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Finger-Knuckle-Print Image Enhancement with Histogram Equalization Methods

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***Abstract*— The performance of a Finger-Knuckle-Print (FKP) recognition system depends on the quality of the FKP image. In this paper, a new approach to enhance the FKP image using the Histogram Equalization (HE) methods was suggested. The quality of the captured FKP image depends on the image contrast which may contain some noise in its background region. The Peak Signal to Noise Ratio (PSNR), Root Mean Square Error (RMSE), Mean and Square Error (MSE) and Quality Index (QI) performance metrics were used to measure the efficiency of the Histogram Equalization methods.**

We have obtained the best FKP images that which enhanced by the method of AHE which is considered the best contrast enhancement technique. The value of PSNR reaches more than 60 dB is an important metric of performance improving the efficiency of this algorithm. The value of MSE, RMSE and QI reflect that the AHE significantly improves the good quality of FKP images by enhancing contrast with AHE, as well as reducing noise and artifacts.

***Keywords*— Finger-Knuckle-Print, quality, Histogram Equalization, performance metrics**

I. Introduction

The need for reliable user identification techniques has significantly increased in the wake of heightened concerns about security and rapid advancements in networking, communication and mobility [1].

Together with the finger print, other hand-based biometrics has attracted lots of attention and personal identification through referring to the palmprint, hand geometry, and hand vein which have all been proposed in the literature [2].

One recent study has revealed that the finger knuckle print is very discriminative [3]. The Finger knuckle print (FKP) refers to the outer part of the finger around the phalangeal joint. In their study [4] Zhang et al. established and released the PolyU FKP database which makes it possible for researchers to work on FKP recognition. Consequently, lot of progress on FKP recognition has been achieved in recent years.

The performance of an identification system depends on the original FKP image and the enhancement algorithm in order to obtain an enhanced image. Therefore the contrast enhancement appeared as a principal field in image enhancement for both human and computer vision. It is widely used for medical image processing and as a preprocessing step [5]-[6].

The histogram equalization (HE) is a very popular technique for contrast enhancement of images [7]-[8]. It is the most commonly used method due to its simplicity and comparatively better performance compared to almost all types of images. HE performs its operation by remapping the gray levels of the image based on the probability distribution of the input gray levels [9]. Many researchers have already achieved studies based on histogram equalization allowing several methods such as HE, AHE, CLAHE, DHE, BPDFHE to appear the ability of these techniques to ameliorate the quality of tested images and improve the performance of biometric recognition system to identify persons.

The rest of the paper was organized as follows: The FKP histogram equalization algorithms were introduced in section 2; Section 3, presents the performance metrics however, section 4 gave the experimental results and finally, our main conclusion were drawn in section 5 before presenting our future perspectives.

II. Overview of Histogram Equalization Methods

A Histogram Equalization

The Histogram Equalization is a technique applied for a general contrast improvement. This process is consists in

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adjusting the intensity which is generally distributed across the image.
A gray scale image (x) is considered to be the number of occurrences of the gray level I and the probability function of occurrence of a pixel of level i in this image noted (x) expressed in through the following equation [10].

$$p_x(i) = p(X = i) = \frac{n_i}{n}, 0 \le i \prec L \qquad (1)$$

Fig.1 Original FKP image / FKP image after HE

B. Dynamic Histogram Equalization

The Dynamic Histogram Equalization (DHE) is a neat contrast enhancement technique based on histogram equalization (HE) method.

This (DHE) technique takes control over the consequence of the usual HE therefore it performs the enhancement of an image without generating any loss of its details [11].

Fig.2 Original FKP image / FKP image after DHE

C. Contrast Limited Adaptive Histogram Equalization (CLAHE)

The Contrast Limited Adaptive Histogram Equalization is a modified part of the adaptive histogram equalization. In this process, the enhancement function is applied over all the neighboring pixels and a transformation function is then derived.
This algorithm calculates the global histogram of a complete image. The CLAHE divides the original image into background regions. Figure 4 shows the result of the FKP feature enhancement by applying CLAHE [10, 12].

Fig.3 Original FKP image / FKP image after CLAHE

D. Adaptive Histogram Equalization Method (AHE)

The Adaptive Histogram Equalization algorithm is defined as a modified part of the Histogram equalization technique.
In this method, the enhancement process is applied over a precise region of any image and regulates the contrast according to the neighbor pixels. Afterwards the histogram is divided into some predefined parts, before adjusting the intensity of that part and consistently distributing into gray scale image [10].

Fig.4 Original FKP image / FKP image after AHE

E. Brightness Preserving Dynamic Fuzzy Histogram Equalization (BPDFHE)

The BPDFHE method uses the image histogram in such a way that no remapping of the histogram peaks takes place.
Only the gray level values are redistributed in the valley portions amongst two successive peaks.

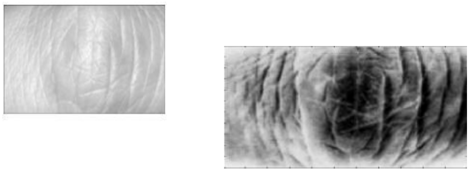

Fig.5 Original FKP image / FKP image after BPDFHE

III. Performance Metrics

A. *Mean Square Error (MSE)*

The MSE represents the cumulative squared error between the enhanced and the original FKP images. The best algorithm can be adopted if it produces lower MSE value. The MSE is calculated using this equation: [23]

$$MSE = \frac{\sum_{M,N} \left[I_1(m,n) - I_2(m,n) \right]^2}{M * N} \qquad (2)$$

where I1 and I2 indicate the original and the enhanced images, respectively. The size of the input images must be same and are denoted by M _ N.

B. Pea*k Signal to Noise Ratio (PSNR)*

The PSNR is defined as the ratio between the high power of a signal and the power of the noise that affects the image quality. The best algorithm can be adopted if it produces higher PSNR values
The following equation defines the PSNR [13]:

$$PSNR = 20\log_{10}\left(\frac{2^{\beta}-1}{\sqrt{MSE}}\right) \qquad (3)$$

Where B represents the bits per example

C. *The Root Mean Square Error (RMSE)*

The RMSE is a frequently used measure of the difference between values predicted by a model and the values actually observed from the environment that is being modeled. These individual differences are also called residuals, and the RMSE serves to aggregate them into a single measure of predictive power.

$$RMSE = \sqrt{MSE}$$

(4)

To evaluate the performance of various histogram equalization methods, we use four performance parameters (PSNR, MSE and RMSE). The obtained results are shown in the following tables and figures.

TABLE I COMPARATIVE STUDY OF PSNR FOR HISTOGRAM EQUALIZATION METHODS

Gallery & Lobe classes	**FKP image**	**PSNR**				
		HE	***DHE***	***CLAHE***	***AHE***	***BPDFHE***
1	1_1.jpg	8.87	16.13	12.34	60.51	23.84
2	1_2.jpg	8.99	16.71	12.06	60.77	23.83
3	1_3.jpg	9.04	16.95	12.03	61.21	25.55
4	1_4.jpg	8.50	16.11	12.40	60.23	23.28
5	1_5.jpg	8.94	16.38	12.68	60.70	23.24
6	1_6.jpg	9.05	17.08	12.22	61.14	23.84
Average1		8.89	16.56	12.28	60.76	23.93
7	1_1.jpg	8.87	16.37	12.44	59.73	28.58
8	1_2.jpg	9.10	15.69	12.96	60.37	25.77
9	1_3.jpg	8.85	16.06	12.56	60.36	26.28
10	1_4.jpg	9.03	15.70	13.26	60.34	29.28
11	1_5.jpg	9.03	15.94	12.98	60.55	28.72
12	1_6.jpg	8.87	16.30	12.44	59.73	26.44
Average2		8.95	16.01	12.77	60.18	27.51
Average		8.92	16.28	12.52	60.47	25.72

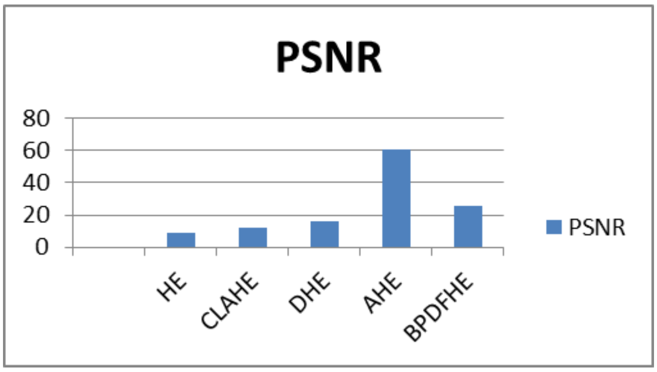

Fig.6 Comparison of PSNR values.

In terms of PSNR, HE, DHE, CLAHE, DHE and BPDFHE give bad results. For example, the HE gives the lowest PSNR value 8.92. DHE, CLAHE and BPDFHE have 12.52, 16.28, and 25.72 respectively.(see table II and figure 3).Therefore , the AHE improve the contrast of tested FKP image and reveals the good quality of obtained image after processing with AHE and the capacity of this method to reduce noise and artifacts.

TABLE II COMPARATIVE STUDY OF MSE FOR HISTOGRAM EQUALIZATION METHODS

Gallery & Lobe classes	**FKP image**	**MSE**				
		HE	***DHE***	***CLAHE***	***AHE***	***BPDFHE***
1	1_1.jpg	8492.76	1594.35	3820.90	0.05	270.24
2	1_2.jpg	8267.41	1397.66	4071.58	0.05	271.30
3	1_3.jpg	8267.41	1321.82	4098.48	0.04	182.48
4	1_4.jpg	9239.09	1601.69	3767.53	0.06	307.49
5	1_5.jpg	8361.36	1505.53	3531.98	0.05	310.55
6	1_6.jpg	8143.30	1283.24	3930.70	0.05	270.24
Average1		8461.88	1450.71	3870.19	0.05	268.71
7	1_1.jpg	8489.55	1534.77	3728.94	0.06	90.72
8	1_2.jpg	8059.15	1764.19	3310.56	0.06	173.18
9	1_3.jpg	8522.61	1620.79	3631.67	0.06	154.32
10	1_4.jpg	8179.64	1762.63	3087.50	0.06	77.30
11	1_5.jpg	8185.43	1667.91	3298.97	0.05	87.91
12	1_6.jpg	8489.55	1534.77	3728.94	0.06	148.75
Average2		8320.98	1647.51	3464.43	0.05	122.03
Average		*8391.43*	*1549.11*	*3667.31*	*0.05*	*195.37*

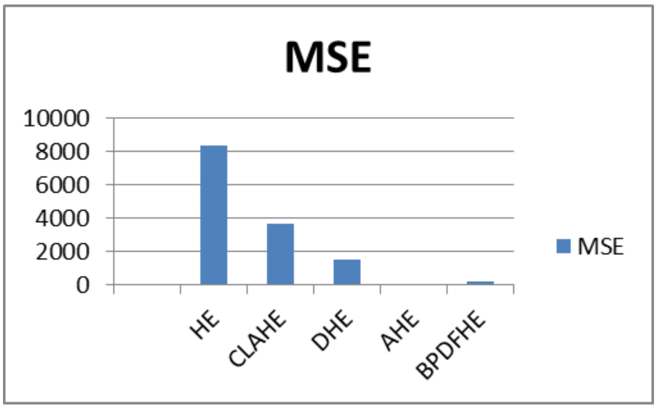

Fig.7 Comparison of MSE values.

According to table III, AHE algorithm reveals with the smallest MSE value. Consequently, AHE algorithm gives the best results in comparison with the others. In the other side, HE, CLAHE, DHE and BPDFHE give these values 8381, 3667, 1549 and 195 respectively. So, the obtained results showing in table III and figure 4 reveal the efficiency of AHE to enhance the contrast of FKP image and ameliorate its quality.

TABLE III COMPARATIVE STUDY OF RMSE FOR HISTOGRAM EQUALIZATION METHODS

Gallery & Lobe classes	**FKP image**	**RMSE**				
		HE	***DHE***	***CLAHE***	***AHE***	***BPDFHE***
1	1_1.jpg	92.15	39.92	61.81	0.24	16.43
2	1_2.jpg	90.92	37.38	63.80	0.23	16.47
3	1_3.jpg	90.35	36.35	64.01	0.22	13.50
4	1_4.jpg	96.12	40.02	61.38	0.24	17.53
5	1_5.jpg	91.44	31.28	59.43	0.23	17.62
6	1_6.jpg	90.24	35.82	62.69	0.22	16.43
Average1		91.87	36.79	62.18	0.23	16.33
7	1_1.jpg	92.13	39.17	61.06	0.26	9.52
8	1_2.jpg	89.77	42.00	57.53	0.24	13.15
9	1_3.jpg	92.31	40.25	60.26	0.24	12.42
10	1_4.jpg	90.44	41.98	55.56	0.24	8.79
11	1_5.jpg	90.47	40.84	57.43	0.24	9.37
12	1_6.jpg	92.13	39.17	61.06	0.26	12.19
Average2		91.20	40.56	58.81	0.24	10.90
Average		91.53	38.67	60.49	0.235	13.61

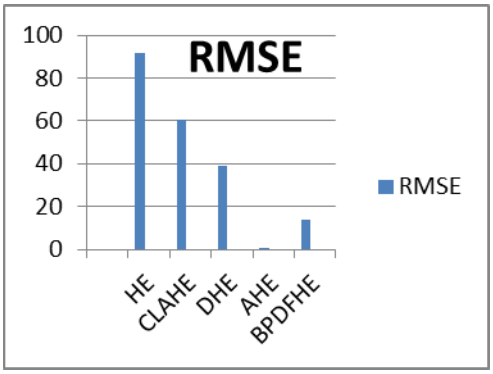

Fig.8 Comparison of RMSE values

For the parameter RMSE, the algorithm is considered better for smaller averages. For example the AHE method will perform better than the others histogram equalization methods (HE, DHE, CLAHE and BPDFHE) with the obtained values 91, 38, 60 and 13.

These different metrics reveal that the AHE algorithm performs better than the others in term of improving the quality of tested FKP images and reducing the noise of the original image. This enhancement let to facilitate the features extraction.

TABLE VI COMPARATIVE STUDY OF QI [14] FOR HISTOGRAM EQUALIZATION METHODS

Gallery & Lobe classes	**FKP image**	**QI**				
		HE	***DHE***	***CLAHE***	***AHE***	***BPDFHE***
1	1_1.jpg	0.40	0.005	$3.38.10^{-5}$	0.69	0.39
2	1_2.jpg	0.42	0.005	$4.50.10^{-5}$	0.72	0.43
3	1_3.jpg	0.42	0.004	$4.93.10^{-5}$	0.83	0.46
4	1_4.jpg	0.42	0.006	$5.41.10^{-5}$	0.87	0.43
5	1_5.jpg	0.42	0.004	$5.07.10^{-5}$	0.76	0.42
6	1_6.jpg	0.41	0.005	$4.30.10^{-5}$	0.82	0.41
Average1		0.41	0.005	$4.59.10^{-5}$	0.67	0.42
7	1_1.jpg	0.40	0.006	$2.64.10^{-5}$	0.74	0.30
8	1_2.jpg	0.39	0.005	$4.52.10^{-5}$	0.85	0.37
9	1_3.jpg	0.39	0.006	$3.50.10^{-5}$	0.75	0.37
10	1_4.jpg	0.40	0.005	$3.27.10^{-5}$	0.79	0.31
11	1_5.jpg	0.40	0.005	$2.91.10^{-5}$	0.86	0.28
12	1_6.jpg	0.39	0.006	$4.57.10^{-5}$	0.72	0.36
Average2		0.395	0.0055	$3.56.10^{-5}$	0.78	0.33
Average		0.40	0.005	$4.07.10^{-5}$	0.72	0.39

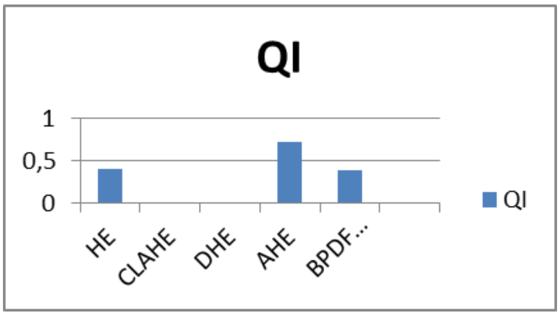

Fig.9 Comparison of QI values.

Regarding table VI and Figrure8, the AHE method shows the best FKP image quality with 0.72 values, whereas, the DHE indicates the bad results with 0.005 values.

From the obtained results, the AHE algorithm reveals the best results from the various parameters, so, it will be employed in our future work in order to enhance the EER value and ameliorate the efficiency of FKP recognition system.

CONCLUION

The image quality has a crucial role in the FKP image identification. In order to improve the FKP image quality, various pre-processing methods are available. In this research, we present the different histogram equalization methods (HE, CLAHE, DHE, BPDFHE and AHE) in order to reduce the noise of captured image and improve the quality. These approaches are evaluated by four performance metrics (PSNR, MSE, RMSE and QI). For all these metrics, we conclude that the AHE gives good results compared to other methods. Consequently, the AHE is efficient for reducing the noise and improving the FKP image quality and it will be the good pre-processing solution to use in our future work.

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