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Effective and Adaptive Fingerprint Image Matching Using Contextual Filters

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***Abstract*-This proposed method deals with several improvements to an adaptive fingerprint enhancement that is based on contextual filtering. The name adaptive denotes that the parameters are automatically adjusted based on the fingerprint image that is given as input. Five processing blocks are used in the adaptive fingerprint enhancement method. In the proposed system the four of these blocks are updated and this method is a novel. In this processing method the updated blocks are global analysis, matched filtering, local analysis and preprocessing. In the preprocessing and local analysis blocks the method simply used here are nonlinear dynamic range adjustment. Second, the process applies one or more forms of order statistical filters to the global analysis and matched filtering blocks. From this proposed method, these blocks produce a new improved adaptive fingerprint image processing techniques. These novel algorithm is appraised toward the NIST developed NBIS software for image recognition that is based on FVC databases.**

***Keywords:* Fingerprint image, Filtering, Fourier transform, image processing, Feature estimation, Quantization transform**

I. Introduction

The human fingertips or the skin of humans which contains ridges and valleys which forms special patterns. These finger prints are formed on pregnancy and permanent throughout the life time. Prints on these are called fingerprints. Certain injuries on the skins like scratches and burnswillsignificantly damage quality of fingerprints temporarily but when fully recovered, patterns will be restored. It has been clearly cited that no personhave the same fingerprints and cannot be changed over different time period, hence they are always unique for every individual. Because of the uniqueness, finger prints is used as apopular biometrics measurements. These are mainly used in law enforcement where they have been used over a long period of time to help for the solving crime. Unfortunately fingerprint matching is a complex pattern recognition problem. Whenever the fingerprint matching is done manually, it takes not only time consuming but education and training of experts that takes for a long time period. Since 1960s many effort made on the development of automatic fingerprint recognition systems. Fingerprint recognition process that is based on the automatization turned out to be success in many forensic applications. Fingerprints must be individuality over the different time period. Thisidentification method is more and more secure and reliable in identification the person instead of using keys, passwords or id-cards can provide.

The problem of fingerprint recognition can be combined into two sub-domains such as fingerprint verification and identification.

Fig.1. A fingerprint image obtained by optical sensor

However the accuracy of the automated fingerprint identification system highly depends on the quality of fingerprints, because feature extraction algorithms may incorrectly extract the features, needed for fingerprint matching. Fingerprints may be dirty, damp, too dry, damaged, etc. Therefore it is necessary to enhance the fingerprint image to the point where we get a clear structure of ridges and valleys on the fingerprint's surface. The Proposed method is based on contextual filtering and their parameters are automatically adjusted based on the finger print image. There are five processing blocks that are used in this method, where four of the blocks are updated in this proposed system. In the preprocessing and local analysis blocks the method simply used here are nonlinear dynamic range adjustment. Second, the process applies one or more forms of order statistical filters to the global analysis and matched filtering blocks. These novel algorithm is appraised toward the NIST developed NBIS software for image recognition that is based on FVC databases.

This paper is organized as follows. In section 2, we give the different methods proposed. Then, the proposed algorithm is presented in Section 3. In section 4 the evaluation of the proposed method illustrates detailed. Finally, the conclusions are provided. The following chapters will introduce these details.

II. Related Work

Different methods have been proposed earlier for enhancement of fingerprint images which are based on image normalization and Gabor filtering. The Hong's algorithm denotes that the inputs of a fingerprint image that applies various steps for the enhancement of the image. The minutiae points can be extracted by enhancing the fingerprint image. A Band Pass Filter Technique is used to extract ridges and to remove the noise and preserve true ridges/structures, they Fails to deal with heavy noise[1].To achieve high security applications requirements, multimodal biometrics is also used as it helps to minimize system error rates. Fingerprint is a unique to the ridges and valleys on the surface of finger of an individual. In a finger image a ridge is a curved line. Some are generally continuous curves, and others called ridge endings which terminate at specific points. Two ridges come together at a point called a bifurcation. Ridge endings and bifurcations are known as minutiae. The segmentation is done by automatic fingerprint recognition system is the of fingerprint images. The separation of fingerprint area (foreground) from the image background is based on image segmentation [2].Contextual filter that uses four main important parameters of fingerprint images that are at a given resolution such aslocal maxima and minima in the ridge and valley widths to yield the enhanced output [3]. In 1994 Millard described a novel method which is based on the Fourier filter which is of directional for the fingerprint image which uses the entire image information, instead of using small regionsof the filtered point. There are two stages in the enhancement they are filtering stage and threshold stage. By applying filtering in this stage is mainly used for removing the unwanted noise from the input image producing a smooth image and for converting the gray scale image in to binary image at the threshold stage [4]. In 1989 Gorman and Nickerson proposed different filters for the fingerprint image enhancement and the coefficients are generated which are of k X k mask, based on the local ridge orientation. The four model parameters, derived from ridge width (Wmax, Wmin), valley width (× × max, × × min) and the minimum radius of curvature are used to describe a fingerprint. It is assumed that the Wmax + Wmin = × × max +× × min. The mask is convoled with the input image. The image can bebinarized and post processed for further fingerprint identification [5]. This method uses Gabor filters,these have the maintwo selective properties such as frequency and orientation. These have a joint resolution in spatial and frequency domains [6]. Josef Bigun uses the technique of image-scale pyramid and directional filtering used to extract local ridge valley. The method is Linear symmetry features are used to extract the local orientation is the greatest advantage [7].

III. Proposed Method

To improve local features extraction, the frequency spectrum has to have an adequate resolution. Therefore, each transformed local area is zero padded to the next higher power of two since an FFT is used to frequency-transform the image. To reduce the magnitude of spectral side-lobes, a two dimensional hamming window is applied to the local area, smoothing the transition between data and the zero-padding. An illustration of the finger print enhancement with variant and 16 of the proposed method. The most pronounced visual effect is that fingerprints processed with the new method preserve larger parts of the original fingerprint, parts which were excluded in the original method.

(1) Local fingerprint image patches are always same to a sinusoidal signal, where the dominant peaks of the two signals are co-located.

(2) The location of the dominant peak in the magnitude spectrum of a local image area carries information about the local orientation and frequency of the fingerprint pattern.

(3) The spectral peak of the dominant magnitude acts as an indicator of the quality of the fingerprint in thatparticular local area.

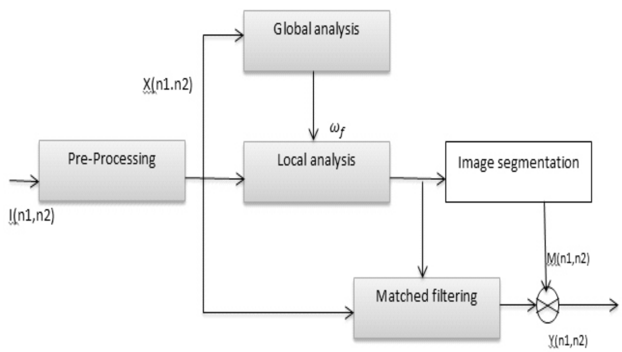

Fig.2. Processing blocks of the proposed method.
Gray blocks: updated processing blocks

The dynamic range of the image can be adjusted in the non-linear preprocessing block. Secondly updatethe previously derived global fingerprint analysis. To provide the fundamental spatial frequency estimation of the fingerprint image, and for noisy images it improves the frequency estimation performance.

Third, based on the estimated or calculated frequency from the global analysis, a local adaptive analysis is done that adjusts the fundamental frequency to match the local imagearea. This proposes the use of a local dynamicrange adjustment method to improve spectral features estimation.

Fourth, the matched filtering is based on the spectral features estimated in the local analysis, where an additional order-statistical filtering of the spectral features is introduced to increase the method's resilience towards noise

Finally, image segmentation separatesfingerprint data from the background.This,taken all together, comprises the proposed new fingerprintenhancement system that automatically tunes its parameters according to each individual fingerprint image.

A. Preprocessing

An innovative non-linear preprocessing block adjusts the dynamic range of the image. Novelupdate to the previously derived global fingerprint analysis is conducted to aid the fundamental spatial frequency estimation of the fingerprint image, and further improves the frequency estimation for the analysis and great performance for noisy images. Let LetI (n1, n2) represent the size that are denoted in horizontally and vertically. It is expressed in 256 grey levels or the image with eight bit. The system performance can be degraded because it cannot use the full dynamic range in detail. With increasing number of levels the more detailed underlyinginformation in the image is admitted. This is equivalent and thus by preserving the basichistogram shape. This nonlinear property of SMQT yields abalanced image enhancement. The number of levels in the binary tree and is equal to thenumber of bits used to represent the SMQT processed image. Always the parameter value is set to 8 to avoid the risk of arresting the important datain heavily noise and mainly used for grayscale imageenhancement.

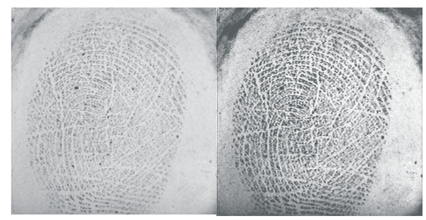

Fig.3. (a) Fingerprint image and (b) corresponding SMQT enhanced image

B. Global Analysis

This paper employs the dominant component in the circular structure corresponds to the fundamental frequency of the image and the fundamental frequency is inversely proportional to a fundamental window size. The global analysis is estimated by the following steps:

(1) New processing stage suppresses data outliers by amedian filter.

(2) A radial frequency histogram is computed from the magnitude spectrum of the median filtered image.

(3) The fundamental frequency of the fingerprint is assumed located at the point where the radial frequency histogram attains its maximal value. The radial frequency histogram is herein proposed to be smoothed in order to reduce the impact of spurious noise.

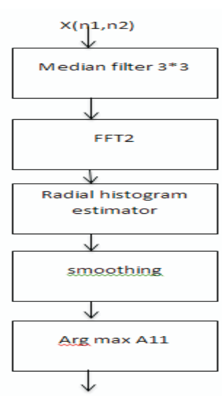

Fig.4. Global Analysis

C.Local Adaptive Analysis

The purpose of the local analysis is to adaptively estimate local spectral features corresponding to fingerprint ridge frequency and orientation. Most parts of a fingerprint image containing ridges and valleys similarities to a sinusoidal signal in noise. They have two distinct spectral peaks located at the signal's spatial frequency, and alignment with the spatial signal. The local area size is denoted in M × M, where M is anodd-valued integer.Where the parameter k is a design parameter,two additionallocal area sizes are introduced. A larger local area size,denoted as M+×+, where M+ = (1 + η) ·M, and a smallerlocal area size, denoted as M××M×, where M× = (1 × η)·M. both have odd-valued integers.

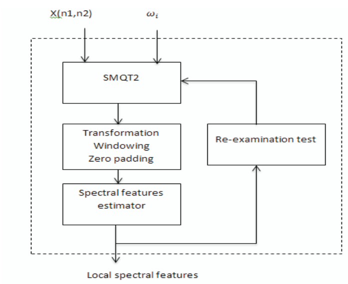

Fig.4. Local Adaptive Analysis

D. Local Dynamic Range Adjustment

Due to low quality images it always suffer from poor contrast and background. Even after the global enhancement some parts are remain constant and does not provide satisfactory result. The method updated here by applying SMQT dynamic range adjustment and requires only 2 bit representation.

1. Data Transformation, Windowing, Zero Padding

To improve local features extraction, the frequencyspectrum has to have an adequate resolution. Therefore, each transformed local area is zero padded to the next higher power of two since an FFT is used to frequency-transform the image. To reduce the magnitude of spectral side-lobes, a two dimensionalHamming window is applied to the local area,smoothing the transition between data and the zero-padding.

2. Spectral Features Estimation

A local spectrum G(ω1,ω2) = |F {H(m1,m2)}| is obtainedby computing the two-dimensional Fourier Transform. The measure is computed based on the extractedfeatures The measure $\frac{P_D}{P_{max}}$ quantifies the significance of thelargest peak in relation to Pmax and the measure $\frac{PD_2}{PD}$ assesses the relationship between the two largest spectralpeaks.

$$Q= +,\ \frac{P_D}{P_{max}}+\left(1-\frac{PD_2}{PD}\right), \quad (1)$$

Where Q is qualityMap and Q = 2 best and Q = 0 worst.

3. Local Area Reexamination Test

Due to the variability in someregions different local area size can be analyzed instead of one. The regions are reexamined by two additional features size. It can be conducted only if Q= QT. from this quality score quality scores Q+ and Q× for each respective stage. Based on the best quality measure the spectral features are chosen.

4. Matched Filtering

The local features ωD,1 and ωD,2 represent the vertical and horizontalspatial frequencies. The frequencies ωD,1 and ωD,2 are highly varying. To reduce the noise in the frequency smoothing has been done side by side which is conducted on the polar coordinates instead of Cartesian coordinates. These can be done by applying order statistical filters and the size is 2L+1×2L+1 where L = _γ ·L f _ and γ is a design parameter. The values are sorted and are arranged in column vector. The size andshape of the statistical filter that automatically adapt to fingerprint and sensor variability.The smoothed spatial frequencies are used to construct afilter f (m1,m2), where (m1,m2) ∈ [×N, N], matched tothe local area at hand. The size of the filter is selected as2N + 1 × 2N + 1, where

$$N = \text{round}\left\langle\frac{\pi}{max(|\omega D,1|),|\omega D,2|}\right\rangle \quad (2)$$

The enhanced output image value at the point (n1, n2)is the local area weighted by the corresponding matched filter

$$Y(n1, n2) = \sum_{m1=-N}^{N}\sum_{M2=-N}^{N} f_{n1,n2}\,(m1,m2).\,X(n1+\ m1, n2+m2).$$

5. Image Segmentation

The sensor has different sizes of the sensor area, a large part of the area occupy the part of the image. To suppress non-relevant parts of a fingerprint image, where there is no fingerprint data, a segmentation of the image is performed.

These can be obtained by applying a binary mask tothe fingerprint image. To remove falselysegmented structured background from the binary mask the method involves some additional post processing techniques.

TABLE.I VALUES OF THE DESIGN PARAMETERS CHOSEN IN THIS PAPER

Parameter	Value
k	3
η	0.3
α	0.6
γ	0.5
QT	1

IV. EVALUATION

The proposed algorithm is acting as a preprocessing stage to the NIST fingerprint recognition system consisting of a minutiae extractor and a minutiae matcher. Each updated processing block in theproposed method the evaluation shows the improvedperformance and carried out by using 12 databases. The proposed method is evaluated by having the same parameter values for all databases. The proposed method improves the EER results for the NIST fingerprint recognition system on all databases.

TABLE II PERFORMANCE OF THE PROPOSED ENHANCED METHOD

	NIST	NIST+ proposed	Relative impr.	NIS	NIST+ proposed	Relative impr.
	FVC2000 Db1a			FVC2000 Db2a		
AAC	3.2%	1.1%	65.6%	1.5%	1.4%	6.7%
EER	5.8%	3.5%	39.7%	4.4%	3.5%	20.5%
FMR100	9.8%	6.6%	32.7%	7.9%	4.9%	38.0%
FMR1000	13.5%	12.0%	13.0%	12.1%	8.0%	33.9%
ZeroFMR	17.1%	19.3%	- 11.4%	20.2%	10.5%	48.0%
	FVC2000 Db3a			FVC2000 Db4a		
AAC	3.3%	1.1%	66.7%	1.6%	0.9%	43.8%
EER	7.6%	3.8%	50.0%	5.5%	3.7%	32.7%
FMR100	14.6%	6.3%	56.8%	10.1%	6.6%	34.7%
FMR1000	19.5%	9.9%	49.2%	17.6%	11.5%	34.7%
ZeroFMR	24.9%	16.8%	32.5%	25.5%	14.4%	43.5%
	FVC2002 Db1a			FVC2002 Db2a		
AAC	1.3%	1.3%	0.0%	1.0%	1.0%	0.0%
EER	3.2%	2.8%	12.5%	2.4%	2.3%	4.2%
FMR100	5.0%	4.0%	20.0%	3.5%	3.2%	8.6%
FMR1000	7.2%	6.1%	15.3%	5.3%	4.8%	9.4%
ZeroFMR	10.8%	9.9%	8.3%	6.3%	10.0%	- 37.0%
	FVC2002 Db3a			FVC2002 Db4a		
AAC	5.3%	2.9%	45.3%	1.9%	1.2%	36.8%
EER	9.9%	6.5%	34.3%	5.3%	3.9%	26.4%
FMR100	18.4%	11.7%	36.4%	8.8%	6.8%	22.7%
FMR1000	28.6%	18.6%	35.0%	12.7%	10.0%	21.3%
ZeroFMR	36.5%	26.3%	27.9%	15.6%	11.7%	25.0%
	FVC2004 Db1a			FVC2004 Db2a		
AAC	7.8%	5.1%	34.6%	5.1%	2.2%	56.9%
EER	13.7%	9.6%	29.9%	10.8%	5.9%	45.4%
FMR100	26.8%	18.9%	29.5%	19.9%	10.5%	47.2%
FMR1000	35.3%	26.4%	25.2%	26.6%	17.5%	34.2%
ZeroFMR	48.7%	30.9%	36.6%	31.0%	22.9%	26.1%
	FVC2004 Db3a			FVC2004 Db4a		
AAC	2.1%	2.1%	0.0%	3.7%	2.8%	24.3%
EER	6.6%	6.2%	6.1%	7.1%	6.6%	7.0%
FMR100	15.1%	12.8%	15.2%	12.3%	10.9%	11.4%
FMR1000	29.7%	19.6%	34.0%	19.1%	14.5%	24.1%
ZeroFMR	39.8%	24.5%	38.4%	22.8%	15.9%	30.3%

V.CONCLUSION

This paper presents an adaptive fingerprint enhancement method. The method extends previous work by focusing on preprocessing of data on a both the level local and global. A non-linear SMQT dynamic range is used in the preprocessing by adjustment method is used to enhance the global contrast of the fingerprint image prior to further processing. Estimation of the fundamental frequency of the fingerprint image is improved in the global analysis by utilizing a median filter leading to a robust estimation of the local area size.

A SMQT dynamic range is used to adjust and achieve steady features extraction that is used in the matched filter design and in the image segmentation. Applying order statistical filtering to the extracted features the matched filter block is improved.The proposed method combines and updates existing processing blocks into a new and robust fingerprint enhancement system. The updated processing blocks lead to a drastically increased method performance where the EER is improved by a factor two, and the AAC is improved by a factor 12, in relation to the original method. The proposed method improves the performance in relation to the NIST method, and this is particularly pronounced on fingerprint images having a low image quality. The evaluation results indicate that the method is able to adapt to varying fingerprint image qualities, and it is stressed that the proposed method has not been tuned in favor towards any database. Rather, one global configuration has been used during the evaluation campaign.

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