Performance Improvement in Gradient based Algorithm for the Estimation of Fingerprint Orientation Fields

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ABSTRACT
Accuracy of fingerprint recognition system is reliable for correct measurement of fingerprint features. Orientation estimation of fingerprint ridges is playing a vital role in image enhancement, segmentation, classification and recognition. The accurate estimation of ridge orientation improves the performance of minutiae extraction and matching algorithm. The noisy fingerprint does not contain the clear ridge structure, that's why ridge orientation estimation is the toughest and challenging task in fingerprint image enhancement. Gradient-based orientation estimation algorithm is widely adopted and most popular method accepted in literature. This paper enhance the consistency level of ridge orientation after changing the range of output direction from [-PI/4, PI/4] to [0, PI] and remove the inconsistency. The implementation is done using java language and the experimental result is made on FVC2000 and FingerDOS databases. The outcome of enhanced new method for estimating ridge orientation give better performance than the existing gradient based approach.

Keywords
Fingerprint recognition, fingerprint enhancement, orientation estimation

1. INTRODUCTION
The frequently increasing requirements of security, biometric technologies have been used widely. For personal identification most reliable and popular technique is the fingerprint recognition among all biometric techniques [1] because the pattern of fingertip is remain unique even for twins, require less storage space and low cost fingerprint sensor. Fingerprint recognition system is used from simple

access control to convicting criminal by forensic and law agencies [2][3]. Lots of research is done on fingerprint recognition and many researchers proposed no. of proven methods. Though, recent literatures demonstrate that still require developing new robust system. Even the main important research issue is the poor quality images give the low performance [3]. Because in reality the quality of the fingerprint is weak due to scare and cuts, dry skin, sensor noise, give high or low pressure on sensor create a noise, and weak ridge and valley pattern of fingerprint, partial fingerprints and latent fingerprints contain complex background and so on.

Image enhancement process improves the quality of an image and ultimately improves the performance of fingerprints recognition systems. The fingerprints made up of two types of features like: minutia or singular points consider as local features and a ridge pattern orientation and frequency consider as global features.

To verify or identify an individual local features are used while the global features describe local orientation of ridges and valleys using orientation fields. Ridge orientation is an important feature because the impact of it is affected to other processes like fingerprint enhancement, classification, segmentation and matching. The ridge orientation can be used in [4-9] image enhancement algorithms, singular points detection [5][10-12][16] and classification [13-19]. If accurate orientation estimation is not found then false recognition is generate.

2. RELATED WORK ON ORIENTATION ESTIMATION
In an image of fingerprint, orientation field indicate the direction of ridges. During literature survey found many methods for ridge orientation estimation. There are many methods are found on gray-scale relationship between pixels [3][21-29,41]. There are many different way to compute the ridge orientation like [22] calculated gray consistency beside 16 directions at every pixel and the orientation of the best consistency is taken as the ridge orientation. Some of them separated pixels into ridge and non-ridge pixels and determined ridge orientation by calculating the consistency of pixel type [23]. Also using the neural network evaluated the exactness of ridge orientation [25][33]. Among all this famous method for ridge orientation estimation is the gradient-based method [3][29-32][39-40].

The acquired values are perfect compared to pixel-alignment method [1][9] that is the main benefit of this algorithm. The ridge orientation estimation is totally depended on relationship of gradient among neighbor pixels. However, the gradients are the orientations at the pixel scale, the orientation of the ridge is orthogonal to the average phase angle of pixels value changes, indicated through gradients. However, only ridge edge gradients are orthogonal to the ridge. Therefore the gradients averaging step is necessary.

3. ORIENTATION ESTIMATION
The implementation of gradient-based method for orientation estimation is done using following steps [35].

- The fingerprint image should be dividing into WxW size blocks.
- In every block for each pixel calculate the gradients Gx and Gy.
- Use the below equations (1) and (2) for determine the local orientation at each pixel (i, j).

$$Vx(i,j) = \sum_{u=i-\frac{w}{2}}^{i+\frac{w}{2}} \sum_{v=j-\frac{w}{2}}^{j+\frac{w}{2}} 2Gx(u,v)Gy(u,v),$$

$$Vy(i,j) = \sum_{u=i-\frac{w}{2}}^{i+\frac{w}{2}} \sum_{v=j-\frac{w}{2}}^{j+\frac{w}{2}} (G^2x(u,v) - G^2y(u,v)), \quad (1)$$

$$\theta(i,j) = \frac{1}{2}\tan^{-1}\left(\frac{Vx(i,j)}{Vy(i,j)}\right) \quad (2)$$

Where, the size of the local window is denoted as W, and the gradient magnitudes in x and y directions are denoted as Gx and Gy.

- Using the following equation (3), the consistency level of orientation field is estimated for the local neighborhood of a block(i, j).

$$C(i,j) = \frac{1}{N}\sqrt{\sum_{(i',j')\in D} |\theta(i',j') - \theta(i,j)|^2},$$

$$\left|\theta' - \theta\right| = \begin{cases} d & \text{if d=}(\theta' - \theta + 360) \bmod 360) < 180, \\ & otherwise, \\ d = 180 \end{cases} \quad (3)$$

  Where, D represents the local neighborhood around the block (i,j) (the size of D is taken 5X5; N is the number of blocks within D; $\theta'(i',j') and \theta(i,j)$ are local ridge orientation at blocks $(i',j') and (i,j)$ respectively.

- If the consistency level is above a certain threshold Tc, then the local orientations around this region are re-estimated at a lower resolution level until C(i, j) is below a certain level.

The equation (3) is implemented for calculate the consistency of the orientation field. But the last point "If the consistency level is above a certain threshold Tc, then the local orientations around this region are re-estimated at a lower resolution level until C(i, j) is below a certain level". The author did not mentioned about clear threshold value and did not mention about that if can't find a certain value, what is the standard to decrease the neighborhood block D until find a certain level of C(i,j). It is difficult to implement the last step in this algorithm. That's why this step is neglecting and apply only equation (2). But because of omitting equation (3) inconsistency is in an orientation.

Then after found that the output direction range is [-PI/4, PI/4] and this range makes the inconsistency in an orientation because the angle between -PI/4 to PI/4 can't contain all the direction in a fingerprint image. After research found the below equation (4) which converts the angle [36]. Using it convert the range [-PI/4, PI/4] to [0 to PI] and remove the inconsistency.

$$\theta = \frac{1}{2}\pi + \frac{1}{2}\begin{cases} \arctan\left(\frac{G_{By}}{G_{Bx}}\right), G_{Bx} \geq 0, \\ \arctan\left(\frac{G_{By}}{G_{Bx}}\right) + \pi, G_{Bx} < 0 \cap G_{By} \geq 0, \\ \arctan^{-1}\left(\frac{G_{By}}{G_{Bx}}\right) - \pi, G_{Bx} < 0 \cap G_{By} < 0 \end{cases} \quad (4)$$

4. EXPERIMENTAL RESULTS AND ANALYSIS

The Implementation of an algorithm is done using java language and for the experiments the databases FVC 2000 DB1, DB2, DB3, DB4 released on the web [37], and FingerDOS database [38] are used. The details of the databases are given in below Table 1 and Table 2. For showing the result 10 fingerprints are taken from the each cluster of the databases. The performance of the proposed method should be checked by two criteria.

Criteria-I: - Removal of Inconsistency
Criteria-II:- Execution Time

The below Table 3 shows the result, that the inconsistency should be remove after changing the range of output direction from [PI/4, PI/4] to [0, PI]. And the Table 4 shows the summary of the execution time that prove that the proposed method give the better result.

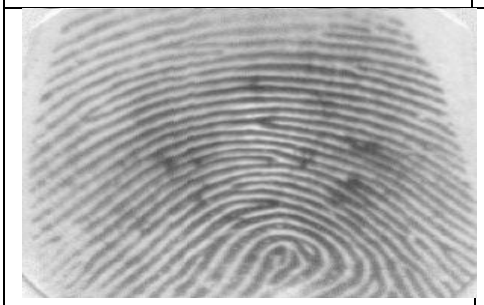
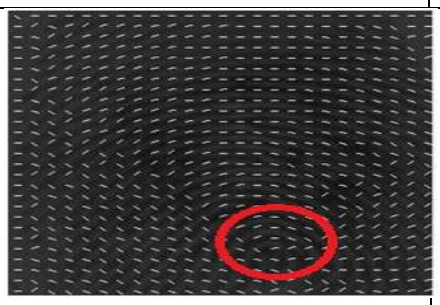
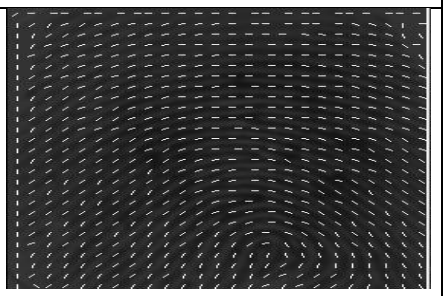
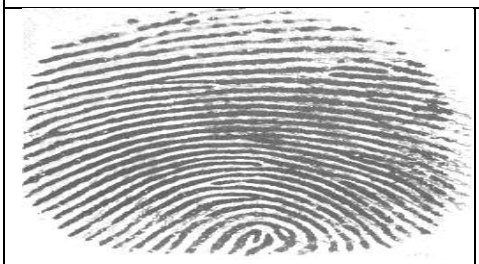
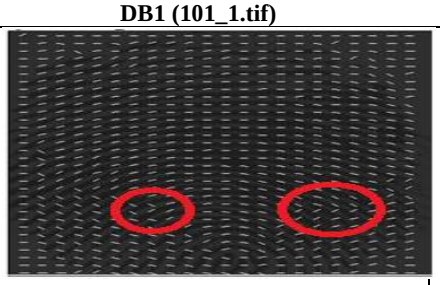
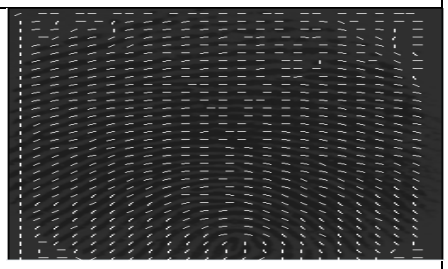
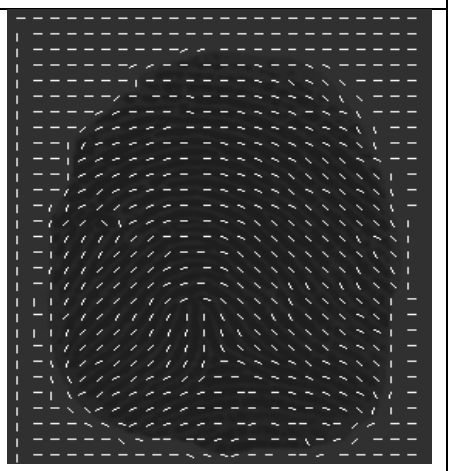
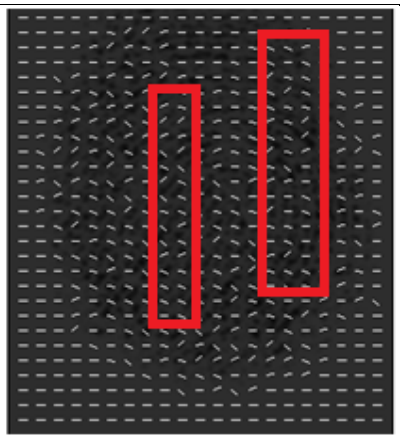
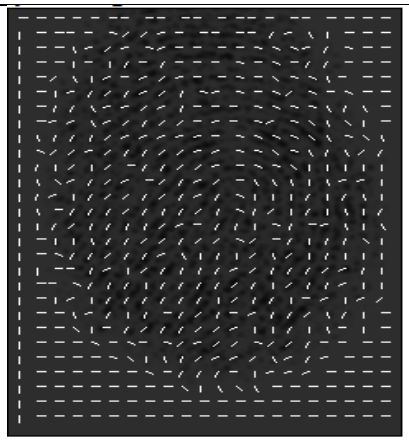
Table 1. FVC2000 Database][37]

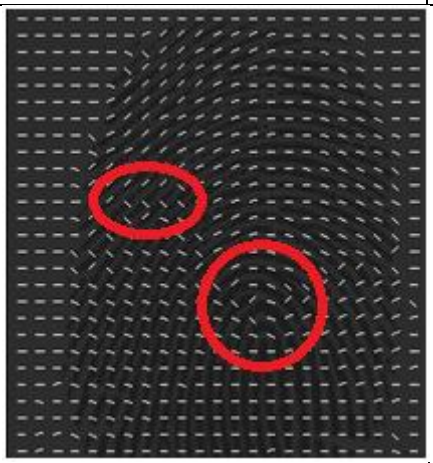
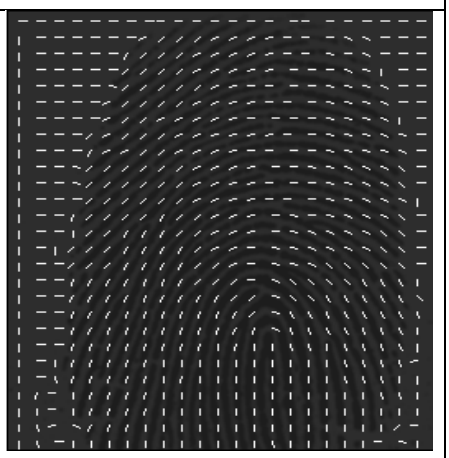
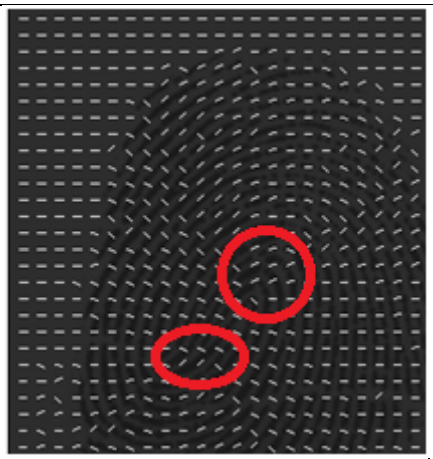
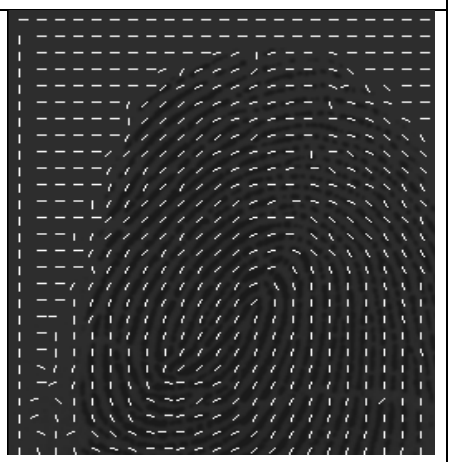
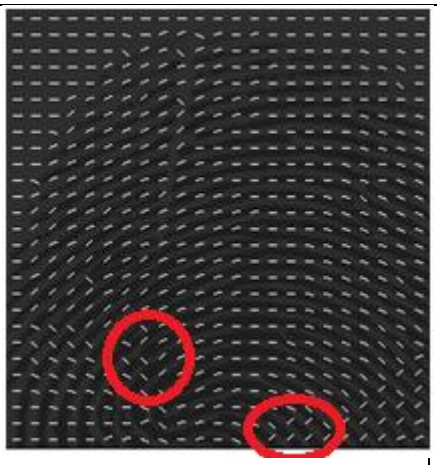
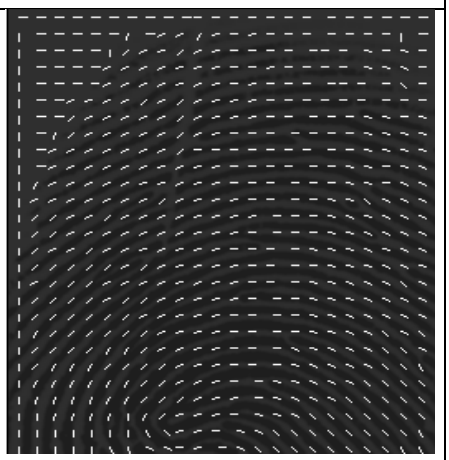
FVC2000				
Set B	**Sensor Type**	**Image Size**	**No. of Impression**	**Resolution**
DB1	Low-cost Optical Sensor	300x300	10x8	500 dpi
DB2	Low-cost Capacitive Sensor	256x364	10x8	500 dpi
DB3	Optical Sensor	448x478	10x8	500 dpi
DB4	Synthetic Generator	240x320	10x8	about 500 dpi

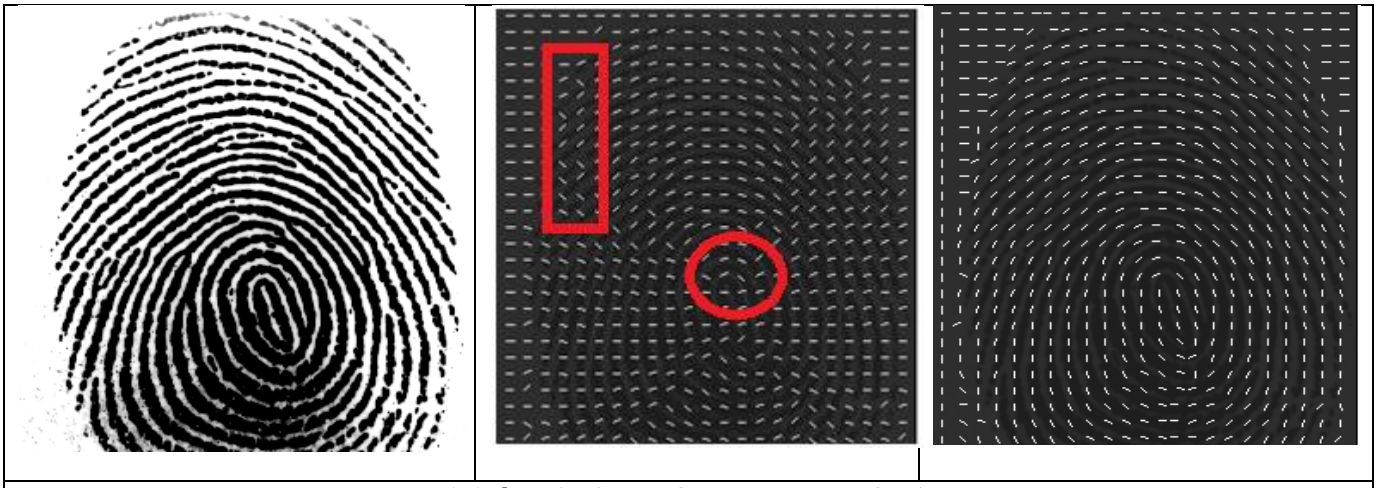
Table 2. FingerDOS Database[38]

FingerDOS			
FingerDOS	**Image Size**	**No. of Impression**	**Resolution**
optical sensor (SecuGeniD-USB SC)	260 x 300	3600=60x6x10 i.e. No. of subjects=60 No. of fingers=6 (index, middle and thumb of right and left hand) No. of impression=10	500 PPI

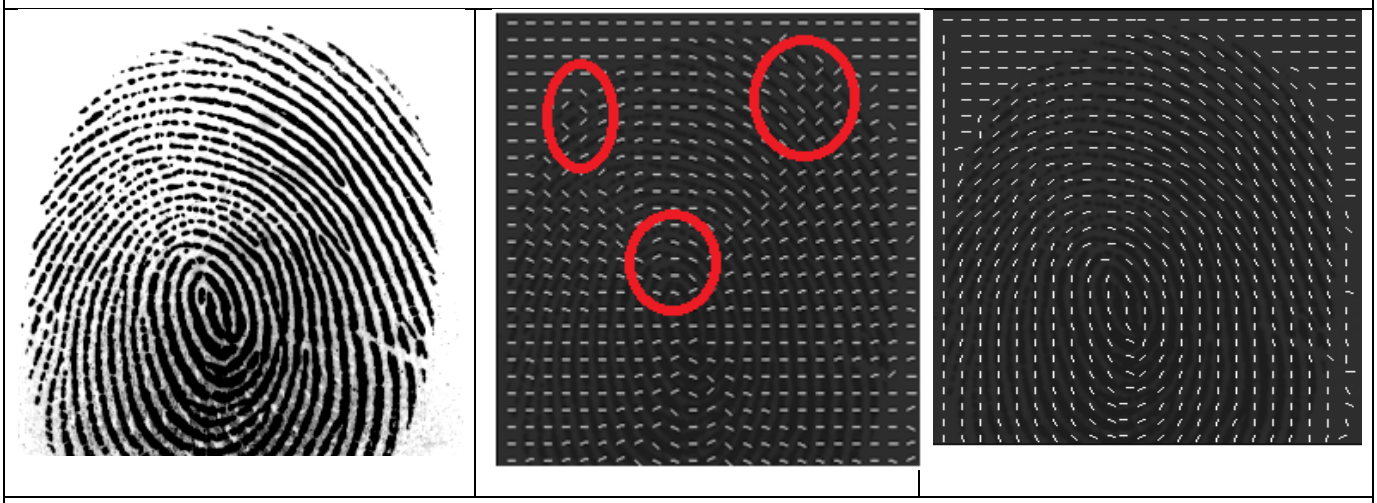
Table 3. Result Analysis on FVC2000 Database and FingerDos Database

FVC2000 Database		
Original Image	**Range [-PI/4, PI/4]**	**Range [0, PI]**
		
DB1 (101_1.tif)		
		
DB2 (101_1.tif)		
		
DB3 (101_1.tif)		
		
DB4 (101_1.tif)		

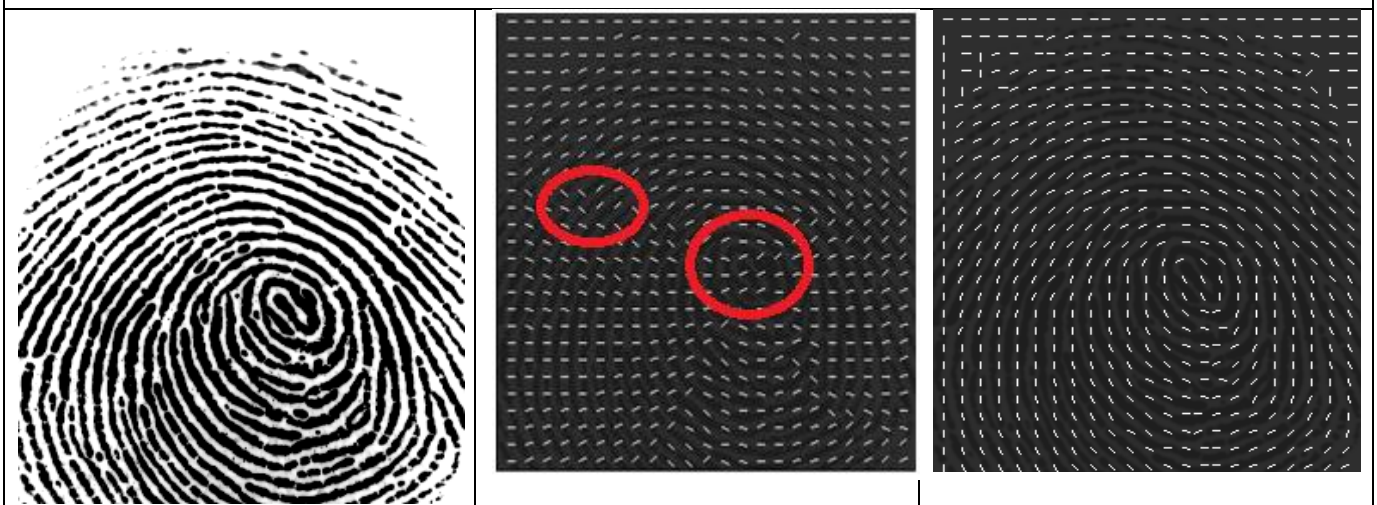
FingerDOS Database		
Original Image	**With Range [-PI/4 to PI/4]**	**With Range [0 to PI]**
		
0101.bmp (LEFT_HAND_INDEX_FINGER)		
		
1201.bmp (LEFT_HAND_MIDDLE_FINGER)		
		
3702.bmp (LEFT_HAND_THUMB)		



0401.bmp (RIGHT_HAND_INDEX_FINGER)



1201.bmp (RIGHT_HAND_MIDDLE_FINGER)



3901.bmp (RIGHT_HAND_THUMB)

Table 4. Summary of an Execution Time (in milliseconds)

Images of FVC2000 and FingerDos Databases	Range [-PI/4, PI/4]	Range [0, PI]
FVC2000_DB1_B_101_1.tif	31	15
FVC2000_DB2_B_101_1.tif	62	47
FVC2000_DB3_B_101_1.tif	156	78
FVC2000_DB4_B_101_1.tif	78	62
LEFT_HAND_INDEX_FINGER_0101.bmp	109	62
LEFT_HAND_MIDDLE_FINGER_1201.bmp	63	15
LEFT_HAND_THUMB_3702.bmp	47	32
RIGHT HAND_INDEX_FINGER_0401.bmp	31	31
RIGHT_HAND_MIDDLE_FINGER_1201.bmp	62	15
RIGHT_HAND_THUMB_3901.bmp	62	47

5. CONCLUSION AND FUTURE WORK

Fingerprint ridge orientation is playing vital role in many processes like fingerprint image enhancement, classification of an image, core and delta point detection. That's why necessary to estimate correct orientation. Fingerprint image contains many noisy regions or blocks with singular points which hardly generate the correct orientation, because of this reason gradient based orientation estimation algorithm can't guarantee for correctness of ridge orientation. And the incorrect orientation gives false singular points, classification and ridge flows. This paper enhances the performance of gradient based orientation estimation algorithm and proposes new and reliable fingerprint orientation estimation without inconsistency. In future work try to implement and improve the performance enhancement algorithms.

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