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# Modified Enhancement Method for Poor Quality Fingerprint Recognition

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**Abstract:** Reliable feature extraction from poor quality fingerprint images is still the most challenging problem in fingerprint recognition system. It needs a lot of pre-processing steps to improve the quality of images, then it needs a reliable feature extractor to extract some distinctive features. Segmentation is one of the most important pre-processing steps in fingerprint identification followed by alignment, and enhancement. We improved the segmentation technique which based on thresholding the energy map, with another one based on morphological operation. Recently, Multiresolution techniques have been widely used as a feature extractor in the field of biometric recognition. We use modern multiresolution techniques; Curvelet, Wave Atoms, Shearlet transforms in extracting distinctive features from the enhanced fingerprint images in a new methodology. The selected features are matched throw K-Nearest neighbor classifier technique. We test our methodology in 114 subjects selected from a very challenges database; CASIA; we achieved a high recognition rate of about 99.5%.

**Keywords**: Fingerprint Recognition, Multiresolution Feature Extraction, Wave Atom, Shearlet, Curvelet, Real Noisy Database, Fingerprint Image Enhancement.

## I. INTRODUCTION

Using biometrics in recognition of persons is an emerging phenomenon. in modern society, due to the wide need of security in many applications. Fingerprint has several advantages over the other biometrics, such as: high university, high distinctiveness, high performance, easy collectability, high permanence, and wide acceptability [1].There are many techniques are proposed in fingerprint enhancement and matching, however most of them have no difficulty in matching good quality fingerprint, but matching low quality fingerprint remains a challenging problem [2]. The process of identification can be divided into the following stages:

A. **Pre-processing Stage:**

Good quality fingerprint image has high contrast and well defined ridges and valleys, while poor quality fingerprint is marked by low contrast and ill-defined boundaries between the ridges and valleys. There are some factors of the uneven force and collection environment that degrade the quality of fingerprint image [3, 4, 5] :

- Presence of creases, bruises or wounds may cause ridge discontinuities.
- A dry skin can cause inconsistent contact of finger ridges with scanner surface causing broken ridges and low contrast ridges.
- Oily or wet skin make the valleys tends to fill up.
- Moister can cause the valleys to appear dark similar to ridge structure
- Sweat on fingerprints leads to smudge marks and connects parallel ridges.
- Variations in impression conditions, ridge configuration.

These factors lead to poor quality fingerprint images. Thus, current fingerprint recognition technologies are vulnerable to poor quality images [6]. In order to facilitate the extraction of the fingerprint feature points, an effective pre-processing step for fingerprint images is essential.

B. Feature Extraction Stage:

In this stage, we need to use a sufficient feature extractor algorithm to give distinctive features. There are over 150 known local ridge characteristics in fingerprint, which can be used for identification process. The most popular characteristics are called minutiae points which are the ridge endings, and the ridge bifurcations. A good quality fingerprint typically contains somewhere in between 40 and 100 minutiae [7].

Forensic experts use this representation which has now become part of several standard for exchanging information between different systems across the world, such as ANSI-NIST slandered [8]. For the past 100 years, the fingerprint features and matching techniques have been based on minutia points, but this technique is not useful when we can’t extract enough and reliable minutia points due to poor quality fingerprint images, or the fingerprint image doesn’t have a sufficient number of points [9]. For this reason, a lot of research have been done in extracting distinctive features from fingerprint images. Recently, researchers attempt to use the multi-resolution transform techniques such as: Wavelet transform, Curvelet transform, Bandlet transform, Contourlet transform, Shearlet transform, and Waveatom transform as feature extractors in many biometric recognition such as face recognition, palm recognition, fingerprint recognition, and

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etc. In this paper, we use the Waveatom transform as feature extractors in fingerprint recognition system.

C. Classification Stage

Once a set of features are extracted from the fingerprint image, the final goal is to confirm the identity of a person whose fingerprint has been previously enrolled into the system. The matching mechanism is the responsible to provide a likeliness score between two fingerprints. In this paper we will use a simple classifier which is the KNN classifier.

The rest of paper is organized as follows: in Section 2 the work related to the fingerprint image enhancement and alignment is described. Our proposed solution is described in Section 4, and the results of our fingerprint identification system are discussed in Section 5. Finally, the conclusion and future work are listed in Section 6.

## II. RELATED WORK

The preprocess stage contains mainly on two processes: the enhancement process and the alignment process. The enhancement process contains several sub-processes such as: orientation image estimation, frequency image estimation, segmentation, and filtering. One of the most popular approach for fingerprint image enhancement is the algorithm of Hong et al in [4]. The main steps of their algorithm were the following processes: normalization, local orientation estimation which based on gradient method, local frequency estimation, region mask estimation (segmentation) which depends on a threshold value to classify the region if it is recoverable or unrecoverable, and filtering with a bank of symmetric Gabor filters, which was designed according to image orientation and frequency. The algorithm was tested on 50 poor quality fingerprint images, and they achieved an improvement results. Filtering is an important step in fingerprint enhancement process. After ridge orientation have been estimated, filtering has to be applied to image to correct false estimation. Although the Gabor filters have an important properties from a signal processing perspective, the Gabor filter based approach has some errors in orientation estimation, and propagate to ridge frequency estimation leading to imperfect reconstruction [3, 10], this is due to bandwidth limitation of Gabor filter. This excited the researchers to improve Hong's algorithm.

Instead of having used Gabor filter in spatial domain, the proposed algorithm in [11] used the Gabor filter in Wavelet domain. Their idea was that the fingerprint approximation of sub image contained fewer noises than in spatial domain, and hence computing the orientation image is more reliable.

Some researchers tried to solve the limitations of traditional Gabor filtering, such as using log-Gabor filtering instead of Gabor filter [12], using a modified Gabor filtering with adaptive parameters [13], using fast Gabor filtering [14], using the anisotropic filter instead of Gabor [15], using a series of notch filter high-pass filter and Gabor filter [16], and using directional morphological filter [17].

All of the previous solutions used the segmentation methodology of [4] which depends on a threshold value to extract the foreground region from the background one. The drawback of this solution is that different noisy level of fingerprint images have different threshold values, furthermore the humidity region in fingerprint image is always black and it considered as a background region.

One of the most popular fingerprint image enhancement techniques was based on Short Time Fourier Transform (STFT) analysis and contextual filtering in the Fourier domain was proposed in [3]. The algorithm had several advantages that the ridge orientation, ridge frequency, and region mask (segmentation) were estimated simultaneously from STFT analysis. This would prevent errors in ridge orientation estimation from propagating to other stages. Furthermore, the estimation was probabilistic and therefore was more robust. The segmentation process of this solution depends on the energy map to be processed, that the background and the noisy regions have a very little structure and hence a very little energy in the Fourier spectrum. The results showed that the proposed algorithm had better than Hong in recognition rate of over a set of 800 images in FVC2002 DB3 database. The drawback of this solution that the energy map is very little in a very noisy regions especially the humidity regions, and so some useful fingerprint structure is lost.

In order to achieve high recognition rate when comparing fingerprint images or even the features extracted from the fingerprint images, these images or features of both the reference sample and the test one have to be aligned. There are three major challenges involved in acquisition the fingerprint samples: translation, rotation and scaling [18]. Fingerprint translation refers to the position of a captured fingerprint with respect to the fingerprint image background, and for optimum functionality of an automated fingerprint recognition system, the fingerprint should be positioned in the central area of the fingerprint image background. Fingerprint rotation refers to the alignment of a captured fingerprint when measured against the image background, and for optimum functionality of a fingerprint recognition system, the captured image should sit at an angle of approximately 0 degrees (more or less upright) relative to the vertical axis [19]. The most effort of research of addressing these challenges is focused on translation and rotation issues, because capturing fingerprint images doesn't lead to scaling problem since most fingerprint images could be scaled as per the dpi specification of the sensors.

Various techniques are proposed to solve the rotation problem, and each of them has its advantages and disadvantages. One of them [20] depended on finding both a core point and a delta point in the fingerprint image to estimate the re-alignment angle. In particular the translation invariance is accomplished by locating the reference point. The drawback of this solution in addition to the difficulty of finding delta point, is that it will fail


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when dealing with Plain Arch (PA) fingerprint class, which does not contain a core or delta point. Another instance where this algorithm may fail, is when dealing with Tented Arch (TA) fingerprint class, which has a single core and a single delta, with the core located almost directly above the delta. Many singular point detection techniques, however, find it relatively difficult to detect this delta point. Another instance where this method is likely to fail is when dealing with the Left Loop (LL) and the Right Loop (RL) fingerprint classes. Although these classes of fingerprint have both the core point and the delta point, in most cases the delta point is not captured.

Because of the problem of finding a reference point in the Plain Arch fingerprint class, researchers attempted to solve this issue by different techniques [18, 21]. The only problem with this recent development is that this technique is dedicated only to those fingerprints that belong to the PA class. This is a problem, because this solution requires to classify the fingerprint classes, then to use the appropriate reference point detection method before re-aligning the fingerprint.

An independent and efficient approach was proposed in [19]. Their approach did not depend on a particular fingerprint class, and so it can be used for all types of fingerprint classes. They used a new reference point named as True Fingerprint Centre Point (TFCP), which determined after segmentation process, and it lied on the centre of Region of Interest (ROI) area. From this point, they determined the rotation angle and direction of rotation.

The rotation problem was handled in [22] by cyclic rotation the extracted feature values in the matching stage. Similarly, in [23] the feature vector of each fingerprint template is rotated with 5 angles; -20, -10, 0, 10, 20; and when matching, the test image is compared for all templates. The drawback of these solution is that they are a time consuming solution

The other solution of translation and rotation issues is what is called the registration. Registration means that you have to choose a base image, then you have to translate the test image to lie exactly on the base image in order to achieve the maximum response between the two images. Registration is a common concept in image process which can achieve the translation and rotation invariant. An approach based on fingerprint registration was proposed in [24], in which the best alignment of two fingerprint images, template and input, is achieved by maximization of Mutual Information (MI) between the extracted features from their orientation fields, i.e., maximization of similarity measures between two fingerprint images.

Another approach based on measuring the similarity between a set of rotated fingerprint images of the registered image over an angular range $-40 \leq \theta \leq 40$, and the input image, was proposed in [25]. The translation was achieved by using the position of the core point in both images. The drawback of this solution is the high expensive computations due to the need of rotating each template 80 times with different rotation angles, then the comparison of each of these rotated images with the input one is considered. Furthermore, the rotation angle of some fingerprint images exceeds this limited range of angles.

Anyway, using the registration techniques to solve the alignment and translation problems in fingerprint recognition system, may be a good solution, but it will cost a lot of computations and does not work well in all cases of fingerprint image qualities.

## III. PROPOSED METHOD

This section contains the following two steps: fingerprint image alignment, and fingerprint image enhancement.

### A. Alignment Process:

There are three major challenges involved in acquisition the fingerprint samples: translation, rotation and scaling. Fingerprint translation and rotation processes are the most important steps in any automatic fingerprint recognition system, since capturing fingerprint images doesn't lead to scaling problem since most fingerprint images could be scaled as per the dpi specification of the sensors [19]. In order to achieve a high recognition rate, the fingerprint images have to be aligned and translated accurately. We implement the proposed algorithm in [19].

This approach is independent of fingerprint classes, and can be used for all fingerprint classes. The algorithm is simple and efficient, and contains the following processes: 1) Segmentation: in which the foreground region is separated from the background region. 2) True Fingerprint Center Point Location: in which an optimum center point (TFCP) is determined, which lies on the center of foreground area. 3) Fingerprint Re-alignment: in which the direction and the rotation angle are determined.

### B. Fingerprint Enhancement Process:

One of the most popular and an effective fingerprint enhancement algorithm is proposed in [3]. The enhancement algorithm is based on short time Fourier transform (STFT) Analysis, and on contextual filtering in the Fourier domain whose parameters depend on the local ridge frequency and orientation. The idea of this algorithm is to create an adaptive filter whose parameters depend on the contextual information of fingerprint image to be able to recover corrupted and occluded regions. The contextual information includes the ridge continuity and the regularity, which is obtained by computing the intrinsic images through the short time Fourier transform (STFT) analysis. The intrinsic images represent the important properties of the fingerprint image as a pixel map. These include: Orientation image, Frequency image, and Region mask.

Our Modifications: The alignment technique in [19], and the fingerprint enhancement technique of [3] are both depended on the segmentation algorithm, which was obtained by thresholding, and for automatic determination of threshold value, the authors used the Otsu’s optimal thresholding [26]. But in case of bad quality fingerprint images as our selected CASIA database, especially the problem of humidity in fingertip, which cause some important regions to be dark or black. This cause the thresholding technique to consider this black regions a part of the background area, and so it will be ignored.

We solve this problem by replacing the process of computing the Energy map by the segmentation technique proposed by [27] as we did in the alignment step. This technique does not depend on the thresholding to estimate the foreground region

C. Feature Extraction:
There are a series of researches that had used the multiresolution feature extraction techniques in Fingerprint Recognition System, which began with Wavelet, followed by Contourlet and Curvelet. We continue with these researches, and use the Shearlet and Wave Atoms transforms in extracting features from fingerprint images. We use the Shearlet transform as the first time as a feature extraction technique in fingerprint recognition.

We determine the singular point location by using the idea of complex filters [28]. After locating the reference point or core point in the fingerprint image,we crop an N x M subimage from the fingerprint pattern with core point at the center. This can be called 'central subimage'. The size of subimage is taken once as 128x128.

Then we divide this central subimage into a number of non- overlapping blocks of size W x W, i.e. W=64. Then we apply the Wave atom, Curvelet, and Shearlet for each of the non-overlapping blocks at Scale = S and Angle = A. After that we take the standard deviation of each of the multiresolution transforms coefficient sets for each scale and angle. Thus the obtained standard deviation for each of the four blocks of a fingerprint image constructs the global feature vector together. The obtained features vector size depends on the applied multiresolution transform.

## IV. RESULT AND DISCUSSION

A. Fingerprint Database:
We select randomly 114 subjects from CASIA Fingerprint Image Database Version 5.0 (or CASIA-FingerprintV5). We eliminate the subject whose most of his fingerprint images do not have a reference point (Arch). In addition, we eliminate the subject whose fingerprint image need a rotation angle more than 90 degree. CASIA-FingerprintV5 contains 5 samples for each subject, so we use 3 for training and 2 for testing.

B. Alignment Results:
When we perform the alignment process on the CASIA-FingerprintV5 database, we face some problems. One of them is the existence of some small black regions within the white regions, and this means that these black regions are considered as a part of the foreground region. This result is a by-product of segmentation process in poor quality fingerprint images.

Another problem is the non-smooth contour of the image segmentation. Both of these problems affect the performance of the alignment technique described, since the alignment technique is based on navigation along the x-coordinate and the y-coordinate, and so while incrementing the navigation variable, it will stop the navigation when it finds a black pixel, since it finds the contour of image segmentation. This will affect the TFCP location, and the upper point location, and as a result it affects the determination of C1, C2, and C3.

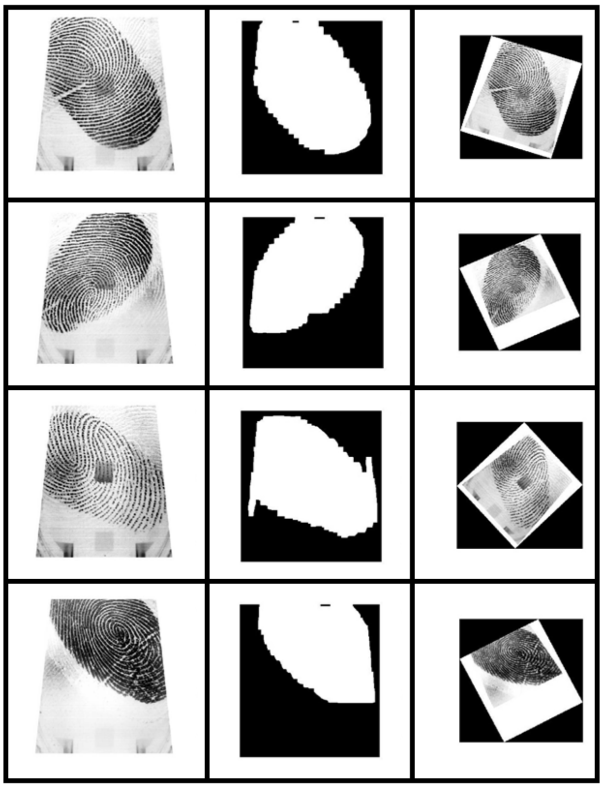

Fig. 1.Image Rotation result according to image segmentation. The left image is the original. The result of segmentation are in the middle column according to [18], and the result of rotation are in the last column. The images are taken from CASIA.

We solve the problems above by using the segmentation algorithm described in [27]. Figure 1 shows the results of alignment, which depend on segmentation process of [19], where the left side is the original images. The middle side is the result of segmentation according to [19], and the right side is the result of rotation.

Figure 2 shows the results of alignment which depends on segmentation process of [27], where the results of segmentation are shown in the middle column according, and the result of rotation are shown in the last column.

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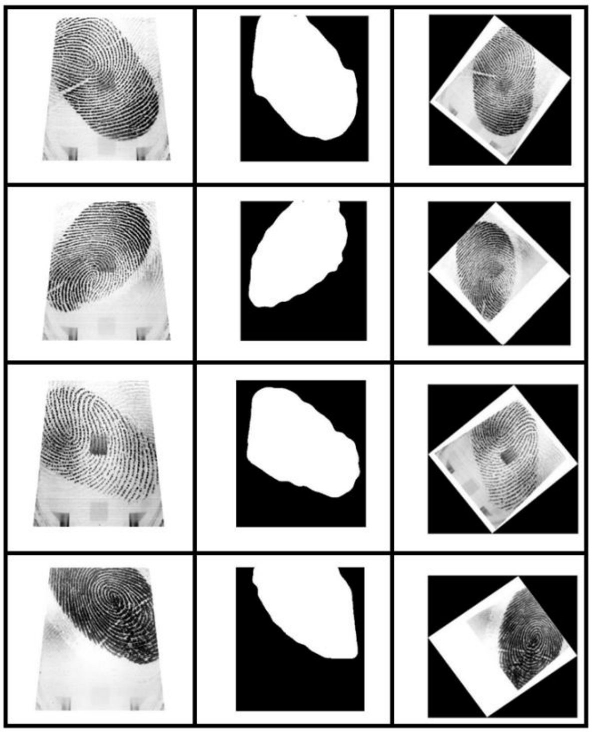

Fig. 2. Image Rotation result according to image segmentation. The left image is the original. The results of segmentation are in the middle column according to [37], and the results of rotation are in the last column. The images are taken from CASIA.

From both figures we can visually observe that the proposed solution is more accurate than the other in determining the angle of rotation because of smoothing the image contour, and removing false small black blocks in the foreground region. Although the used algorithm of rotation is robust, it has some drawbacks. The algorithm cannot perform well in some images which need to be rotated and have cuts in the image boundaries, especially if the image is cut in more than one side, i.e. the images which are shifted outside the scope of image boundaries, such as the images of CASIA-FingerprintV5 database.

The segmentation process leaves some small black parts in the top boundary of fingerprint image, especially in fingerprint which its upper part is lost. We solve this problem by implementing a method which eliminates these parts.

C. Enhancement process results:

We use the enhancement algorithm proposed by [3], in which the region mask is obtained by thresholding the energy image. When we apply the algorithm on CASIA-FingerprintV5 database, we obtain an efficient enhancement results in most types of poor quality images. The algorithm can connect the ridge discontinuity, and treats the fingertips creases and dryness. But we cannot obtain an optimum segmentation when dealing with the humidity in some images. This is because of the very bad qualities of the fingerprint images, where the humidity and dryness get together in the same fingertip, and this leads to segment some parts and to lose the others. Furthermore the background regions are not clean as the other databases such as FVC family. It contains some small grey blocks in different regions, which affects the segmentation process which based on single thresholding the grey level variation. Single thresholding will lose some information about the ridge regions which are hardly appeared in bad quality fingerprint images. For this reason we replace the segmentation step of Chikkerur et al. algorithm with the algorithm proposed by [29]which we use it in the alignment step.

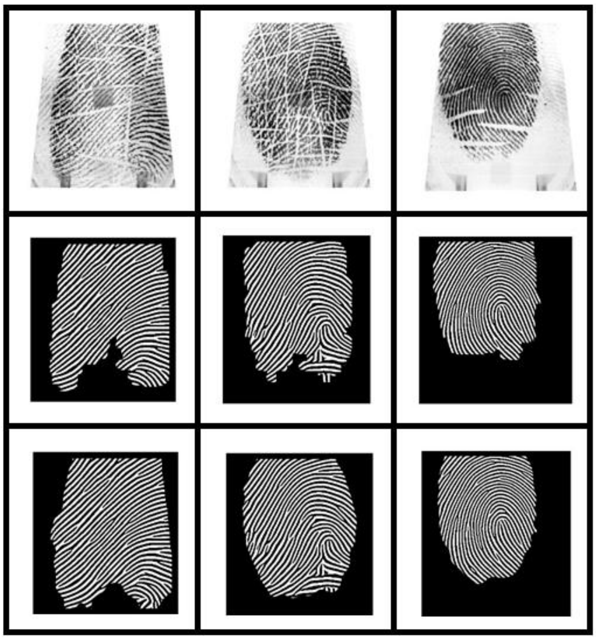

Fig. 3.Enhancement result of both the original technique and the modified one. The upper row shows some bad samples with a lot of creases of CASIA-V5 database. The middle row shows the result of the original technique. The last row show the result of the modified technique.

The segmentation process of [27] was based on computing the range image over blocks of size 16x16 then applying a local adaptive thresholding to select an appropriate threshold level for each block.

The modified enhancement technique gives a slight improvement in some poor quality images with a lot of creases and wounds as shown in Figure 3, where the upper row shows some bad samples with a lot of creases of CASIA-FingerprintV5 database, the middle row shows the result of the original technique, and the last row shows the result of the modified technique.

We also see that both enhancement algorithm can connect the discontinuities of the ridges, and improve the contrast between ridges and valleys, however the enhancement results of the modified algorithm give a better region mask image than the original since the segmentation technique in the modified algorithm depends on an adaptive thresholding with each block.

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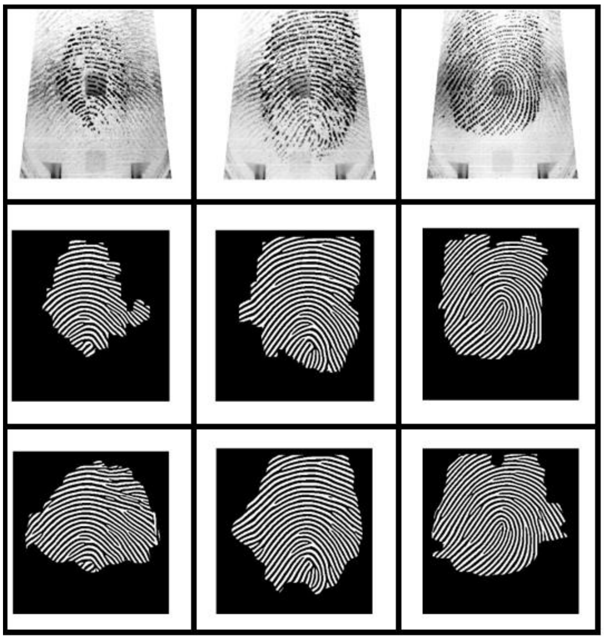

Fig. 4.Enhancement result of some dry fingertip samples for both the original technique and the modified one. The upper row is three samples images from CASIA-V5. The middle row shows the result of the original technique. The last row shows the result of the modified.

Another reason that degrades the quality of fingerprint images is the dryness of fingers, which leads to fragmented and low contrast ridges. Figure 4 shows some of these images and the result of the original and the modified algorithm, where the upper row is three samples images from CASIA-FingerprintV5 database, the middle row shows the result of the original technique, and the last row shows the result of the modified technique.

The Humidity of the fingertip may degrade the quality of the fingerprint images. Some samples of these types, and the results of the original and the modified enhancement algorithm are shown in Figure 5, where the upper row is three samples images from CASIA- FingerprintV5, the middle row shows the result of the original technique, and the last row shows the result of the modified one.

For core point detection we use the complex filters algorithm [28] to determine the singular point location.

The result of applying this technique on our selected database successes in most fingerprint images, and fails only to detect the core point in 6 images, three of these images are partial fingerprint and they don't have core points, and the others are poor ridge structure images, that the algorithm determines a location around the accurate core point. After detection the core point, a region of size 128x128 around the core point is cropped. This region is used to extract the features from it, since this region contains information which used to identify the fingerprints image. Furthermore, we need to minimize the features as soon as possible, to build a fast recognition system.

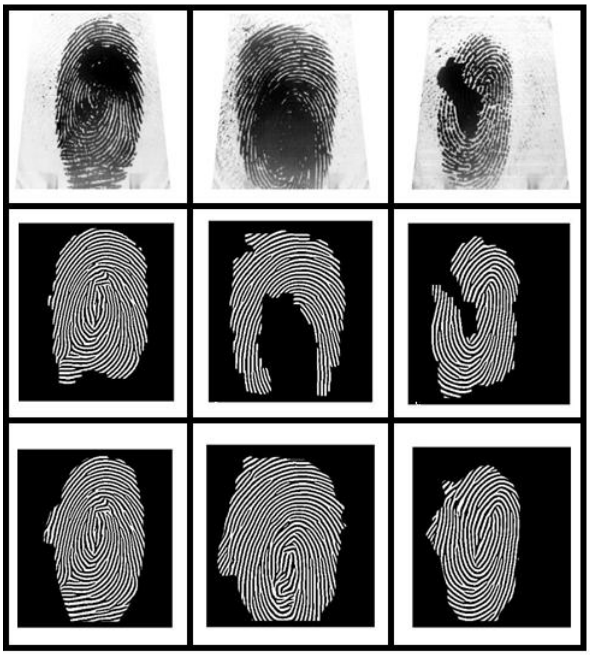

Figure 5: Enhancement result of the humidity in some fingerprint samples for both the original technique and the modified one. The upper row is three samples images from CASIA-V5. The middle row shows the result of the original technique. The last row shows the result of the modified.

D. Matching Techniques results:

The features vectors are classified by KNN, and the recognition results are illustrated in Table (1). We run the algorithm with different values of nearest neighbors K, and the highest recognition rate is when K=1. For a copped area of 128x128, the Wave atom has the highest recognition rate (99.5%).

TABLE 1 FINGERPRINT RECOGNITION RESULTS

| Feature Extractor | Recognition Rate |
|---|---|
| Wave Atom [29] | 99.5% |
| Curvelet | 87% |
| Shearlet | 87% |

## V. CONCLUSION

Accurate segmentation is an important step for the efficiency and the accuracy of subsequent enhancement and feature extraction stages. Segmentation based on one threshold value for the entire fingerprint image may lose some important information at least visible and intensity regions, while segmentation based on the range image feature over blocks and local adaptive thresholding, performs better than the original since it selects an appropriate threshold level for each block.

Furthermore, applying segmentation after enhancement may lose the humidity regions in fingerprint image since there is no regular signal in these regions, and hence the Fourier transform of these regions is constant and these parts will not be processed through a complete

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enhancement process. Segmentation based on morphological operations, closing and opening operations, before enhancement can segment these humidity regions.
An accurate displacement and rotation of fingerprint images are critical issues that affect the performance of feature extraction techniques, and decrease the recognition rate. Our used methodology is translation invariant, since we use the core point as a reference point.

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