

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Article Info

Article history:

Received Jul 10th, 2012
Revised Oct 4th, 2012
Accepted Oct 26th, 2012

Keyword:

Face Recognition
Discrete Cosine Transform
Linear Discriminanat Analysis
Dimensionality Reduction
K – Nearest Neighbor Classifier
Recognition rate

ABSTRACT

In this paper, a new Face Recognition method based on Two Dimensional Discrete Cosine Transform with Linear Discriminant Analysis (LDA) and K Nearest neighbours (KNN) classifier is proposed. This method consists of three steps, i) Transformation of images from special to frequency domain using Two dimensional discrete cosine transform ii) Feature extraction using Linear Discriminant Analysis and iii) classification using K Nearest Neighbour classifier. Linear Disceminant Analysis searches the directions for maximum discrimination of classes in addition to dimensionality reduction. Combination of Two Dimensional Discrete Cosine transform and Linear Discriminant Analysis is used for improving the capability of Linear Discriminant Analysis when few samples of images are available. K Nearest Neighbour classifier gives fast and accurate classification of face images that makes this method useful in online applications. Evaluation was performed on two face data bases. First database of 400 face images from AT&T face database, and the second database of thirteen students are taken. The proposed method gives fast and better recognition rate when compared to other classifiers. The main advantage of this method is its high speed processing capability and low computational requirements in terms of both speed and memory utilizations.

1. INTRODUCTION

Face recognition [1] has been very active area of research in recent years mainly due to increasing demand in security, law enforcement applications and surveillance. Face recognition is one of the challenging problems in research, till now there is no unique solution for all face recognition problems. But everyone accept that the face recognition system is good, if it has less computational complexity, good recognition performance, occupies less memory and has good generalization capability. In any Face Recognition system Dimensionality Reduction and Feature Extraction are very important aspects. Face images though small in size are having large dimensionality, this leads to very large computational time, complexity and memory occupation. The performance of any classifier mainly depends on high discriminatory features of the face images [2] – [3].

In this method Two dimensional Discrete Cosine Transformation with LDA is used for dimensionality reduction and feature extraction. When dimensionality of the face images is high, Linear Discriminant Analysis is not applicable. To resolve this problem a combination of two dimensional Discrete Cosine Transform and LDA methods are used. Two dimensional Discrete Cosine Transform gives discriminant features of the images of dimensionality 100 for first database and 16 for the second database, which are applied to LDA. LDA searches the directions for maximum discrimination of classes in addition to dimensionality reduction and finally produces image features of dimensionality 39 for first database and 12 for second database. K Nearest Neighbor Classifier classifies the images based on their LDA features.

The rest of this paper is organized as follows: Section 2 discusses DCT computation on face images. Section 3 discusses the LDA. Section 4 describes the K Nearest Neighbor Classifier. Section 5 shows simulation results. Section 6 presents concluding remarks, and discusses possible modifications and improvements to the system.

2. DISCRETE COSINE TRANSFORM

The discrete cosine transform is widely used algorithm in different applications particularly in data compression. Face images have high correlation and redundant information which causes computational burden in terms of processing speed and memory utilization. The DCT has the property that, it can concentrate most of the visually significant information of the face image in just a few coefficients. These coefficients can be used as a type of signatures for the face images that are useful for face recognition tasks [4] – [6]. Since lower frequencies are more visually significant in an image than higher frequencies, the DCT discards high-frequency coefficients and quantizes the remaining coefficients. This reduces data volume without sacrificing too much image quality [6] - [8], [16].

The DCT of an M × N gray scale matrix of the face image *f (x, y)* is defined as follows:

$$T(u,v)=\sum_{x=0}^{M-1}\sum_{y=0}^{N-1} f(x,y)\alpha(u)\alpha(v)\times\cos\left[\frac{(2x+1)u\pi}{2M}\right]\cos\left[\frac{(2y+1)v\pi}{2N}\right] \quad (1)$$

Where $\alpha(u)=\sqrt{\frac{1}{M}}$ for u = o

$= \sqrt{\frac{2}{M}}$ for u = 1,2,…,M-1 (2)

The values T (u, v) are the DCT coefficients. This technique is efficient for small square inputs such as image blocks of 8 × 8 pixels.

3. LINEAR DISCRIMINANT ANALYSIS (LDA)

Linear discriminant analysis (LDA) finds the directions for maximum discrimination of classes in addition to dimensionality reduction [10] – [15]. This is achieved by maximizing the ratio of the magnitude of between – class scattering matrix to the magnitude of within – class scattering matrix. Within – class scattering matrix is defined as

$$S_W=\sum_{i=1}^{C}\sum_{x\in\{c_i\}}(x-m_i)(x-m_i)^T \quad (3)$$

Where **C** is the number of classes, $\mathbf{C_i}$ is a set of data within the i th class, and m_i is the mean of the i^{th} class. The within class scatter matrix represents the degree of scatter within classes as a summation of covariance matrices of each class. A total scatter matrix $\mathbf{S_T}$ and a total mean **m** are defined as

$$S_T=\sum_x (x-m)(x-m)^T \quad (4)$$

and $$m=\frac{1}{n}\sum_x x=\frac{1}{n}\sum_{i=1}^{C} n_i m_i \quad (5)$$

Where n is the number of total samples and n_i is the number of samples within the i^{th} class. Then we get $$S_T=S_W+\sum_{i=1}^{C} n_i(m_i-m)(m_i-m)^T \quad (6)$$

The second term in the above equation is defined as a between – class scatter matrix $S_{B,}$ so that the total scattering matrix is the sum of the within – class scatter matrix and the between – class scatter matrix.

$$S_B = \sum_{i=1}^{C} n_i (m_i - m)(m_i - m)^T \tag{7}$$

and $$S_T = S_W + S_B \tag{8}$$

The between – class scatter matrix represents the degree of scatter between classes as a covariance matrix of means of each class. The projection of d – dimensional input samples onto r – dimensional space (r << d) is done by $y = W^T x$ Transformation matrix W is obtained in such a way that it maximizes the criterion function J(W) given as

$$J(W) = \arg\max_W \left| \frac{W^T S_B W}{W^T S_W W} \right| \tag{9}$$

The columns of optimal W are the generalized eigen vectors w_i that correspond to the largest eigen values in $S_B W_i = \lambda_i S_W W_i$

4. K - NEAREST NEIGHBOUR RULE

Nearest neighbor rule is one of the most popular and old rule. Given C classes, ω_i, i = 1, 2, … , C, and N training points, x_i , i = 1, 2, … , N, such that a point x ε R^l in the l – dimensional space, with the corresponding class labels. Given a point x whose class label is unknown, the task is to classify x in one of the 'c' classes. The rule consists of following steps:

i) Among the N training points, search for the k neighbors closest to x using a distance measure (Euclidean, Mahalanobis). The parameter k is user – defined but it should not be a multiple of C. That is, for two classes k should not be an odd number.
ii) Out of k – closest neighbors identify the number k_i of the points that belongs to class ω_i. Obviously $\sum_{i=1}^{C} k_i = k$
iii) Assign x to class ω_i, for which $k_i > k_j$, $j \neq i$. In other words, x is assigned to the class in which the majority of the k – closest neighbors belong.

For large N (in theory N → ∞), the large k is the closer the performance of the KNN classifier to the optimal Bayesian classifier is expected to be. However for small values of N, a larger k may not result in better performance.

A major problem with the KNN classify, as well as with its close relative the KNN density estimator is the computational complexity associated with searching for the k nearest neighbors, especially in high dimensional spaces. This search is repeated every time a new point x is classify, for which a number of suboptimal techniques have been subjected.

5. NUMERICAL RESULTS

5.1. Simulation Results – 1

The Proposed new face recognition method was applied on two different databases. The first database is AT&T (ORL) face database, containing 40 subjects and each subject having 10 images of size 112 × 92 and the second is student's database consists of thirteen students face images each with 5 images of different facial expressions, poses and background conditions. For simulations and proposed method evaluation Matlab is used on a PC with Intel(R) core (TM) 2 Duo CPU and 2 GB RAM. The obtained results for tow databases are given separately as follows.

5.1.1. AT&T (ORL) Face DATABASE

Before doing simulation size of the face images are reduced to 10 × 10 using matlab code. These reduced size images are used as inputs to the DCT and it gives 100 features per image as output. But simulation results shows that 50 features per face image gives maximum recognition hence only 50 features per image are used for further use. The graph drawn between Image size vs recognition rate is shown in figure 1 and the graph drawn between number of features per sample (Sample dimension) vs recognition rate is shown in figure 2. From these figures it is clear that Image size of 10×10 with sample dimension 35 is giving maximum recognition rate of 100%.

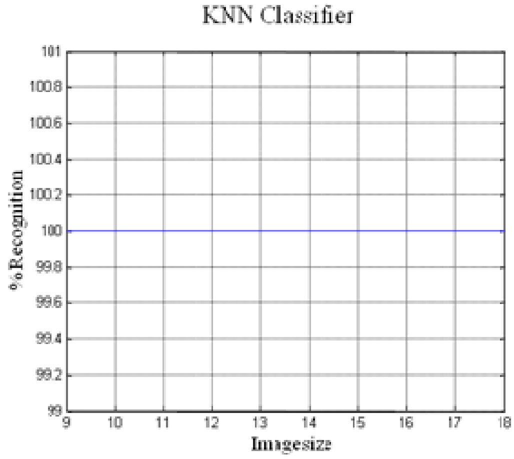

Fig – 1, Plot of Recognition Rate verses image size

The feature vectors of the face images obtained at the output of the two dimensional DCT are given to the LDA as input. LDA produces 39 most discriminate features per image that leads better classification. The discriminant features of the face images produced by the LDA are given to the K Nearest Neighbors Classifier for classification. K Nearest Neighbors Classifier (KNN) gives fast and accurate classification of face images hence it can be used in real – time applications.

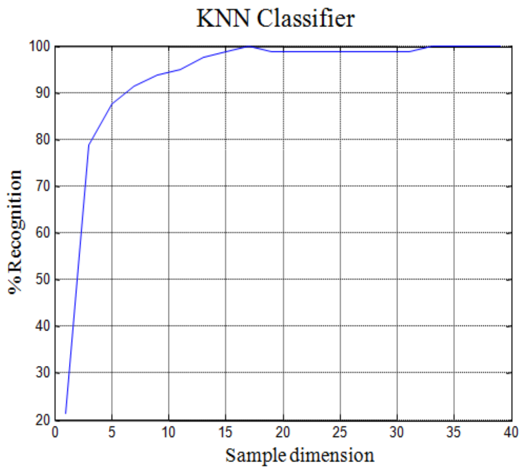

Fig – 2, Plot of Recognition Rate versed Sample dimension

AT&T (ORL) face database consists of 40 subjects and each subject having 10 images of size 112 × 92 with different facial expressions, poses and background conditions. In the simulations three different combinations of training and test images from the database are used as

i) 280 training images and 120 test images
ii) 320 training images and 80 test images
iii) 360 training images and 40 test images

Simulation was done with the above three sets of data and the obtained results are summarized in the tabular form as shown in table 1.

No of features per image used in DCT as input = 100
No of features per image used in LDA as input = 50

No of features per image used for classification = 35

For 320 training samples, the average training time taken is 6.7240 sec. For 80 test samples the average testing time taken is 0.3120 sec that means 0.0039 sec time is taken for the testing of one sample. This is very small classification time when compare to any other classifier having comparable recog nition rate to that of KNN classifier.

5.1.2. Students Database

This database consists of 13 classes and each class consists of 5 samples. One sample of each class is shown in figure 3. Before doing simulation the size of the face images are reduced to 4 × 4 using matlab code. These reduced size images are used as inputs to the two dimensional DCT and it gives 16 features per image as output. But simulation results shows that 4 features per face image gives maximum recognition hence only 4 features per image are used for further use. The graph drawn between Image size vs recognition rate is shown in figure5 and the graph drawn between number of features per sample (Sample dimension) vs recognition rate is shown in figure6.

No of classes	No of Training Samples	Samples per class	No of Test Samples	Samples per class	Recognition Rate (Max)
40	280	7	120	3	99.1667
40	320	8	80	2	100
40	360	9	40	1	100

Table – 1 Recognition Rate for different Training and Test Samples for AT & T Database

No of classes	No of Training Samples	Samples per class	No of Test Samples	Samples per class	Recognition Rate (Max)
13	39	3	26	2	96.1538 (25 out of 26)
13	52	4	13	1	100

Table – 2 Recognition Rate for different Training and Test Samples for Students Database

Fig – 3 One sample from each Class of the Student database

Fig – 4(a) Test Face Fig – 4(b) Recognized Face

From these figures it is clear that Image size of 4×4 with sample dimension 4 is giving maximum recognition rate of 100%. The test face image and recognized face images are shown in figure 4(a) and 4(b).

The feature vectors of the face images obtained at the output of the two dimensional DCT are given to the LDA as input. LDA produces 12 most discriminate features per image that leads better classification. The discriminant features of the face images produced by the LDA are given to the K Nearest Neighbors Classifier for classification.

In the simulations two different combinations of training and test images are used as

i) 52 training images and 13 test images
ii) 39 training images and 26test images

Simulation was performed on the above two sets of data and the obtained results are summarized in the tabular form as shown in table 2.

No of features per image used in DCT as input = 16
No of features per image used in LDA as input = 13
No of features per image used for classification = 4

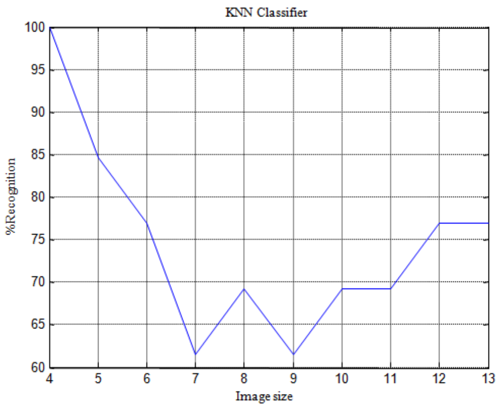

Fig – 5, Plot of Recognition Rate verses image size

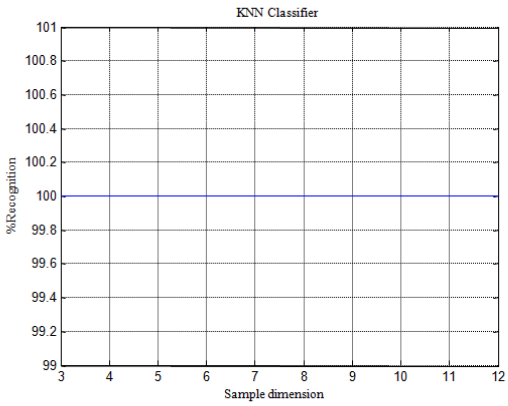

Fig – 6, Plot of Recognition Rate verses Sample dimension

Classifier	No of training samples	Training time(sec)	No of test samples	Test time (sec)	Test time per sample (sec)	Recognition Rate (MAX)
KNN	320	6.7240	80	0.3120	0.0039	100
EUCLEDIAN	320	6.7240	80	9.577	0.1197	100
LINEAR	320	6.7240	80	0.2340	0.0029	98.75
DIAGLINEAR	320	6.7240	80	0.0620	0.00078	98.75
DIAGQUADRATIC	320	6.7240	80	0.0630	0.000788	95
MAHALANOBIS	320	6.7240	80	1.0600	0.01325	95

Table – 3 Comparision of Recognition Rates, Training and Test times of various Classifiers

For 52 training samples, the average training time taken is 1.46 sec. For 13 test samples the average testing time taken is 0.19 sec that means 0.0146 sec time is taken for the testing of one sample. This is very small classification time when compare to any other classifier having comparable recog nition rate to that of KNN classifier.

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5.2. Simulation Results – 2

Finally the performance of the proposed classifier is demonstrated in comparison with Euclidean, Linear, Diagonal Linear, Diagonal Quadratic and Mahalanobis classifiers for two face databases as bellow.

5.2.1. AT&T(ORL) Face Database

For this face database the variation of Recognition rate with Image size and sample dimension for all classifiers are shown in figures 7 and 8. The final observations are put in the following table 3.

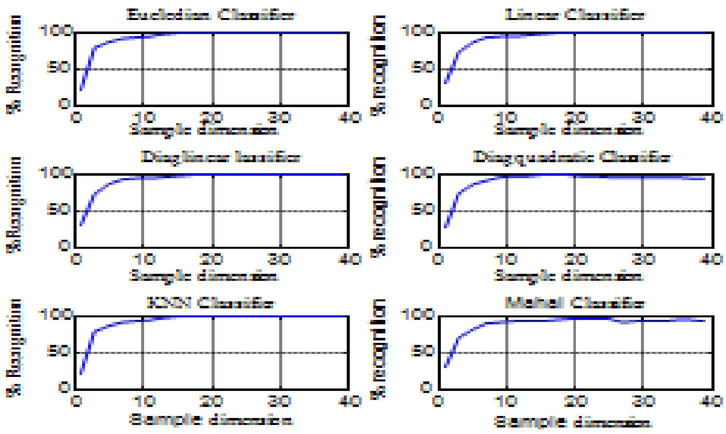

Fig – 7 Plot of recognition rate verses sample dimension for all classifiers

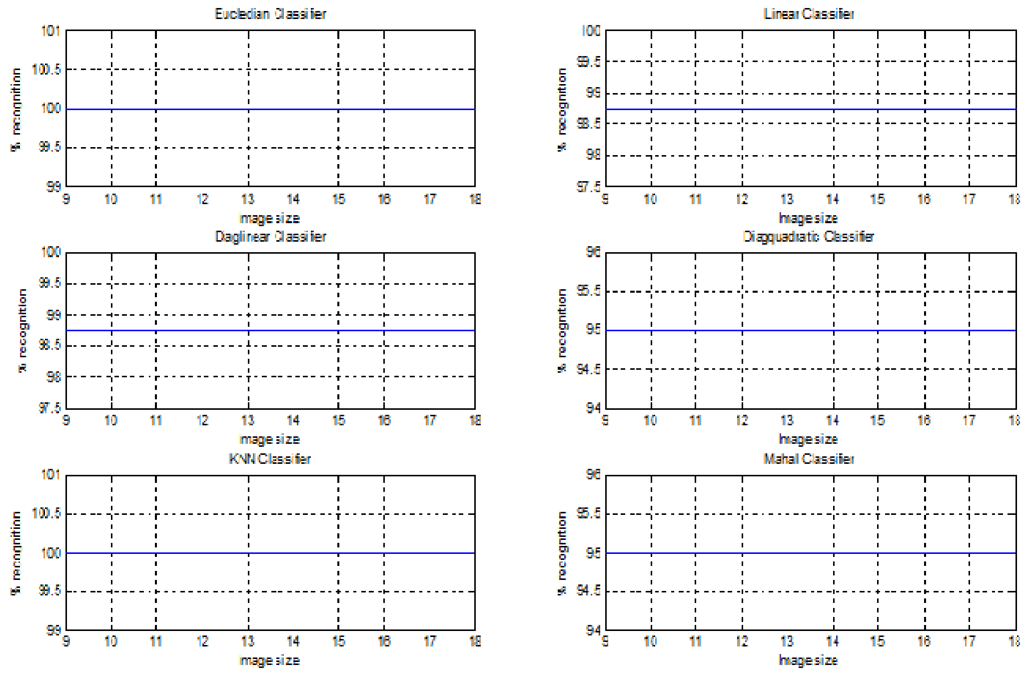

Fig – 8 Plot of recognition rate verses Image size for all classifiers

5.2.2. Students Database

For this database the variation of Recognition rate with Image size and sample dimension for all classifiers are shown in figures 9 and 10.

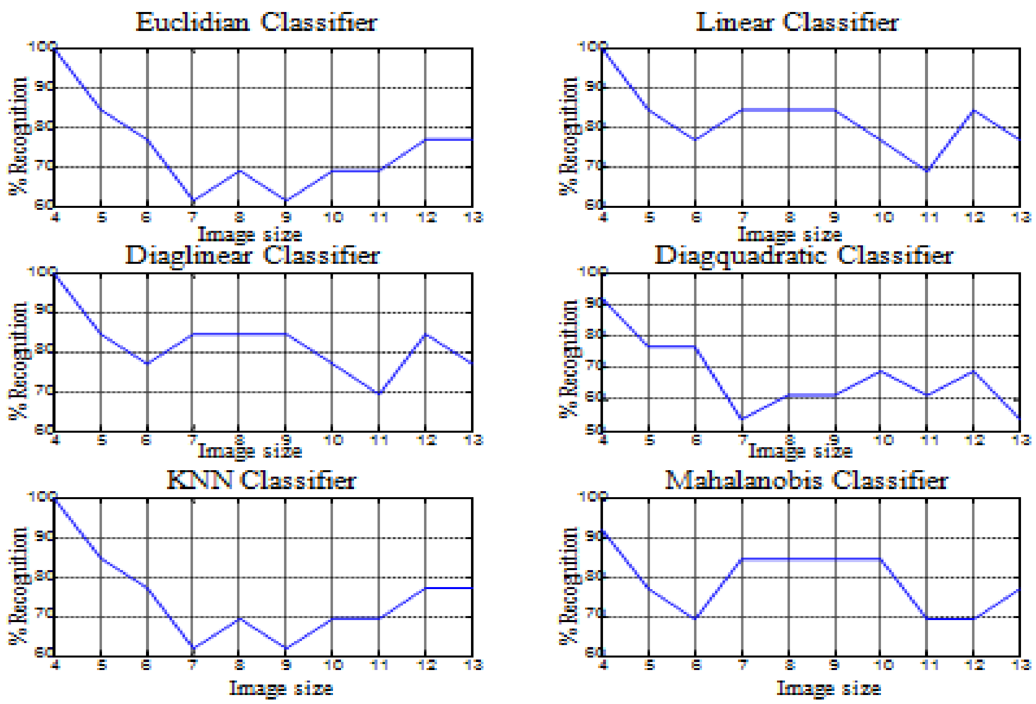

Fig – 9 Plot of recognition rate verses Image size for all classifiers

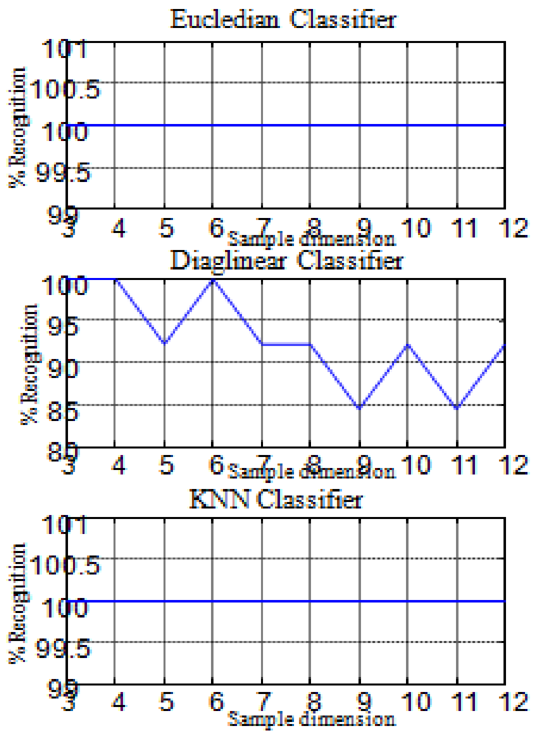

Fig – 10 Plot of recognition rate verses sample dimension for all classifiers

From the information mentioned in the above table 3 and also from the graphs it is very clear that KNN and Euclidian classifiers are having 100% recognition rates. But Euclidian classifier is taking relatively large time for testing when compare to KNN classifier, that means KNN is relatively fast when compared to Euclidian classifiers, this leads the KNN classifier to use in online applications.

6. CONCLUSION

In this paper, a new Face recognition method is presented. This new method is a combination of two dimensional DCT, LDA and K Nearest Neighbors Classifier. By using these algorithms an efficient face recognition method with maximum recognition rate of 100% was proposed. Simulation results using AT & T face database and students database demonstrated the ability of the proposed method for optimal feature extraction and efficient face classification. The new face recognition method can be used in many applications such as security systems and others.

The ability of our proposed face recognition method was demonstrated on the basis of obtained results on AT & T face database and students database. To generalize the method we have to achieve 100% Recognition rate on other face databases and also on other combinations of training and test samples.

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