INCREASING THE NUMBER MINUTIAE EXTRACTED IN FINGERPRINT IMAGES BY IMPLEMENTING BIORTHOGONAL WAVELET FUSION BASED ON REGIONAL VARIANCE

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ABSTRACT

Biometric identification systems usually use fingerprint images. The higher quality of fingerprint image, the more accurate identification of persons is. Finger prints provide complementary and redundant information Usually, two or more fingerprint images are captured from the person in different positions, and the fusion process of images usually increase the information quantity of the fused image compared to the original ones. Different fusion approaches exist. The present paper aims to increase the number of fingerprint minutiae by implementing biorthogonal wavelet fusion of fingerprint images based on the regional variance. The obtained results are analyzed in terms of minutiae extracted from the original and the fused fingerprint images. Simulations show that the number of minutiae detected in the fused fingerprint image is increased.

***Keywords*:** biometric, fingerprint, regional fusion, biorthogonal wavelet transform, minutiae

1. INTRODUCTION

Fingerprint recognition is used to **identify or confirm the identity of an individual based on the comparison of two fingerprints**. Its quality has a high importance in accurate extraction of minutiae requires images of high quality. Different fingerprint images obtained in various positions may have complementary information. These images taken from the same source are first aligned accorded to a base one (Xi and Geng, 2018), and then fusion techniques (Kaur *et al.*, 2021) are applied to increase information in it. Wavelet technology is widely used for image fusion (Patil, 2016; Kaur *et al.*,

2021) by employing the pixel-level method which separates connection between pixels and region-based method where different image regions are extracted and fused based on regional characteristics (Bikash *et al.*, 2019). Current studies in this field show that image fusion based on regional characteristics performs more fusion effects than pixel–level fusion without regional division (Rane *et al.*, 2017).

The minutiae are the points the fingerprint recognition system uses for comparison or identification as they are found on the surface tips of a human finger. The number of images is important for an accurate identification process. The present paper aims to fuse these fingerprint images left occasionally by an individual to increase the number of the minutiae. Usually, the image fusion is performed in the wavelet domain. Different approaches for image fusion exist as well as different wavelets used in these approaches. The approach of the chosen wavelet fusion is based on regional variance. In the present paper biorthogonal wavelets are used for image purposes. Every fused image undergoes to minutiae extraction. For every wavelet used in the fusion process, terminations and bifurcations are counted on fused fingerprint image and a comparison is done. The target is to increase number of minutiae.

Section two gives literature review, section three describes image fusion, section four briefly describes wavelets transform, section five informs about the proposed algorithm, experimental results are obtained and analyzed in section six. Finally, conclusions are done and future work is reported.

2. LITERATURE REVIEW

Biometric identification of individuals is widely used nowadays, and fingerprint-based identification is the most commonly used. Fingerprint recognition has been a proven method for personal identification, and the higher the image quality is, the better individual identification is. However, Hara (2009) says that there is still a lot of work to be done for a better quality of the fingerprint image. Fusion approach is widely used in image processing in different areas as computer vision, images taken from satellite, robot vision, in medical images, in vehicle guidance etc. (Kaur *et al*., 2021) analyze different methods of implementing fusion techniques in spatial and transformed domains by presenting their positive and negative sides. Although there is a lot of work in the field of fusion techniques for image processing, there is relatively little work on fusion in fingerprint images.

Maltoni (2009) treat the increase in fingerprint image quality when biometric information is obtained from various sources.

Singh *et al*., (2019) reviewed biometric fusion focusing on three questions: what to fuse, when to fuse, and how to fuse.

Leghari *et al*., (2021) a CNN based model for fusion of feature level of fingerprint image is proposed and implemented by implementing two schemes. The first scheme combines the features of fingerprint images and online signatures before the fully connected layers while the second scheme combines the features after the fully connected layers, comparing the obtained accuracy of each schema.

Gafurov *et al*., (2011) analyzed fingerprint fusion based on these three scenarios: a) two fingers captured by the same scanner; b) the same finger captured by two different scanners; and c) two fingers both captured by two different scanners. The authors concluded that fusion of different fingers both collected by different scanners are the best.

Alajlan *et al*., (2013) proposed a fuzzy adaptive genetic algorithm for the improvement of authentication performance of this multimodal biometrics computing the optimal weights required for fusion of matching scores from two modalities.

3. IMAGE FUSION

Images of the same scene obtained from single or heterogeneous sensors are processed using image fusion theory to increase information based on maximum combination of the obtained information yielding a complete and accurate description of the minutiae existing in the fingerprint images. The fused algorithm processes relevant information from two or more images usually taken in different positions into a single one, which contains most of the information from the source images (Gong *et al*., 2020). Figure 1 depicts a general schema of image fusion.

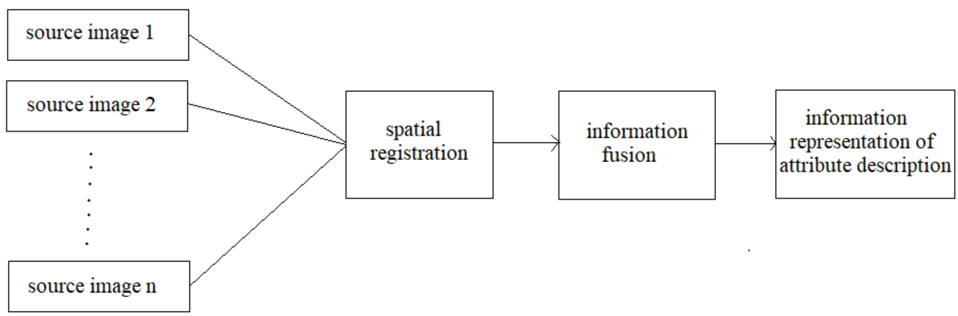

Fig. 11: Image fusion schema.

Information provided by multiple images modes is necessary to fuse the effective information in order to match the geometric positions of images analyzed in spatial domain (Gong *et al*., 2020; Enesi *et al*., 2021).

4. WAVELET DECOMPOSITION

Wavelets are oscillations which start at 0 up to some amplitude valueS, decreasing back to 0 as illustrated in Figure 2. Each scale component has a frequency range and carries a resolution matching its scale. Wavelets are convolved with the signal for analyzing it in time and frequency domain. A mother wavelet, shifted with the signal ranging from 0 to T, is multiplied with some portion of the signal. The result is integrated to obtain the wavelet coefficients (Bhataria and Shah 2018) as shown in Figure 3.

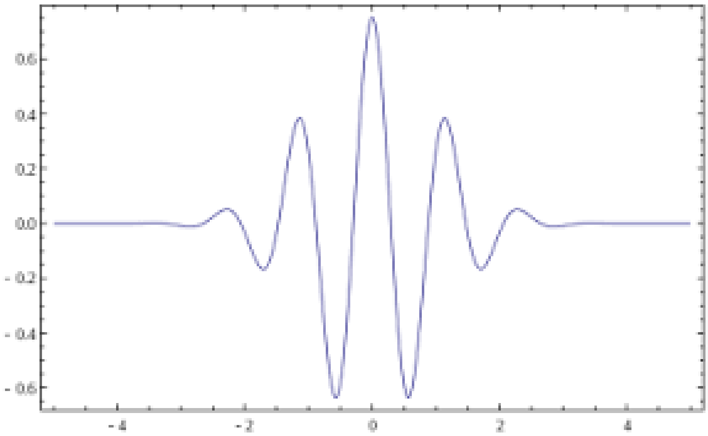

Fig. 12: Mother wavelet.

Wavelet transformation is a highly used for image processing purposes.

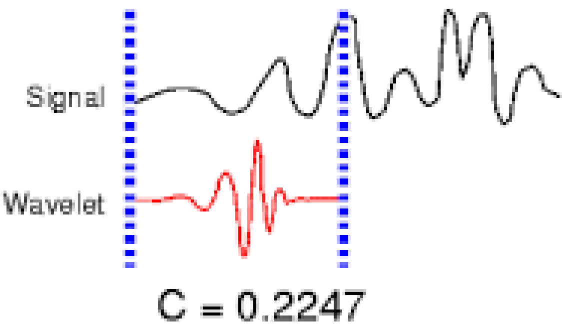

Fig. 13: Obtaining wavelet coefficients.

A mother wavelet has average 0. Usually, it is scaled by a factor ‘a’ and translated by a factor ‘b’, the general formula is presented in equation 1.

$$\psi_{a,T}(t) = \frac{1}{\sqrt{a}}\,\psi\left(\frac{t-T}{a}\right) \quad (1)$$

The wavelet transform of the signal y(t), denoted by $W_x(a, T)$ is presented in equation 2.

$$W_x(a,T) = \int_{-\infty}^{+\infty} y(t)\frac{1}{\sqrt{a}}\psi^{*}\left(\frac{t-T}{a}\right)dt \quad (2)$$

To design orthogonal wavelet basis, the conjugate mirror filter H(ω) is used and the relation is shown in equation 3.

$$\left|H_{\phi}(\omega)\right|^{2} + \left|H_{\phi}(\omega+\pi)\right|^{2} = 2 \quad (3)$$

where $H_{\phi}(0) = \sqrt{2}$

A conjugate mirror filter is used to construct orthogonal wavelet basis (Shaker, 2020). Scaling filter is used to determine the scaling function.

Regional image fusion based on wavelet transform

Regional feature refers to local or geometric features in an image (Gostashby and Nikolov, 2007). Correlation between neighborhoods pixels is considered for the regional fusion approach to evident the characteristics of the region and reducing the noise (Pajares and Cruz, 2004). The fusion process takes the appropriate approach for the two or more images to match as much it as can with each other to obtain local representation according to the characteristics of the image. Joint area representation is performed based on the two images’ regional representations. Respective regions of the source images, image union region and rules fusion determine the key aspects of fusion schema. Figure 4 depicts fusion of target and background region based on image segmentation.

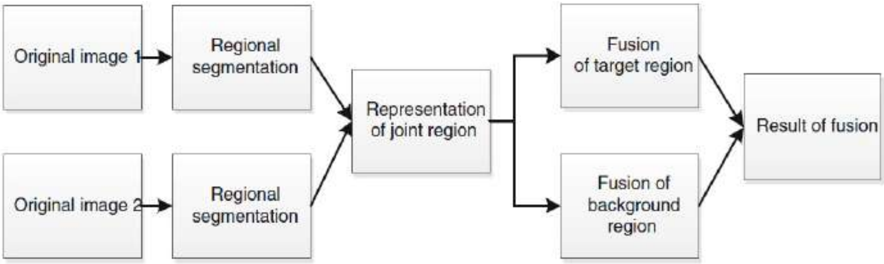

Fig. 14: Image fusion based on regional segmentation.

The block diagram of image fusion based on wavelet transform is in Figure 5 depicted.

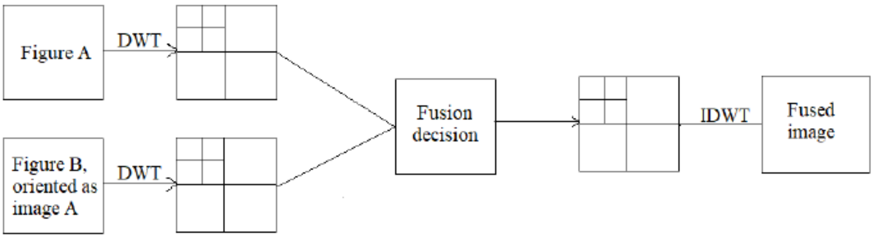

Fig. 15: Block diagram of image fusion based on DWT.

The wavelet transform of each image is performed to obtain low/high frequency components of the image. Decompositions layers are fused according to respective fusion algorithms and the fused wavelet pyramid is obtained. The reconstruction from the wavelet pyramid coefficients is the fused image (Gong *et al.*, 2020, Goshtasby and Nikolov, 2007).

The fusion process consists of: i) wavelet transform of the image in low/high frequency sub bands, ii) low frequency coefficients are obtained by applying the averaging method, iii) the variance of high frequency components is found applying a 3 x 3 sliding window and highest values are chosen as high frequency coefficients for image reconstruction, iv) IDWT is applied for fused image reconstruction (Gong *et al.*, 2020)(Naji, 2020).

5. PROPOSED IMAGE FUSION ALGORITHM

Fingerprint images which are to be synthesized are transformed in spatial domain first to match the geometric position as much as can (Agarwal and Bedi 2015).

STEP 1: Orientation and scaling of the second image according to the first one
Detect Features in both images Extract Features descriptors from every image Match Features descriptors Select corresponding points in every image Putative point matches are located Transform second one according the first one

Algorithm 1 Detailed pseudo-code for aligning the images

Due to limited accuracy of the spatial transformation process, artifacts are found around the edges of the transformed image.

DWT is applied on both images to obtain low and high frequency coefficients (Amolins *et al.*, 2007).

STEP 2: Image fusion based on biorthogonal DWT
Input: Both fingerprint images are obtained Decompose first image using DWT (level 1, different wavelets); vector C0 and matrix S0 are obtained The other image is decomposed using multi-scale dyadic DWT (level 3, mother wavelet is biorthogonal 6.8); vector C1 and matrix S1 are obtained Wavelet coefficients (c1 or c2) are obtained in the format: C(1) = A(1) H(1) V(1) D(1) C(2) = A(2) H(2) V(2) D(2) A 3 x 3 sliding window filter is applied and new coefficients are obtained Averaging of A(1) and A(2) values of each image yields in Low pass coefficients Maximum value of respective H, V and D of each image yields in High pass coefficients IDWT is applied on the obtained coefficients

Algorithm 2 Detailed pseudo-code for image fusion

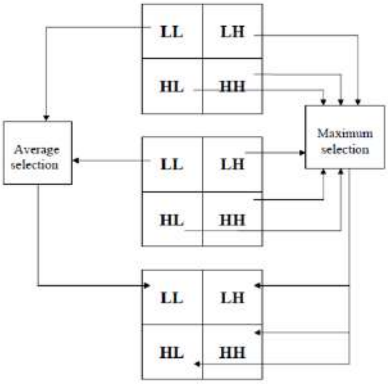

Fig. 16: Averaging and Maximum selections respectively on Low and High pass coefficients are used to obtain new coefficients.

Each decomposition layer is fused according to appropriate fusion algorithms, based on regional variance features of low/high frequency components. Fusion schema is in Figure 6 depicted. Different wavelets are implemented and the pyramid of fused wavelet is obtained for each one. IDWT is applied, and fused image are obtained. To calculate the number of terminations and bifurcations, an extraction minutiae algorithm is performed (Jiang *et al.*, 2015).

6. EXPERIMENTAL RESULTS

CASIA Fingerprint Image Database version 5.0 is a public database used for fingerprint images. Images are captured using URU4000 fingerprint sensor. Volunteers are asked to rotate the fingers with various levels of pressure. All fingerprint images are 8-bit gray level bmp files with resolution 328x356.

The three digits at the name of the image file compound the unique identifier of the person, L and R denotes the left and right hand, 0 stands for the thumb, 1 for the second finger, 2 for the third finger and 3 stands for the fourth finger. Fingerprint images are with damages and noises. The images considered in this paper are: 200_L0_1 and 200_L0_3, 220_L2_0 and 220_L2_1, 235_R2_1 and 235_R2_4, 257_R3_1 and 257_R3_4.

The second image is spatially transformed according to the first one based on the putative points (Figure 7).

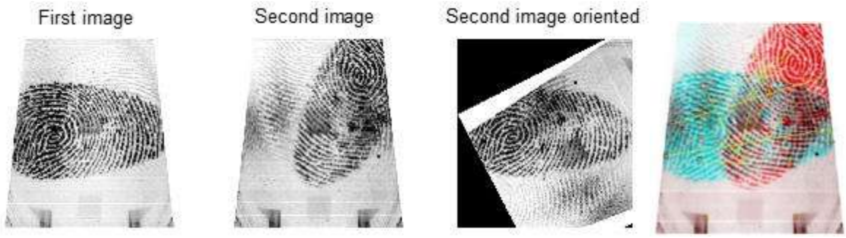

Fig. 17: Spatial transformation of 200_L0_3.bmp according to the 200_L0_1.bmp and putatively matched points

Wavelet transformation is used for fusion based on regional variance. The fused one for images 200_L0_1 and 200_L0_3 is in Figure 8 depicted.

Fig. 18: Fused image for 200_L0_1.bmp and the spatially transformed 200_L1_3.bmp.

Regarding the (Jiang *et al.*, 2015, Shaker, 2020) minutiae extraction is applied in fused fingerprint image, the number of terminations and bifurcations is counted. Figure 9 depicts minutiae extracted for fingerprint 200_L0_1.bmp and its fused version with wavelet bior2.4. To remove false minutiae, the considered Euclidian distance value is not less than 6.

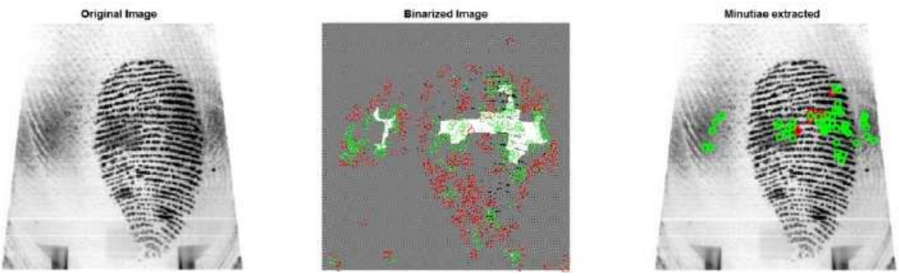

Fig. 19: Minutiae extracted for image 200_L0_0.bmp.

There are many for minutiae extraction, but Papillon 9.02 is the official version used by the Albanian police department for biometric person identification. Although it is fast, the manual technique for minutiae extraction used by a fingerprint expert is the most accurate one. Minutiae extraction is obtained automatically by Papillon 9.02 and manually by police expert, and the comparison between the two methods is in Figure 10 depicted.

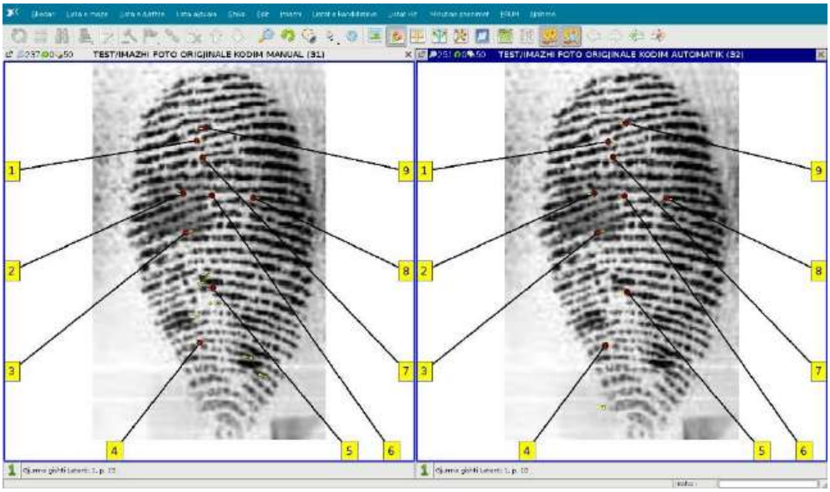

Fig. 20: Minutiae correspondences between the two methods.

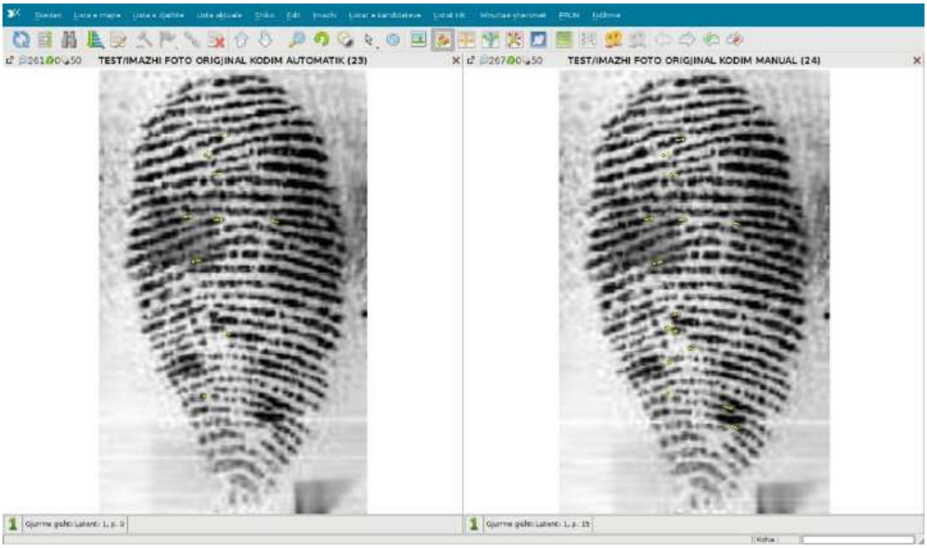

Fig. 21: Minutiae detected in original image by two technics.

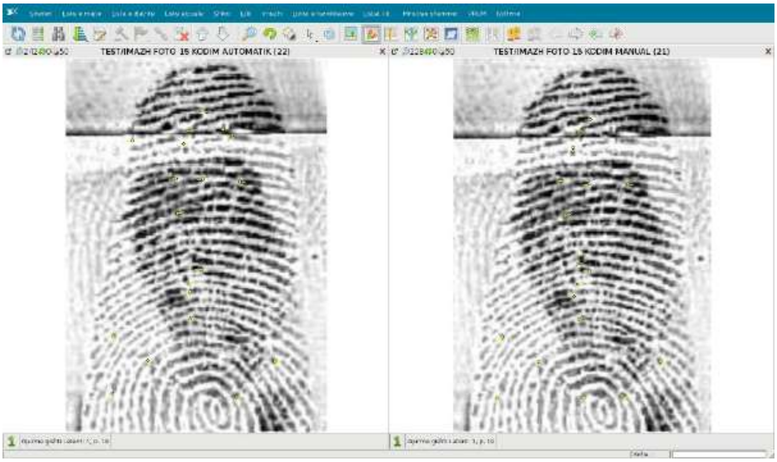

Fig. 22: Minutiae detected in the fused image with bior6.8.

Different wavelet can be used for image fusion. Biorthogonal wavelet transform has advantage comparing with other wavelet transformation regarding the reconstruction. In this paper is considered bior6.8 wavelet for image fusion. The automatic and manual minutiae extraction is performed in the original and the fused image, results are illustrated in figures 11 and 12.

Tab. 1 Number of terminations and bifurcations detected

	Automatic detection Papillon 9.2			Manual detection		
Image	Minutiae	Terminations	Bifurcations	Minutiae	Terminations	Bifurcations
First Image	9	6	3	15	15	0
Second Image	7	6	1	12	10	2
The fused one	19	10	9	19	15	4

Table 1 reports that the number of minutiae in the fused image is increased when compared to both original images.

The proposed algorithm will be tested on images taken randomly from the dataset CASIA-Fingerprint Image Database V5 (200 – 299): 220_L2_0 and 220_L2_1, 235_R2_1 and 235_R2_4, 257_R3_1 and 257_R3_4. Fingerprint images are randomly selected from left and right hands, in different positions relative to each other and with damages.

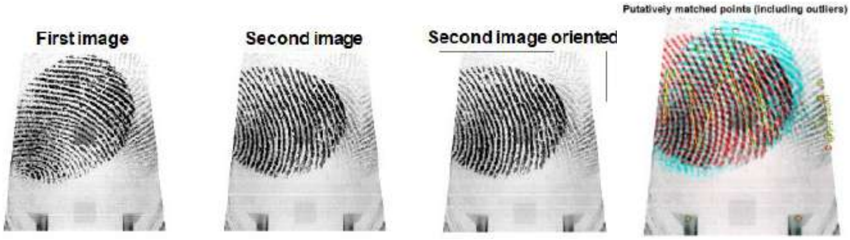

Fig. 13: Fingerprint images 220_L2_0 and 220_L2_1 and the oriented one

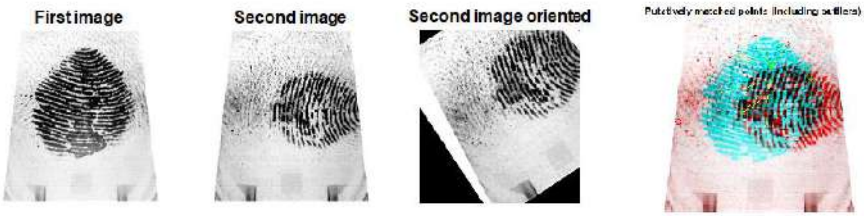

Fig. 14: Fingerprint images 235_R2_1 and 235_R2_4 and the oriented one

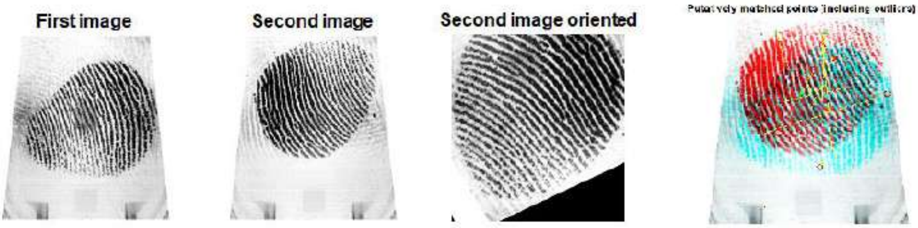

Fig. 15: Fingerprint images 257_R3_1 and 235_R3_4 and the oriented one

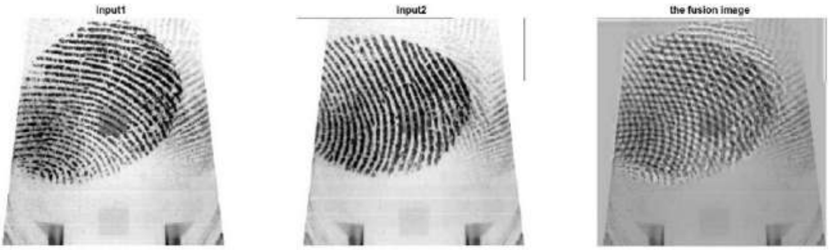

Fig. 16: Fingerprint images 220_L2_0 and 220_L2_1 and the fused one

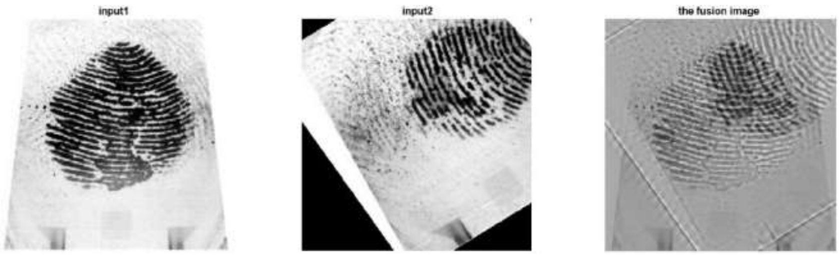

Fig. 17: Fingerprint images 235_R2_1 and 235_R2_4 and the fused one

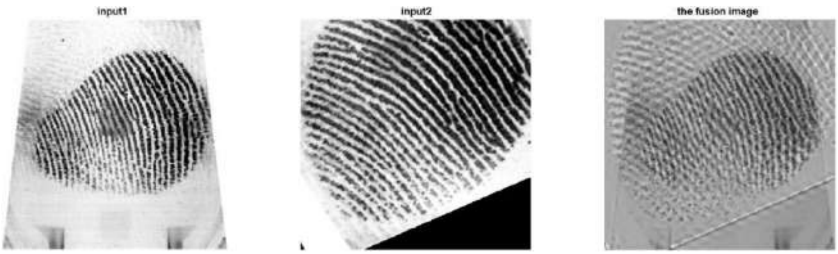

Fig. 18: Fingerprint images 257_R3_1 and 257_R3_4 and the fused one

In the following, minutiae must be extracted from fingerprint images, specifically from both fingerprints and the fused one. Then a comparison is performed. Papillon 9.02 software will be used to extract the minutiae.

Table 1. Number of terminations and bifurcations detected

	Automatic detection Papillon 9.2			Manual detection		
Image	Minutiae	Terminations	Bifurcations	Minutiae	Terminations	Bifurcations
220_L2_0.bmp	26	11	15	34	16	18
220_L2_1.bmp	29	10	19	35	13	22
220_L2_01_fused_bior6.8	37	12	25	50	23	27
235_R2_1.bmp	41	17	24	44	20	24
235_R2_4.bmp	6	5	1	10	7	3
235_R2_14_fused_bior6.8	44	19	25	56	26	30
257_R3_1	13	11	2	17	11	6
257_R3_4	16	0	16	19	5	14
257_R3_14_fused_bior6.8	28	12	16	29	15	14

7. CONCLUSIONS

The paper proposes and implements an image fusion transform based on regional variance to improve the accuracy of fingerprint recognition. Fingerprint images are spatially aligned according to each other and fused by implementing average and maximum respectively for low and high frequency coefficients using different bior6.8 wavelet. Experimental results implemented on various fingerprint images from CASIA v5 database show that the number of minutiae detected is increased.

8. FUTURE WORKS

To give an accurate result of the proposed method more tests will be implemented on public FVC2004 and FVC2006 database of fingerprints, as well as more wavelets will clarify this result.

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