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ANALYSIS ON DIRECTIONAL FILTER BANK FOR PRESERVING TEXTURE IMAGE

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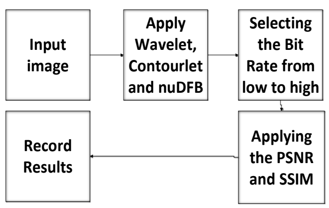
Graphical abstract



Abstract

Directional filterbank such as contourlet become popular due its ability to capture two dimensional curves efficiently. In this work, transform with directional filterbank is tested to preserve texture information in texture images. Our initial hypothesis is that, transform with directional filter bank will be able to preserve texture information efficiently when compare to wavelet. However this hypothesis is limited if the texture information contained in the images consist of directional information. Textures in this work are referring to repetition pattern in an image. The directional filterbank selected for testing are Non-uniform Directional filterbank (NuDFB) and Contourlet. The texture images are applied with both transforms and the non-linear approximation method is used to capture the significant coefficients of the transformed pixels. The implementations are then compared with wavelet transform as a benchmark. From the experimental result it can be seen that wavelet implementation still managed to outperform directional filter bank transform at higher bit rate. In low bit rate however some significant improvement can be seen from the Peak Signal to noise ratio (PSNR) especially to texture images that contains directional information. In term of Structural Similarity it supports the results of Peak Signal to noise ration with a rare different values. As a conclusion, the directional filterbank transform able to preserve texture information in texture images especially the directional information but limited to a very low bit rate data.

Keywords: Directional filterbank, texture image

1.0 INTRODUCTION

Texture images through time need a significant representation in the digital world. For period of time the Discrete Wavelet Transform DWT was one of the best representing tools of image digitally. DWT can perform its transform by a significant way that split frequencies of images and represent image perfectly[1]. Texture images have more information which results the need of higher frequency preserving. The way of using filters in the DWT makes it widely used for many of imaging applications which serves the Texture images needs. DWT in two dimensions (2-D) uses the filters in a way that parts the frequency of image according to its value and to its dimension. The dimensions are Horizontal and vertical, and the frequency according to its value for each dimension. In spatial domain. DWT makes four parts of frequency sections which they are: 1) the diagonal region which is formed of applying highpass filter for each horizontal and vertical (HH). 2) Horizontal region which is resulted of applying highpass filter for horizontal and lowpass filter for vertical (HL). 3) Vertical region which is formed of applying lowpass filter for horizontal and highpass filter for vertical (LH). 4) Detailed region which is the result of applying lowpass filter for both horizontal and vertical (LL) (coarse region). Moreover DWT can perform its transform for more than one level. For the first level the full image will be decomposed then for the second level the detailed region will be the base of the second level. For the third level the detailed region resulted from the second level will be the base.

Figure 1 shows the regions partition for the wavelet transform for three level decomposition.

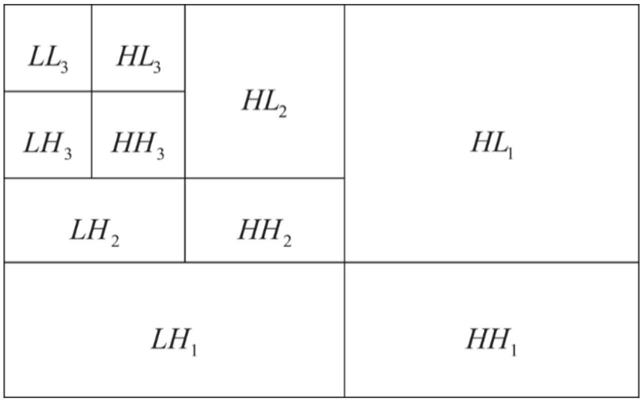


Figure 1 DWT 3 level decomposition[2]

This partition gives a singular pointed capturing of data of the image. Frequency partition in DWT provides a multiresolution property for the transform which is necessary for texture images processing. More resolution used in the transform means that more detailed data processing is required for texture images that have more important data. Moreover it is suitable for some application such as nonlinear approximation (NLA), compression and denoising. With all that advantages but wavelet still cannot capture the directional data of image. Which requires to have a transform with directionality for capturing directional data of image which is provided by Directional Filter Banks (DFB)[3].

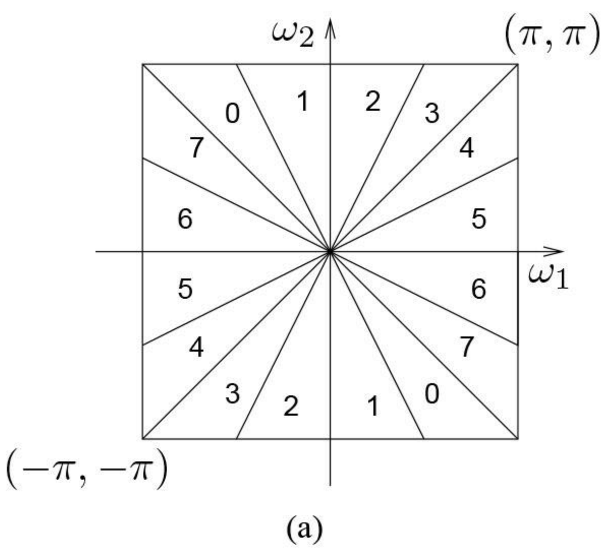


Figure 2 the DFB frequency partition [4]

Directional Filter Bank (DFB) introduced by Bamberger and Smith [4] provides a frequency partition according to multidirections. This filter bank creates a new area for researchers to have the directionality in their transforms. DFB have a good filtering for the high frequencies regions but it shows some weakness for the lowpass region. Figure 2 shows the partition of DFB.

DFB provides the multidirection property but there are still to overcome low frequencies regions to be solve. The best transforms that have the suitable format are Contourlet Transform (CT) [5] and the Non Uniform Directional Filter Bank (NUDFB) . Each transform has a different way of solving low frequency capturing of DFB.

CT is a well-known transform that is used for the same applications of wavelet with additional property of directionality. The idea of the CT is to capture the high frequencies with using the DFB for directionality and also capturing the low frequencies by Laplacian Pyramids (LP)[6].

In the CT the responsible of the multiresolution is the LP. Applying more resolution level requires applying LP more times as denoted by the dots in Figure 3. After applying the LP then it applies the DFB for directionality. In this process more coefficients are created than in the original image size which we call "redundancy". This redundancy is unwanted in many applications of image processing such as compression and denoising. CT is the base of other similar transforms such as Non-subsampled CT (NSCT)[7] which capture data of texture images more effectively but has much more redundancy. CT has good feature for preserving texture images and capturing data, however it has high redundancy complexity.

NUDFB is a transform that has multiresolution and multidirection property with less redundancy and complexity. The key of NUDFB is using the DWT to be the base of multiresolution property instead of LP in the CT. DWT is non redundant transform as well DFB. This will resulted to a non-redundant transform. Figure 4 shows the spatial domain of the nuDFB.

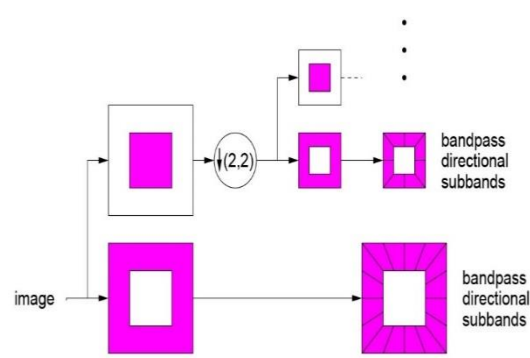


Figure 3 The CT process

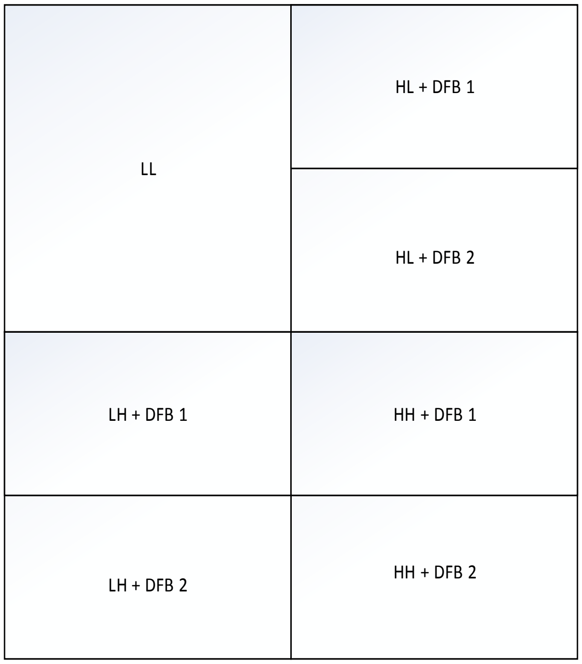


Figure 4 nuDFB spatial decomposition

nuDFB uses a certain number of directional levels for each level of resolution unlike CT where the number of directional level can be adjusted. NuDFB uses six levels of DFB for each resolution level. As a result less complexity will be obtained but with limited directions. NuDFB has seven levels of frequency partitions. Six of them with DFB and the coarse partition just as in DWT. The LL level will be applied with DFB if more levels are required. nuDFB has more advantage of less complexity and redundancy compare with CT which gave it a larger place of preserving texture images. In this paper we compare the performance of the three transforms base on Nonlinear Approximation (NLA).

2.0 METHOD

NLA is a method of measuring the performance of a system by comparing the original signal and the production of that system. It uses numerical computation that compute a complicated functions (target function) with an easier way to compute called the approximant [2]. For digital systems NLA can give a good results of any systems performance, which makes it popular in image processing. For this reason we used it in our work.

The steps followed to get the results in this paper as shown in Figure 5. The level of the resolution level is five for the three transforms. For the level of the directionality is 6 for both CT and nuDFB. The directional filter bank is applied at two resolution levels. We applied each of CT, DWT and nuDFB separately. After getting the image coefficients based on each transform then we chose the bit rate for testing. We start applying low bit rate with 0.025%. In this step we take only a small part of the coefficients of the image. Then we reconstruct the image to have reconstructed image for comparing with the original. After getting the reconstructed image with the chosen bit rate, we increase the bit rate to 0.05 until 0.5 chosen maximum because we only focus on low bit rate. Then we calculate the performance using PSNR and SSIM.

The first method is by using PSNR. PSNR is based on the peak signal to calculate the similarity of a reconstructed image. PSNR estimate the error of the produced image compare with the original image. While SSIM is used to compare based on structural similarity to support the PSNR result. Second method is SSIM which detects the change of structural information of the image which gives more accurate results. For texture images using these methods is useful for performance testing. SSIM is a good tool for testing the performance of the transform. PSNR deals with the estimated error which deals based on the coefficient of image and SSIM which deals with the structure of image. These two deferent methods will gave the full image of the transform performance. After getting the results of the resulted image of that bit rate then we increase the value and repeat the process. The images used are mainly texture image types and the images that have directional information. With the increasing of the bit rate used the better NLA will occur. For the DFB the expected is to have a good result at the low bit rate because of its excellence in the high pass region of frequencies.

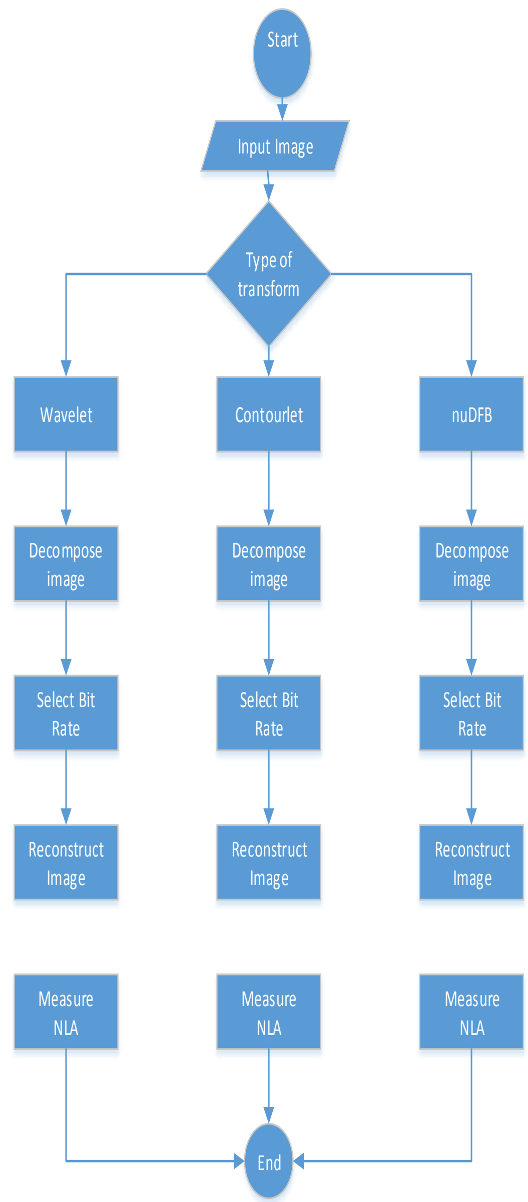


Figure 5 experimental setup

3.0 RESULTS AND DISCUSSION

Results in Table 1 based on 5 levels decomposition with 2 level directional information, the directionality is 6. The underlined results in Table 1 show the comparative results between the nuDFB and CT where the bold results shows the highest results including WT. Results shows that for texture images in the low bit rate the NLA has a high value but not always higher than DWT. The comparison of both CT and nuDFB shows that these transforms behaviors is almost the same. The difference between both transforms doesn't show much different between both of them although they are differently structured. For some images like Zoneplate, contourlet has the highest values. For nuDFB for the Fingerprint 1 image has the highest values for the low bit rate. It might results a better results if more level of DFB used in the transform, because DFB is the responsible of the high frequency band in image. When applying NLA we depend on the chosen bit rate. It is clear from results that nuDFB performance almost parallel with WT at higher bit rate which give it advantage over CT. NLA depend on the chosen bit rate to reduce the pseudo Gibbs effect in low frequency data, only 2 levels of directional decomposition are applied.

From this result we can say that these two multidirectional and multiresolution transform can be used for preserving texture images equally. For Finger print images nuDFB has better results. In some cases the nuDFB has the highest values of PSNR and SSIM. In high bit rate for Fingerprint images nuDFB behaves similar to the wavelet transform. This give the nuDFB more advantage over CT. In some cases like in the fingerprint 4 the nuDFB has higher values than CT of PSNR at the lowest two bit rate but in the SSIM the higher value was for CT. That means the errors of the higher coefficients is lower for the nuDFB but for the SSIM CT is better.

In most cases the PSNR and SSIM are in almost the same. CT and nuDFB are both good transforms for capturing the texture in images, they both give a satisfied results. The selection of transform is for example, for compression better we use nuDFB due to nonredundancy.

4.0 CONCLUSION

This paper shows the efficiency of the multidirectional multiresolution transform CT and nuDFB compare to the multiresolution transform which is DWT in this paper. It is clear that the images that contain directional information needs the directionality to capture data more effectively. The performance is the same for directional based transforms nuDFB and CT, nuDFB is a better option due to its non-redundant and low complexity.

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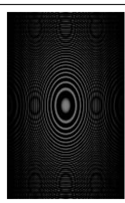
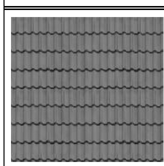
APPENDIX

TABLE OF RESULTS

Table 1 Comparing DWT, CT and nuDFB using NLA (PSNR & SSIM)

Image	Bit Rate %	PSNR			SSIM		
		nuDFB	CT	WT	nuDFB	CT	WT
 Texture	0.025	**16.83**	16.23	**16.87**	**0.47**	0.46	**0.49**
	0.05	**18.44**	17.97	18.13	**0.63**	0.61	**0.66**
	0.1	**20.24**	20.06	**20.45**	**0.77**	0.76	**0.8**
	0.15	**21.43**	21.09	**22.03**	**0.84**	0.83	**0.87**
	0.2	**22.19**	22.11	**23.42**	0.88	0.88	**0.92**
	0.25	**24.09**	23.16	**24.81**	0.91	0.91	**0.94**
	0.3	**24.73**	24.27	**26.28**	0.93	0.93	**0.96**
	0.35	**25.82**	25.21	**27.29**	**0.95**	0.94	**0.97**
	0.4	**27.06**	26.22	**29.11**	0.96	0.96	**0.98**
	0.45	**28.09**	26.88	**30.56**	0.97	0.97	**0.99**
	0.5	**29.21**	27.85	**32.04**	**0.98**	0.97	**0.99**
 Zone plate	0.025	13.99	**14.29**	13.16	0.44	**0.51**	0.35
	0.05	15.89	**16.57**	14.28	0.62	**0.74**	0.55
	0.1	17.77	**19.85**	16.95	0.79	**0.91**	0.78
	0.15	19.31	**22.48**	18.95	0.87	**0.96**	0.89
	0.2	20.83	**24.53**	21.64	0.91	**0.98**	0.95
	0.25	21.17	**26.45**	24.33	0.94	**0.99**	0.97
	0.3	22.37	**28.65**	27.35	0.96	**0.99**	**0.99**
	0.35	23.72	**29.75**	**30.37**	0.97	**0.99**	**0.99**
	0.4	25.03	**31.81**	**33.28**	0.98	**1**	**1**
	0.45	26.95	**33.71**	**36.65**	0.99	**1**	**1**
	0.5	28.47	**35.61**	**40.23.**	0.99	**1**	**1**
 Roof texture	0.025	28.64	**29.13**	**30.01**	0.74	**0.75**	**0.77**
	0.05	30.74	**31.3**	**32.24**	0.78	**0.79**	**0.81**
	0.1	33.15	**33.37**	**34.35**	0.83	0.83	**0.86**
	0.15	34.67	**34.7**	**35.84**	0.87	0.87	**0.9**
	0.2	**36.67**	35.83	**37.18**	0.9	0.9	**0.92**
	0.25	**37.41**	36.88	**38.46**	**0.93**	0.92	**0.94**
	0.3	**38.72**	37.89	**39.74**	**0.94**	0.93	**0.96**
	0.35	**40.02**	38.88	**41.04**	**0.96**	0.95	**0.97**
	0.4	**41.38**	39.87	**42.39**	**0.97**	0.96	**0.98**
	0.45	**42.81**	40.87	**43.8**	**0.98**	0.97	**0.98**
	0.5	**44.32**	41.89	**45.31**	**0.98**	0.97	**0.99**

 Grass	0.025	**17.24**	16.99	**17.25**	**0.49**	0.48	**0.48**
	0.05	**19.83**	18.85	**18.44**	0.65	0.65	**0.66**
	0.1	**20.68**	20.34	**20.75**	0.79	**0.8**	**0.81**
	0.15	**21.96**	21.73	**22.4**	0.86	0.86	**0.88**
	0.2	23.16	**23.2**	**23.93**	0.9	0.9	**0.92**
	0.25	**24.35**	24.33	**25.21**	0.92	**0.93**	**0.95**
	0.3	**25.46**	25.39	**26.79**	0.94	**0.95**	**0.96**
	0.35	26.33	**26.36**	**28.32**	0.96	0.96	**0.97**
	0.4	**27.51**	27.47	**29.69**	0.97	0.97	**0.98**
	0.45	**28.63**	28.56	**31.07**	0.98	0.98	**0.99**
	0.5	**29.93**	29.48	**32.55**	0.98	0.98	**0.99**
 Bark	0.025	**17.24**	16.99	**17.25**	**0.49**	0.48	**0.48**
	0.05	**19.83**	18.85	**18.44**	0.65	0.65	**0.66**
	0.1	**20.68**	20.34	**20.75**	0.79	**0.8**	**0.81**
	0.15	**21.96**	21.73	**22.4**	0.86	0.86	**0.88**
	0.2	23.16	**23.2**	**23.93**	0.9	0.9	**0.92**
	0.25	**24.35**	24.33	25.21	0.92	**0.93**	**0.95**
	0.3	**25.46**	25.39	26.79	0.94	**0.95**	**0.96**
	0.35	26.33	**26.36**	28.32	0.96	0.96	**0.97**
	0.4	**27.51**	27.47	29.69	0.97	0.97	**0.98**
	0.45	**28.63**	28.56	31.07	0.98	0.98	**0.99**
	0.5	**29.93**	29.48	32.55	0.98	0.98	**0.99**
 Finger print 1	0.025	**17.2**	15.84	17.09	0.39	0.39	**0.4**
	0.05	**18.16**	17.11	17.73	**0.5**	0.49	**0.51**
	0.1	**19.37**	18.72	**19.61**	**0.61**	0.6	**0.63**
	0.15	**20.83**	20.19	**20.96**	**0.68**	0.66	**0.7**
	0.2	**21.83**	21.44	**22.34**	**0.73**	0.71	**0.75**
	0.25	**23.61**	22.27	**23.76**	**0.78**	0.75	**0.79**
	0.3	**24.79**	23.36	**24.86**	**0.81**	0.78	**0.83**
	0.35	**25.56**	24.28	**26.31**	**0.84**	0.81	**0.86**
	0.4	**26.91**	25.13	**27.77**	**0.87**	0.83	**0.89**
	0.45	**28.04**	25.96	**29.09**	**0.9**	0.85	**0.92**
	0.5	**29.38**	26.95	**30.54**	**0.92**	0.88	**0.94**
	0.025	22.79	**22.81**	23.13	0.65	**0.66**	**0.67**
	0.05	25.08	**25.38**	**26.27**	0.74	**0.75**	**0.78**
	0.1	28.36	**28.64**	**30.01**	0.84	0.84	**0.87**
	0.15	30.54	**30.89**	**32.59**	0.89	0.89	**0.92**
	0.2	32.25	**32.67**	**34.76**	0.92	0.92	**0.95**
	0.25	33.75	**34.21**	**36.71**	0.94	0.94	**0.97**
	0.3	35.16	**35.57**	**38.54**	0.95	**0.96**	**0.98**

Finger print2	0.35	36.54	**36.82**	**40.28**	0.96	**0.97**	**0.99**
	0.4	37.94	**37.99**	**42**	0.97	**0.98**	**0.99**
	0.45	**39.37**	39.12	**43.73**	0.98	0.98	**0.99**
	0.5	**40.86**	40.23	**45.51**	**0.99**	0.98	**1**
	0.025	22.58	**22.87**	**23.2**	0.67	**0.68**	**0.69**
	0.05	25.17	**25.54**	**26.41**	0.75	**0.76**	**0.78**
	0.1	28.66	**28.87**	**30.19**	0.84	0.84	**0.87**
	0.15	30.87	**31.15**	**32.74**	0.89	0.89	**0.92**
	0.2	32.54	**32.69**	**34.87**	0.92	**0.93**	**0.95**
	0.25	34.02	**34.49**	**36.79**	0.94	**0.95**	**0.97**
	0.3	35.4	**35.85**	**38.58**	0.96	0.96	**0.98**
	0.35	36.75	**37.1**	**40.29**	0.97	0.97	**0.98**
Finger print 3	0.4	38.12	**38.26**	**41.97**	0.97	**0.98**	**0.99**
	0.45	**39.52**	39.4	**43.65**	0.98	0.98	**0.99**
	0.5	**40.99**	40.52	**45.38**	0.99	0.99	**1**
	0.025	**23.37**	23.23	**23.66**	0.68	**0.69**	**0.71**
	0.05	**26**	25.85	**25.05**	0.78	**0.79**	**0.81**
	0.1	29.08	**29.28**	**30.53**	0.87	0.87	**0.9**
	0.15	31.28	**31.55**	**33.26**	0.91	0.91	**0.94**
	0.2	32.91	**33.46**	**35.59**	0.94	0.94	**0.96**
	0.25	34.53	**35.1**	**37.67**	0.95	0.95	**0.97**
	0.3	36.08	**36.57**	**39.62**	0.96	0.96	**0.98**
	0.35	**37.59**	37.35	**41.56**	0.97	0.97	**0.99**
	0.4	**39.17**	39.02	**43.45**	0.98	0.98	**0.99**
	0.45	**40.79**	40.24	**45.3**	0.98	0.98	**0.99**
Finger print 4	0.5	**42.56**	41.43	**42.56**	**1**	0.99	**0.99**
	0.025	22.03	**22.21**	**22.5**	0.64	**0.65**	**0.67**
	0.05	24.66	**24.86**	**26.21**	0.73	**0.75**	**0.77**
	0.1	27.77	**28.24**	**29.9**	0.83	0.83	**0.87**
	0.15	30.05	**30.57**	**32.54**	0.88	**0.89**	**0.92**
	0.2	31.8	**32.42**	**34.75**	0.92	0.92	**0.95**
	0.25	33.36	**34**	**36.74**	0.94	0.94	**0.97**
Finger print 5	0.3	34.82	**35.4**	**38.62**	0.95	**0.96**	**0.98**
	0.35	**43.94**	42.2	**40.44**	0.96	**0.97**	**0.99**
	0.4	37.67	**37.9**	**42.2**	0.97	**0.98**	**0.99**
	0.45	**39.14**	39.07	**43.94**	0.98	0.98	**0.99**
	0.5	**40.66**	40.21	**45.76**	0.98	0.98	**1**