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A modify Correlation Filters for face Verification

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Abstract

Face verification is an important tool for authentication of an individual and it can be of significant value in security and e-commerce applications.In this paper, a new method for a minimum average correlation energy filter using a reduced number of training imagesto provide high discrimination capability and a sharp detected correlation peaks with shift invariance and variation tolerance characteristics with a high performance rate reached to 95% .The performance of the modified filter was evaluated by calculating the peak to side lobe ratio, the false acceptance ratio, the false rejection ratio and the equal error rate. The computational experiments were done on a (Mat lab 2008) on the FACE 94 database.

Keywords: Authentication, Correlation Filter, Minimum Average Correlation Energy Filter and face verification.

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تعديل مرشحات الارتباط للتحقق من الوجه

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الخلاصة

التحقق من الوجه هي اداة مهمة لمصادقة الفرد ويمكن ان تكون ذات قيمة كبيرة في التطبيقات الامنية والالكترونية . في هذه الورقة طريقة جديدة لمرشح معدل الحد الادنى لطاقة الارتباط باستخدام عدد قليل من صور التدريب لتوفير امكانية التمييز العالية , كشف قمم الارتباط الحادة , خاصية التحولالثابت و خصائص التسامح بالاختلاف مع نسبة اداء عالية وصلت الى 95%.حيث تم تقييم الاداء للمرشح المقترحوذلك بحساب (PSR) , (FAR) , (FRR) و (EER).وقد اجريت التجارب الحسابية في برنامج (MATLAB 2008) على قاعدة البيانات (FACE 94) .

1. Introduction

Correlation filters are widely used in pattern recognition based applications like automatic target recognition and biometric-based recognition systems [1]. A basic space invariant correlation filter is known as the matched spatial filter (MSF) whose impulse response is the complex conjugate of the reference image [2]. The MSF is used to maximize the signal-to-noise ratio if a reference image is present in additive white noise. It works inadequately when there is distortion or scaling of the reference image. The synthetic discriminant function (SDF) filter uses a multiple training set of images of an object made from different orientations of the image. The shortcoming of SDF filters is that they produce a large side lobe and lack sharp correlation peaks. As a result, the SDF filter shows a low discrimination capability [3].A variety ofadvanced correlation filters are available [4].Research has shown that among the correlation filters family the MACE filter has the best results when tested [5].

2. Minimum Average Correlation Energy (MACE) Filter

Mahalanobis et al. [6] proposed the minimum average correlation energy filter MACE filter minimizes the average correlation energy (ACE) of the correlation outputs due to the training images while simultaneously satisfying the correlation peak constraints at the origin. The effect of minimizing the ACE is that the resulting correlation planes would yield values close to zero everywhere except at the location of a trained object, where it would produce a strong peak.

A set of face image are used to train the filter, suppose that we have N facial images from a certain subject. We consider each 2-dimensional image as a $d\times1$ column vector $\boldsymbol{x}_i$(i= 1, 2, . . .,N) by lexicographically reordering the image, where d is the number of pixels. The discrete Fourier transform (DFT) of $\boldsymbol{x}_i$is denoted by $\boldsymbol{X}_i$, and we define the training image data matrix in frequency domain as $X = [\, \boldsymbol{X_1}\ \boldsymbol{X_2} . . . \boldsymbol{X_N}]$. X is a $d \times N$ matrix. Let the vector **h** be the correlation filter (correlation template) in the space domain and $\boldsymbol{H}$be its Fourier transform. The correlation result of the ith image and the filter could be written as

$$c_i(m,n) = \boldsymbol{h}(m,n) \circ \boldsymbol{x_i}(m,n) \tag{1}$$

$= (\mathbf{h}, \boldsymbol{x_i}^{(m,n)})$

Where∘ denotes correlation, and (,) denotes inner product of two vectors. Here$\boldsymbol{x_i}^{(m,n)}$ is a vector obtained by circularly shifting the *ith*training image bym pixels horizontally and n pixels vertically, and reorder it to a 1-dimensionalvector. Keep in mind that **h** and $\boldsymbol{x_i}$ are both 1-dimensional vectors obtained byreordering a 2-dimensional array. Since the correlation actually operates on a2-dimensional plane, here we use two indices, m and n, to indicate the elementsin these vectors. From Eq. (1), we can see that each value in the correlationoutput plane is simply an inner product of the filter and the input image. By Parseval's theorem, the correlation energy of $c_i(m,n)$ can be rewritten as follows using its frequency domain representation $C_i(u,v)$:

$$E_i = \sum_m \sum_n |c_i(m,n)|^2 = \frac{1}{d} \sum_u \sum_v |C_i(u,v)|^2$$

$$= \frac{1}{d} \sum_u \sum_v |H(u,v)|^2 \, |X_i(u,v)|^2$$

$$= \frac{1}{d} h^{+} D_i \, h \tag{2}$$

Where D_i is a $d \times d$ diagonal matrix containing the power spectrum of training image $\boldsymbol{X_i}$, along its diagonal. The superscripts +denote *conjugate transpose*.The objective of the MACE filter is to minimize the average correlation energy over the image class while simultaneously satisfying an linear constraint that the correlation values at the origin due to training images take on pre-specified values stored in vector $\boldsymbol{u}$, where$\boldsymbol{u}= [u_1 u_2 \cdot \cdot \cdot u_N]^T$. i.e.

$$c_i(0,0) = {X_i}^{+} \boldsymbol{H} = u_i \tag{3}$$

The average correlation energy over all training images is

$$E_{avg} = H^{+} D H \tag{4}$$

Where $D = \frac{1}{N} \sum_{i=1}^{N} D_i$

Minimize E_{avg} subject to the constraint, $X^{+} H=u$.The final optimal solution of the MACE filter is obtained in vector form using Lagrange multipliers [6]as given in Eq.(5).

$$H = D^{-1} X(X^{+}D^{-1}X)^{-1} u \quad (5)$$

The performance of the MACE filter increases for training images which are used for filter synthesis. However, the recognition performance decreases for non-training intra-class images [6, 7]. In practice many images of interest have strong low frequency components. Since the MACE filter effectively whitens the spectrum (on the average), it enhances high frequency components. It is therefore sensitive to variation, i.e., to images outside of the training set, as well as to additive (high frequency) noise.It is better that the MACE filter overcomes its limitations and can work well using a reduced number of training images per subject.

3. Proposed Methodology: The methodology can be divided primarily into three majorsteps as follows:

3.1 Hanning window

Prior to computing the DFT, a Hanning window is applied on image as a smoothing windows that can be used to extract the desired information from the DFT spectrum by determining (low frequency) information and remove (high frequency) noisefrom the face image.

Frequencies characteristics of Hanning window have a wide peak with reduced slidelobesas shown figure 1[8, 9, and 10].The Hanning window is a discrete window function given by [11]:

$$w(n) = \frac{1}{2}\left(1 - \cos\left(\frac{2\pi n}{N-1}\right)\right) \quad (6)$$

For $n = 0, 1, 2\ldots N - 1$, where N is the length of the window and w is the window value.

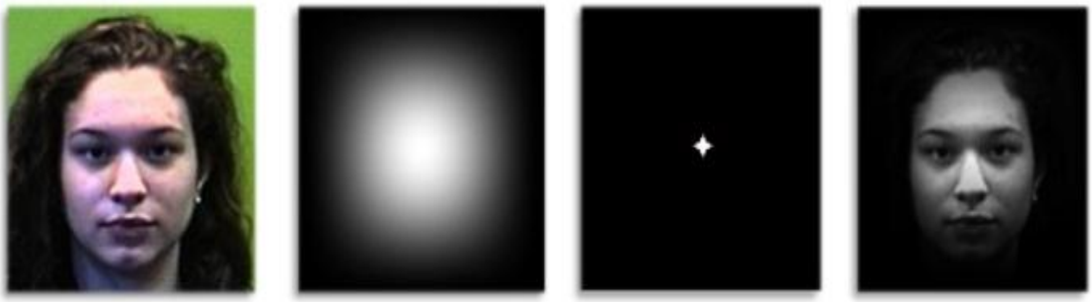


Fig. 1: Application of Hanning window on image: (a) Original image (b) the Hanning windowfunction (c) the logarithmic power spectrum of the Hanning window function (d) thewindowed image

3.2 MACE filter extraction

Only two face training images were utilized to design a single correlation filter for each subject.

3.3 Recognition Process of face images

Recognition is performed by cross-correlating a test image with the designed filter and the obtained correlation output was then used to decide whether it was an authentic image or an impostor image.For authentic the correlation output has sharply peaked with no such for impostors. The recognition process of the face verification using a designed MACE filter is shown in Figure 2.

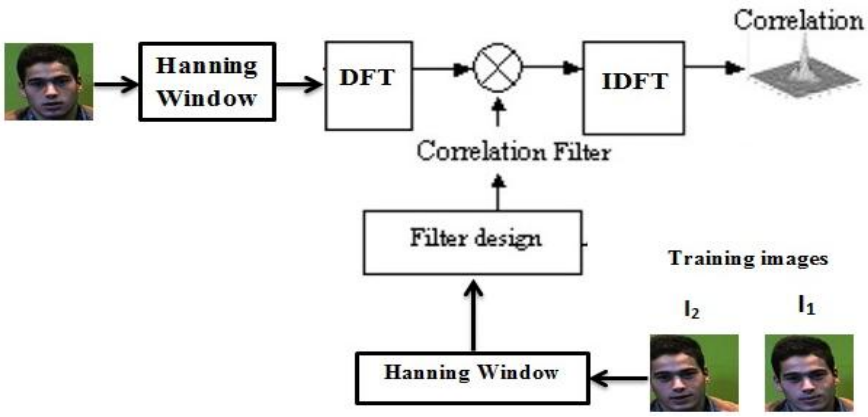


Fig.2: Block diagram for the recognition process using a designed MACE filter

The performance of the proposed technique was evaluated by measuring the peak-to-side lobe ratio (PSR) [12]. The PSR can be defined as:

$$PSR = \frac{\text{peak} - \text{mean}}{\sigma} \quad (7)$$

Where peak indicates the correlation output and the mean and standard deviation (σ) comes from the sidelobe region surrounding the peak region .Figure 3 illustrates how the PSR is estimated. First, the peak is located (shown as the bright pixel in the center of the figure). The mean and the standard deviation of the 20x20 sidelobe region (excluding a 5x5 central mask) centered at the peak are computed. The PSR is the ratio of (peak-mean) to standard deviation as shown in Eq. (7).

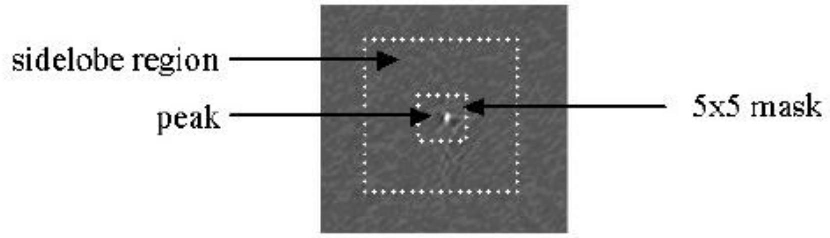


Fig.3: This figure shows how the peak to side lobe ratio (PSR) is estimated.

For a given verification PSR threshold value, the performance can be measured by the false acceptance ratio (FAR) and false rejection ratio (FRR), defined as:

FAR= Number of impostor images having PSR < threshold value

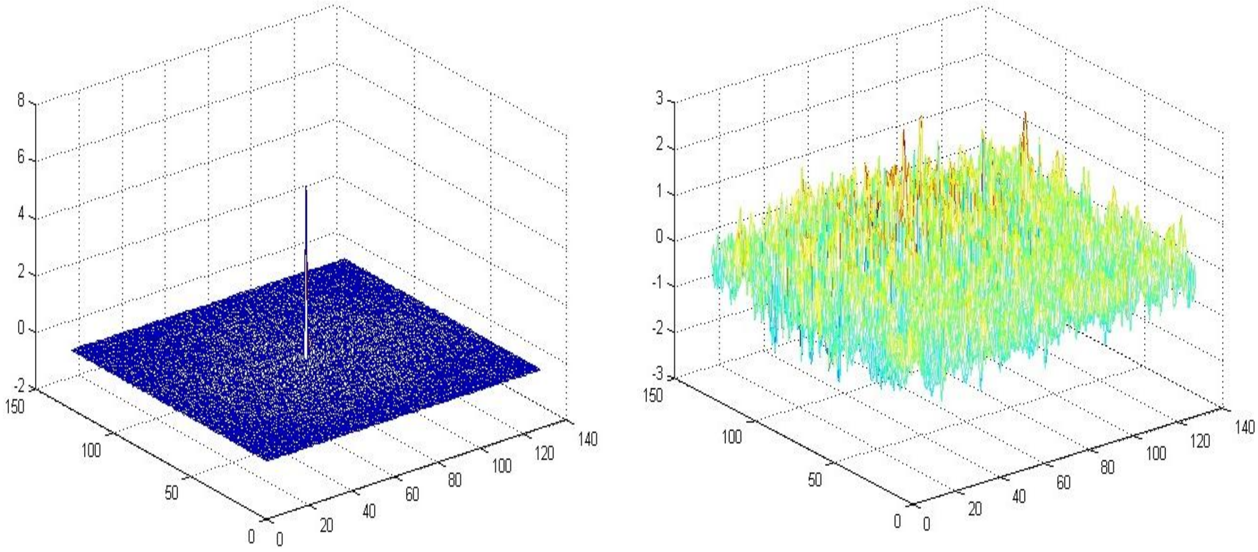
FRR= Number of authentic images having PSR > threshold value

The equal error rate (EER) is the point where FAR and FRR are equal

4. Experiment Results and discussions

A numerical experiment was carried out on a (Mat lab 2008) for the face verification using the correlation filters technique. The performance of the designed MACE filter for each subject was evaluated in terms of PSR and EER on the **FACE 94** image database [13]. The total images of 'FACE 94' are (3,060) where there are 153 persons for each one 20 images were taken. The database contains face images of both genders with considerable expression changes and very minor variation in head turn.

In the present study, a set of 600 face images of 30 subjects which consist of 20 face images of each subject were used. As explained earlier, a single MACE filter is synthesized for each subject using only two training images.The cross correlation for the designed filter and the test images was obtained for 600 images in which 20 images belonged to true class images and 580 images belonged to false class images. The correlation output is shown in Figure 4. A sharp peak was obtained for the authentic images and no such peak for imposter images.



(a) (b)

Fig.4: Correlation outputs when using a MACE filterdesigned for subject A. (a) Input is a face imagebelonging to subject A. (b)Input is a face imagenot belonging to subject A .

The value of PSR was computed using Eq. (7). A large value of PSR was obtained for an authentic face image. A value of PSR less than (<0.01) was obtained for an imposter face image. For the performance evaluation, a graph was plotted between PSR and the number of images.The PSR performance of the proposed MACE filter is shown in Figure 5 for subjects 1 and 2, respectively. The PSR values of authentic images are represented by the lines with circles and imposter PSRs are shown by lines with squares. It is observed from the PSR graph that for all the false class face images (20 x 29 =580) had values of PSR of less than 0.01. The PSR values of the two training images that were used to synthesize the modified MACE filter are shown in the graph as the highest peak values.

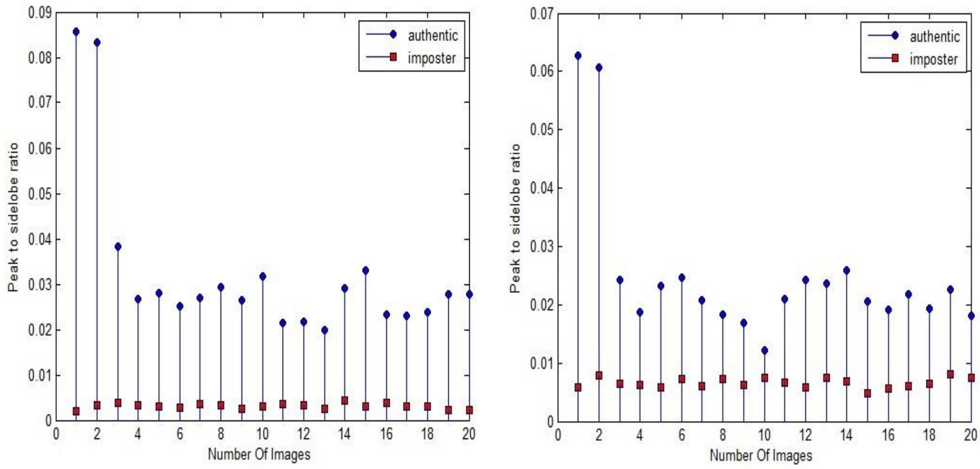


Figure 5: PSR performance for (a) subject 1 (b) subject 2

The performance of the recognition algorithm was further evaluated by calculating the equal error rate. The false acceptance ratio and the false rejection ratio are determined by using the absolute difference of the PSR values. For each subject, a single PSR value was chosen as the reference PSR.The absolute difference of this reference PSR value with the authentic and imposter images was calculated.The absolute difference of the PSR values for the authentic subjects is approximately greater than 0.005 for all the imageswhile for almost all imposter images this value is less than 0.005.

The EER values obtained for the proposed MACE filter are shown in Table 1. The EER were calculated for 14 different synthesized MACE filter using only 2 training images from 20 images for each subject. As shown in Table 1, for twelve subjects the proposed correlation filter gave a zero EER and for subject 7 and subject 13 low values of EER. This indicates that the proposed MACE filter from only 2 training images per subject showed high discrimination capability where the EER for 14 different synthesized proposedMACE filters is 95%.

Table 1:EER calculation for theproposedMACE filter

Subject	FAR, FRR=0	FRR, FAR=0	EER
1	0	0	0
2	0	0	0
3	0	0	0
4	0	0	0
5	0	0	0
6	0	0	0
7	5	1	1
8	0	0	0
9	0	0	0
10	0	0	0
11	0	0	0
12	0	0	0

13	2	6	1
14	0	0	0

5. Conclusion

A MACE filter was designed to verify the efficiency of a face-based recognition system. The proposed correlation filtering technique was demonstrated on the face images of a FACE 94 database. The performance of the proposedMACE filter for face verification was evaluated in terms of PSR and EER. A graph between the PSR values and number of images was plotted and showed good discrimination ability for the face recognition system. The discrimination of face images was also evaluated by EER. Based on the obtained computational experiment results, the proposed filter was able to discriminate by face recognition between true class samples from those that were false.

6. References

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