Correlation Filter based Fingerprint Verification System

Suvarna Joshi
Lecturer
MIT College of Engg.Pune

Dr.Abhay Kumar
Professor
School of Electronics, DA Univesity, Indore

ABSTRACT
Biometrics is an important security tool which can be used for human identification and authentication to offer a higher level of security than conventional identification methods. Among all available biometrics, Fingerprints are a good choice as they are unique to a person. Fingerprint recognition is a complex pattern recognition problem. This paper proposes fingerprint verification based on correlation filters because of their properties like shift invariance, ability to accommodate in-class image variability and closed form expressions. The performance of a specific type of correlation filter called the minimum average correlation energy (MACE) filter [1] has been evaluated using a FVC database.

General Terms
Pattern Recognition, Image processing, Biometrics

Keywords: **Fingerprint Recognition, correlation filter,Minimum average correlation energy**

1. INTRODUCTION
Biometric based recognition or biometric is science of indentifying a person based on his physiciologial and/or behavioral traits(modalities).Physiciologial traits are concerned with physiology of human body and include fingerprint, face, hand geometry, iris, retina, DNA, palm geometry. Behavioral modalities are concerned with behavior of person such as signature, gait, and keyboard typing rhythm. Biometric based authentication systems are having many advantages over traditional token based ,id card or password based verification systems. Passwords can be forgotten, keys and cards may be lost or stolen, but biometrics like face, finger, voice, iris, retina, hand-geometry, etc. are more difficult to compromise. Biometric traits can't be easily duplicated, transferred. Fingerprints are unique to a person and have a long history of usage in criminal identification. Early fingerprint recognition was based on inked fingerprints whereas the current interest is in identifying the fingerprints acquired via digital live-scan devices. Most existing fingerprint algorithms use ridge endings and bifurcations, i.e., minutiae, [2], [3], [4] for fingerprint verification/identification.

MACE-Correlation filters have been applied successfully to automatic target recognition (ATR) [5] problems. Matched spatial filter (MSF) is the basic correlation filter whose impulse response (in 2-D, point spread function) is the flipped version of the reference image. Performance of matched spatial filter is very good for detection of noisy and corrupted images or objects. Results of MSF are poor for images which appears with distortions(e.g.,rotations, scale changes).For detection of each appearance of an object one MSF will be required Due to this for complex pattern recognition MSF are not adequate **.** Hester and Casasent [6] has introduced synthetic discriminant function (SDF) filter to address this problem.. The SDF filter is a linear combination of MSFs where the combination weights are chosen in such a way that the correlation outputs corresponding to the training images would yield pre-specified values at the origin. These pre-specified peak values are often referred to as peak constraints. The peak values corresponding to the authentic (also called the true class) are typically set to 1, and hence this SDF filter was known as the equal correlation peak (ECP) SDF filter. In principle, a single ECP SDF filter corresponds to many MSFs. Object recognition is performed by cross-correlating an input image with a synthesized template or filter and processing the resulting correlation output.The correlation output is searched for peaks, and the relative heights of these peaks are used to determine whether the object of interest is present or not. The locations of the peaks indicate the position of the objects.[7]Although the ECP SDF filter produces pre-specified correlation peak values, it also results in large sidelobes. Sometimes these sidelobes are larger than the pre-specified peak values leading to misclassifications. The reason for this is that ECP SDF design controls only the correlation values at the origin and nowhere else.

2. CORRELATION FILTER

2.1 Basics
Correlation filters are attractive for object recognition due to their shift invariance and distortion tolerance .The basic idea of fingerprint recognition based on correlation filter has been shown in **Figure 1** .

A person's finger enrolment can be done by designing a correlation filer from training images of corresponding finger. A correlation filter is designed in frequency domain. So Design of correlation filters has been done by using Fourier transform of training images. Correlation can be computed more efficiently in frequency domain as compared to image domain because of efficient FFT algorithm. Correlation filter output is analyzed for occurrence of sharp peak and according to that decision is made about whether test image is imposter or genuine.

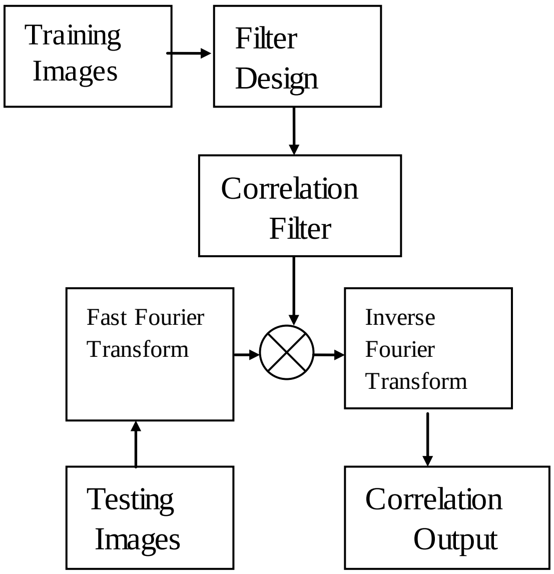

Figure 1 Recognition process by Correlation Filters

Correlation output due to an authentic person have prominent peak. Correlation output for authentic and imposter is as shown in figure 2 and figure 3 .

Correlation output consists of sharp peak if test image is at center with respect to training images. If there is shift in test image with respect to training images then peak present in correlation output also undergoes shift from origin by the same amount due to linear shift invariant property of correlation filters. IF we consider correlation output for an imposter it doesn't have any peak.

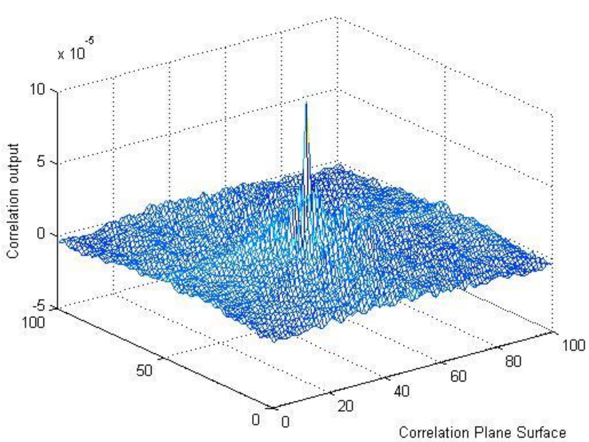

Figure 2 Correlation output for authentic person

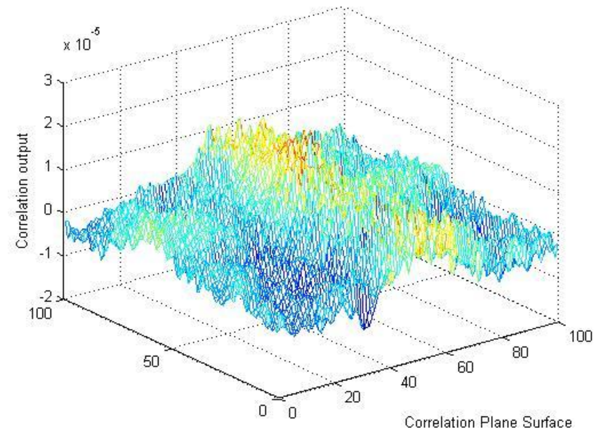

Figure 3 Correlation output for imposter person

2.2 Peak to Side Lobe Ratio

PSR is used as a performance metric for correlation filter. We can take a decision regarding to filter performance for a particular test image on the basis of PSR.Test image will be declared as authenticate if PSR is high. Imposter images will have low PSR values.PSR is good measure for evaluation of performance as compared to correlation peak because of its invariability to uniform illumination changes in test images.PSR is defined by equation 1

$$PSR = \frac{Peak - Mean}{Std\ Deviation} \qquad (1)$$

Peak correlation and its location are obtained using correlation output. Mean and standard deviation are calculated corresponding to window with size S1.A small area around peak S2 removed from S1 for performing this calculation. This is shown in figure 4

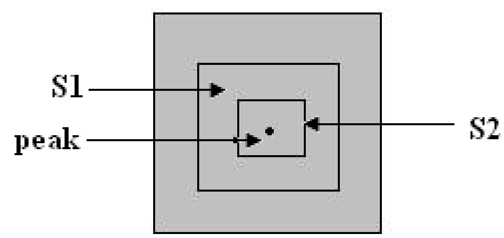

Figure 4 Peak to side lobe ratio computation

3. MINIMUM AVERAGE CORRELATION ENERGY FILTER

ECP SDF provides inadequate performance for Pattern recognition as input noise is not considered in this algorithm. Correlation output may not have sharp peak at origin even though test image is centered with respect to training images. Kumar[8] has proposed a method in which noise tolerance can be built with SDF filter design in the minimum variance synthetic discriminant function (MVSDF) method. But this method only places constraint for occurrence of peak in correlation output and doesn't solve sidelobe problem.A new correlation filter is proposed by kumar et al[9] which is based on idea of minimizing energy of correlation plane values without consideration of origin value. In addition to that this filter places constraints on values at origin for all training images. MACE filter consists of sharp peak for genuine test images.

We assume that there are N training images, and each image of size d x d

Steps to perform MACE filter can be summarized as below

1) Computation of 2D -FT of ith training image

2) Resultant image matrix conversion in single column vector

3) Frequency domain representation of test image by performing 2D-FT of test image.

4) Representation of the 2D filter with column vector

Solution of MACE filter can be given as

$$h = D^{-1}X(X^{+}D^{-1}X)^{-1} u \qquad (2)$$

In above equation u is column vector with N elements which contains the prespecified correlation peak values of the training images and the d x d diagonal matrix D contains along its diagonal the average power spectrum of the training images (i.e., average of the magnitude squares of the columns of X). Note that the synthesized h is a column vector with d elements and the 2-D correlation filter is obtained by reordering the column vector back to a 2-D array. The + symbol represents the complex conjugate transpose .

4. DATABASE DESCRIPTION

Performance of MACE filter has been evaluated on FVC database.FVC database has been collected by BioLab - University of Bologna[10].This database is freely available for researchers. Four different databases (DB1, DB2, DB3 and DB4) were collected by using the following sensors/technologies.

1) **DB1:** low-cost optical sensor "Secure Desktop Scanner" by KeyTronic
2) **DB2:** low-cost capacitive sensor "TouchChip" by ST Microelectronics
3) **DB3:** optical sensor "DF-90" by Identicator Technology
4) **DB4**: synthetic fingerprint generation.

Each database is 110 fingers wide (w) and 8 impressions per finger deep (d) (880 fingerprints in all); fingers from 101 to 110 (set B) have been made available to allow parameter tuning before the submission of the algorithms; the benchmark is then constituted by fingers numbered from 1 to 100 (set A).

Figure 5 shows a sample image from each database:

5. FINGERPRINT VERIFICATION RESULTS

The performance of MACE filter for finger print verification has been tested on FVC database. A single MACE filter was designed for each of the 10 persons using a variable number of training images from that person fingerprint. We first used only 3 training images for the creation of each person's MACE filter. And then training images are further increased upto 6 training images. Increasing the number of training images tends to increase the margin between the genuine and the imposter and thus, giving better discriminating ability. Following graph i.e. fig.6 shows improvement in recognition accuracy along with images.

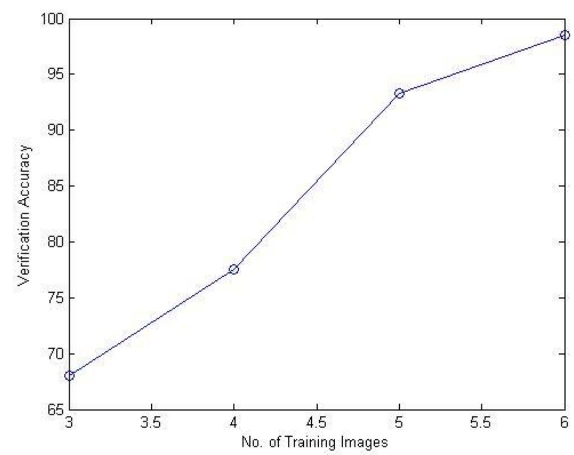

Figure 6. Accuracy v/s number of training images

For authentics, the correlation output should be sharply peaked and it should not exhibit such strong peaks for impostors.Some samples correlation outputs of the finger print images are shown in Figure 7.

Fig 7(a) shows a training image from DB2 of FVC database and corresponding correlation output for that image. Fig 7(b) is the another image from same person's finger print .So we observe the sharp correlation peak .While finger print image in Fig 7(c) and Fig 7(d) are of imposter ,so it doesn't have sharp correlation peak.

6. CONCLUSION

The performance of Minimum correlation filters for finger print verification is presented. Based on the results obtained, it is found that MACE filter is a good means for finger print recognition .It was determined that using 6 training images per person, the MACE filters are capable of discriminating true class samples from the false one with nearly 98% correct classification. These results are promising and demonstrated the potential use of minimum average correlation filters as an interesting option for finger print recognition.

7. REFERENCES

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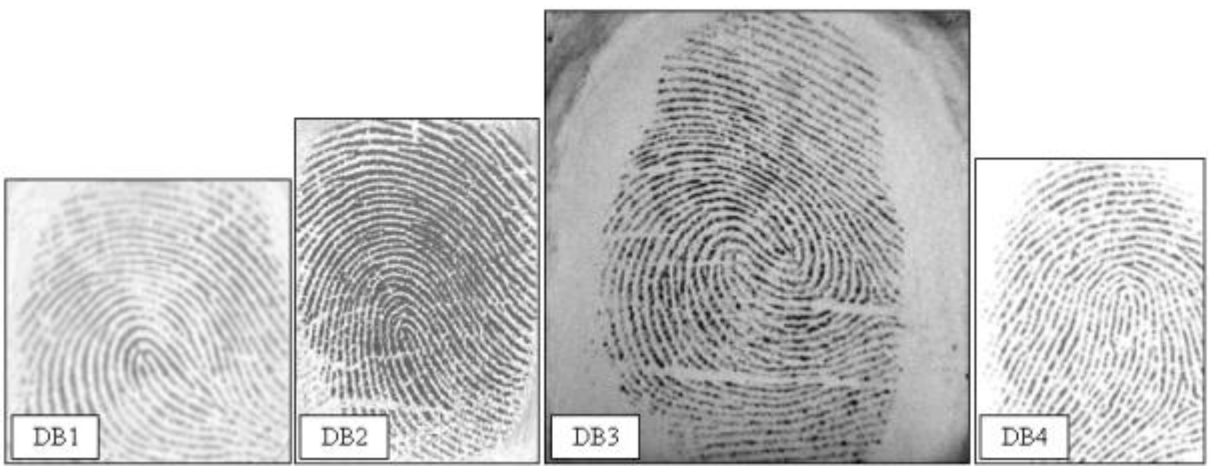
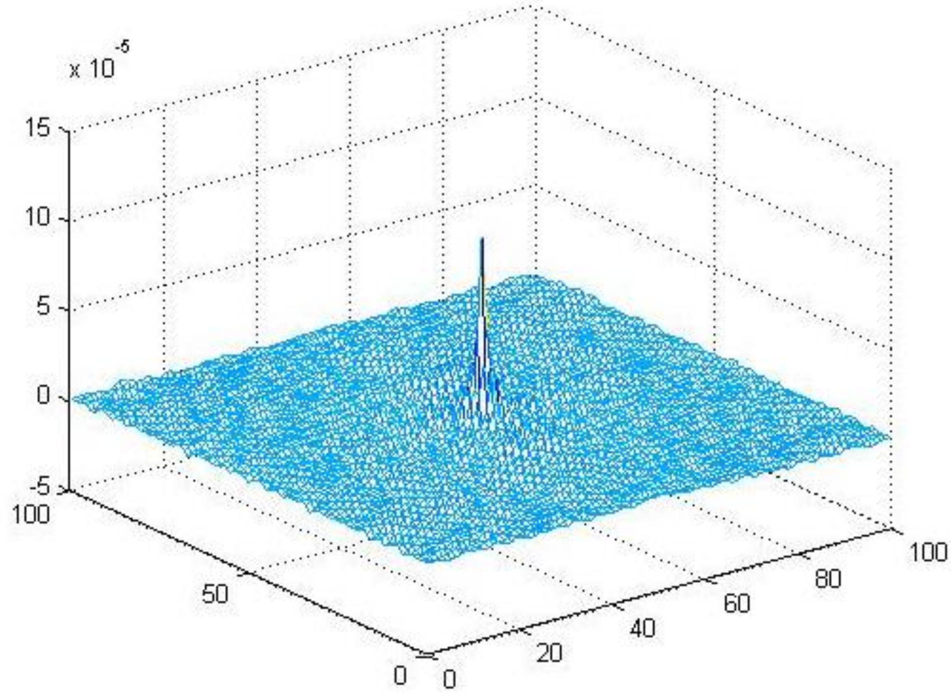
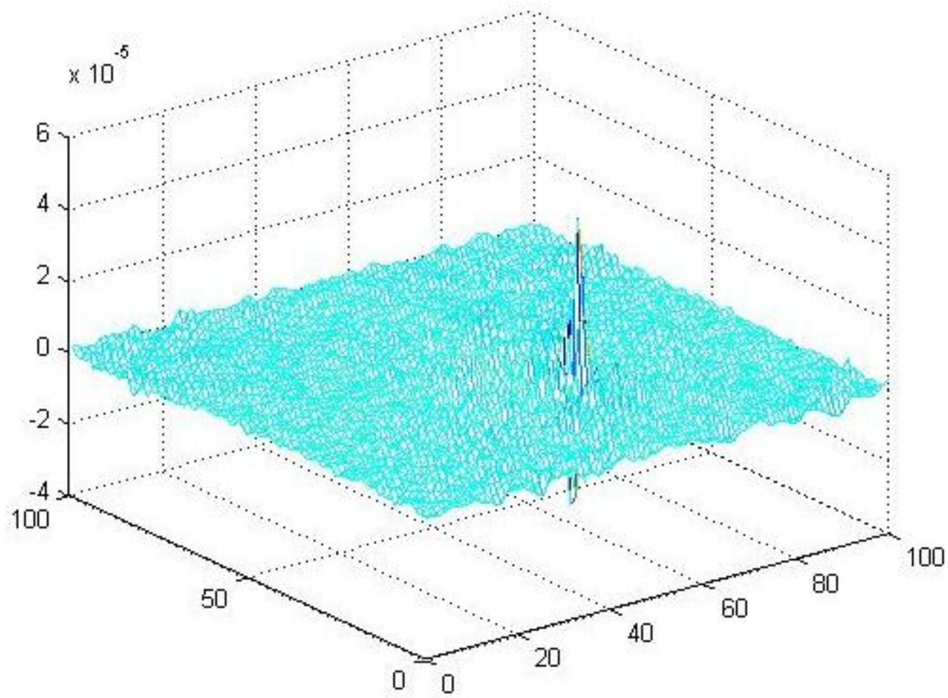


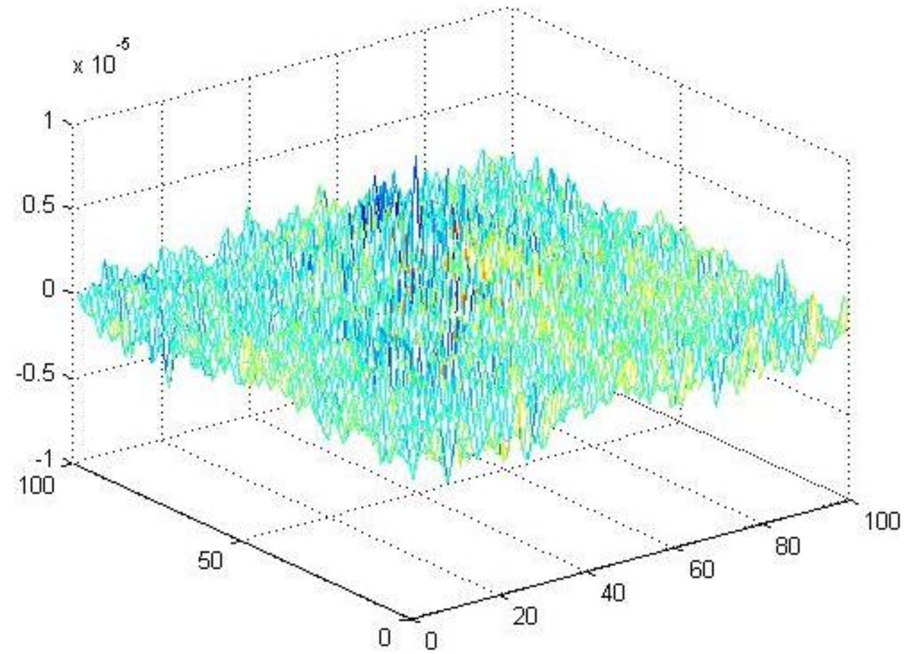
Figure 5 FVC 2000 database sample images



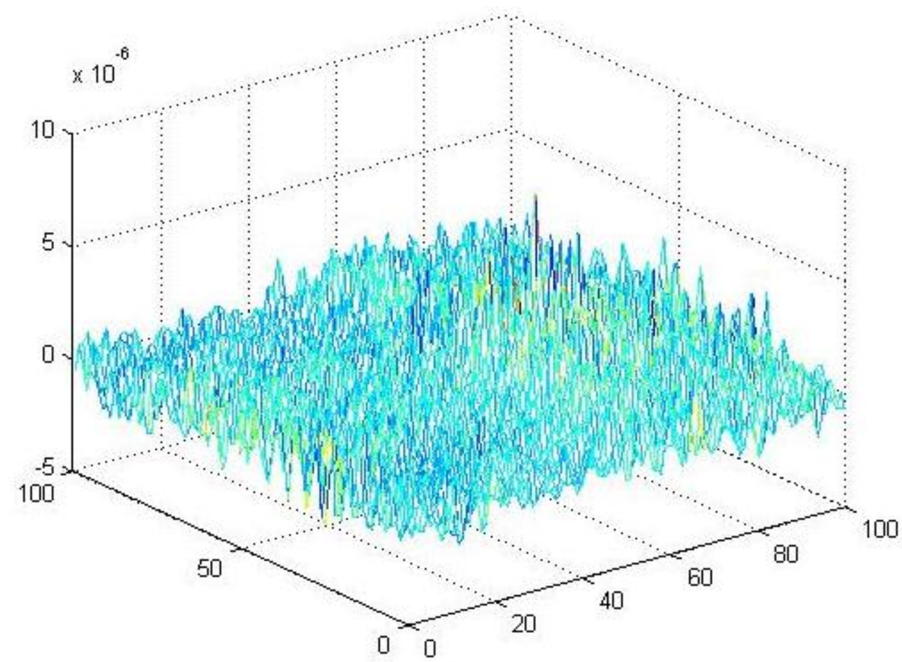
7 (a) Training image **Correlation Output**



7 (b) Testing image **Genuine**



7 (c) Testing image **Imposter**



7 (d) Testing image **Imposter**

Figure 7(a-d) Correlation outputs for sample fingerprint images using 3 training images