# CHAPTER 8

# Experimental Results and Discussion

## 8.1 Database

For experimentation of the proposed system, DB1, DB2, DB3 and DB4 fingerprint images in database FVC2002 are used. Each database contained 800 fingerprints from 100 different fingers. The description of the FVC2002 database is given in Table 8.1.

**Table 8.1 Description of the FVC 2002 fingerprint dataset**

| Dataset | Scanner type | Image size | Resolution |
|---|---|---|---|
| DB1 | Low-cost Optical Sensor | 388x374 | 500 dpi |
| DB2 | Low-cost Capacitive Sensor | 296x560 | 500 dpi |
| DB3 | Capacitive Sensor | 300x300 | 500 dpi |
| DB4 | SFinGe v2.51 | 288x384 | 500 dpi |

## 8.2 Experimental Results of Preprocessing and Post processing Stage

The experimental results are analyzed by considering the following parameters and the results are depicted in table 8.2:

**True Minutiae ($M_T$)** **:** Minutiae mark by a human expert.

**Extracted Minutiae ($M_E$)** **:** Minutiae after post-processing.

**False Minutiae ($M_F$)** **:** Minutiae extracted by the algorithm that do not coincide with $M_T$.

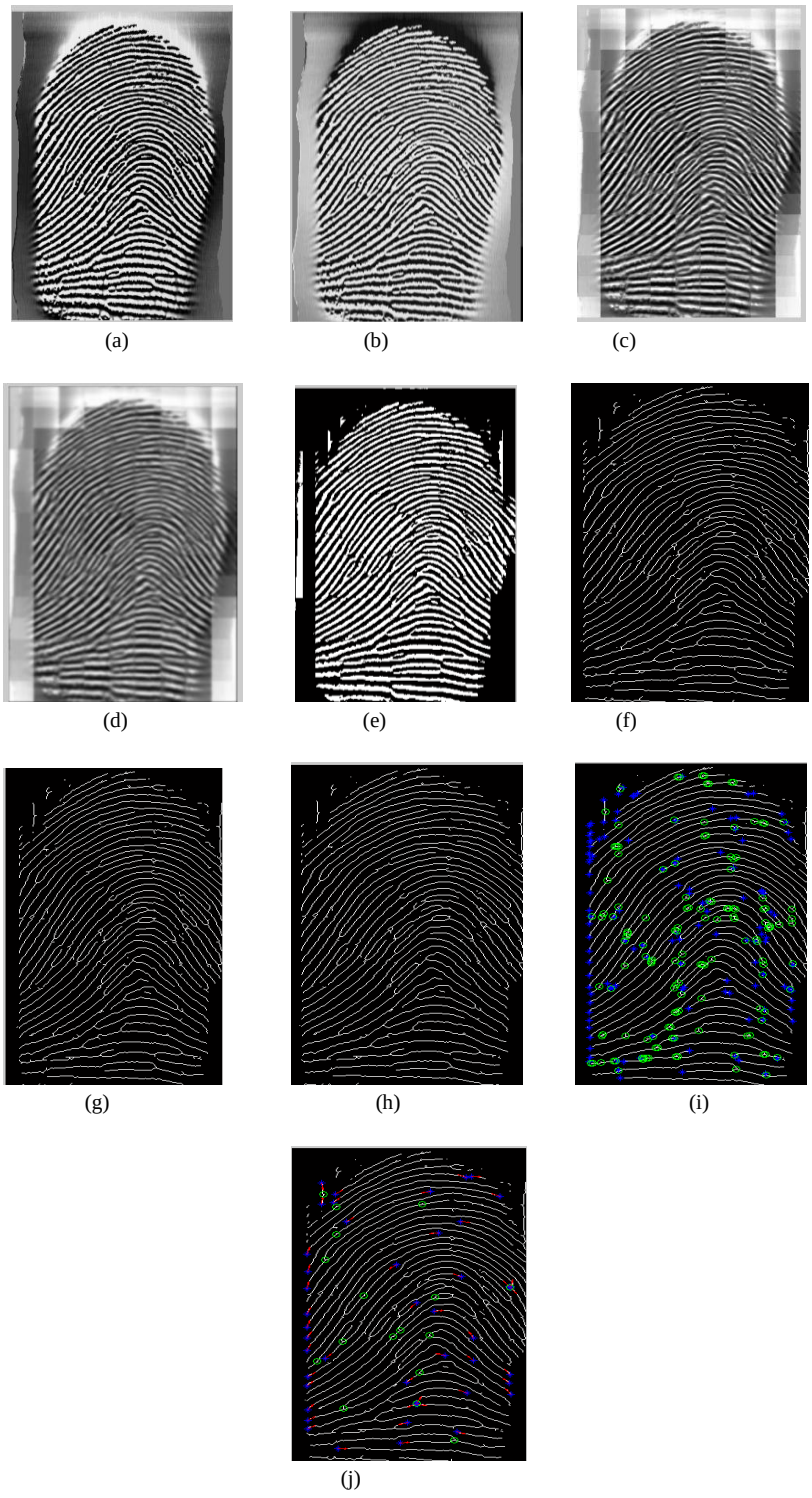
**Dropped Minutiae ($M_D$)** **:** Minutiae marked by a human expert that are not extracted by the algorithm.

**Type-exchange Minutiae ($M_{TE}$)** **:** Minutiae extracted by the algorithm that coincide with $M_T$ except the minutiae type.

The Average error rate of false minutiae is $M_F/M_E$, dropped minutiae is $M_D/M_T$ and type exchange minutiae is $M_{TE}/M_E$. The total error rate is the sum of them [35] and it is 1.184%. The execution time is 1.9 seconds. Figure 8.1 shows the different fingerprint patterns, after processing through the different stages of the proposed system.

**Table 8.2 The performance evaluation of the proposed method using different fingerprint images**

| **Name**(*.tif) | **True Minutiae($M_T$)** | **Extracted Minutiae($M_E$)** | **False Minutiae ($M_F$)** | **Dropped Minutiae($M_D$)** | **Type-exchange Minutiae($M_{TE}$)** |
|---|---|---|---|---|---|
| **1_5** | **31** | **49** | **24** | **13** | **2** |
| **1_6** | **29** | **44** | **21** | **11** | **3** |
| **2_1** | **22** | **42** | **16** | **7** | **1** |
| **2_4** | **26** | **39** | **19** | **9** | **1** |
| **2_7** | **24** | **62** | **46** | **5** | **4** |
| **3_1** | **36** | **48** | **17** | **12** | **2** |
| **3_4** | **25** | **47** | **16** | **5** | **1** |
| **8_8** | **48** | **66** | **37** | **16** | **5** |

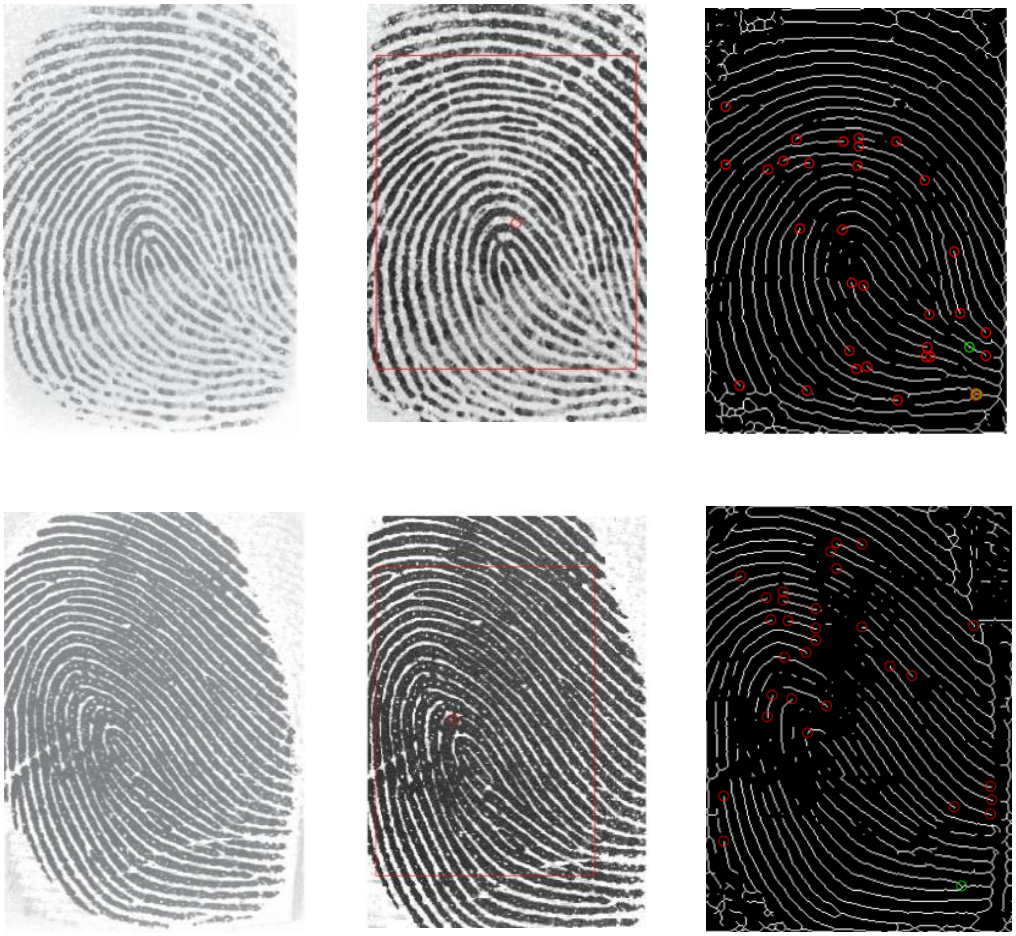



(a) Input fingerprint image, (b) Normalization image, (c) Primary Enhancement, (d) Secondary enhancement, (e) binarization, (f) thinning, (g) remove bridge, (h) remove spur, (i) minutiae extraction, (j) purifying minutiae.

**Fig 8.1. The different steps of fingerprint implemention.**

## 8.3 Experimental Results on hFPM Fingerprint Matching

Fingerprint image from the FCV2002 with the core point and minutiae feature is shown in Fig. 8.2. The core point is extracted using [71] and the minutiae feature is extract by using crossing number[33].



(a) Fingerprint (b) Core point (c) Minutiae point

**Fig 8.2 Showing original image, core point and minutiae points.**

***Evaluation:*** Two parameters, namely False Matching Rate (FMR) and False Non-Matching Rate (FNMR) are used for the evaluation of the proposed system. Equation (9) and (10) provides the FMR and FNMR.

$$FMR = \frac{Number\ of\ imposter\ \ fingerpr\,\text{int}\,accepted}{Total\ number\ of\ imposter\ test} \quad (9)$$

$$FNMR = \frac{Number\ of\ \ genuine\ \ fingerpr\,\text{int}\,rejected}{Total\ number\ \ of\ \ genuine\ test} \quad (10)$$

The first 100 individual images are used to evaluate the FMR and FNMR for the proposed experimentation. FMR is computed based on comparing the first impression of each individual with the first of the others and thus the total number of impostor tests equals ( $\frac{100*99}{2}$ =) 4950 [90]. FNMR is computed based on the total number of genuine tests (compare each impression with the seven others for all individuals) and equals ( $\frac{8*7}{2}*100$ =) 2800.

Fig. 8.3 shows the performance of FNMR and FMR using DB1, DB2, DB3 and DB4 FVC2002 dataset. The EER(Equal Error Rate) is obtained from the crossing point of FNMR and FMR, which is around at the threshold values of 25 to 35 which is shown in the above figure 8.3.

The algorithm is also tested in different quality of fingerprint images with different angle of rotation. The different qualities of fingerprint images such as dry images, normal images and dark images are collected from FVC2002 database.The fingerprint images is compared with a base image. A base image is taken from the same finger with rotation in four angle, i.e. -20 degree, -10 degree, 10 degree and 20 degree.

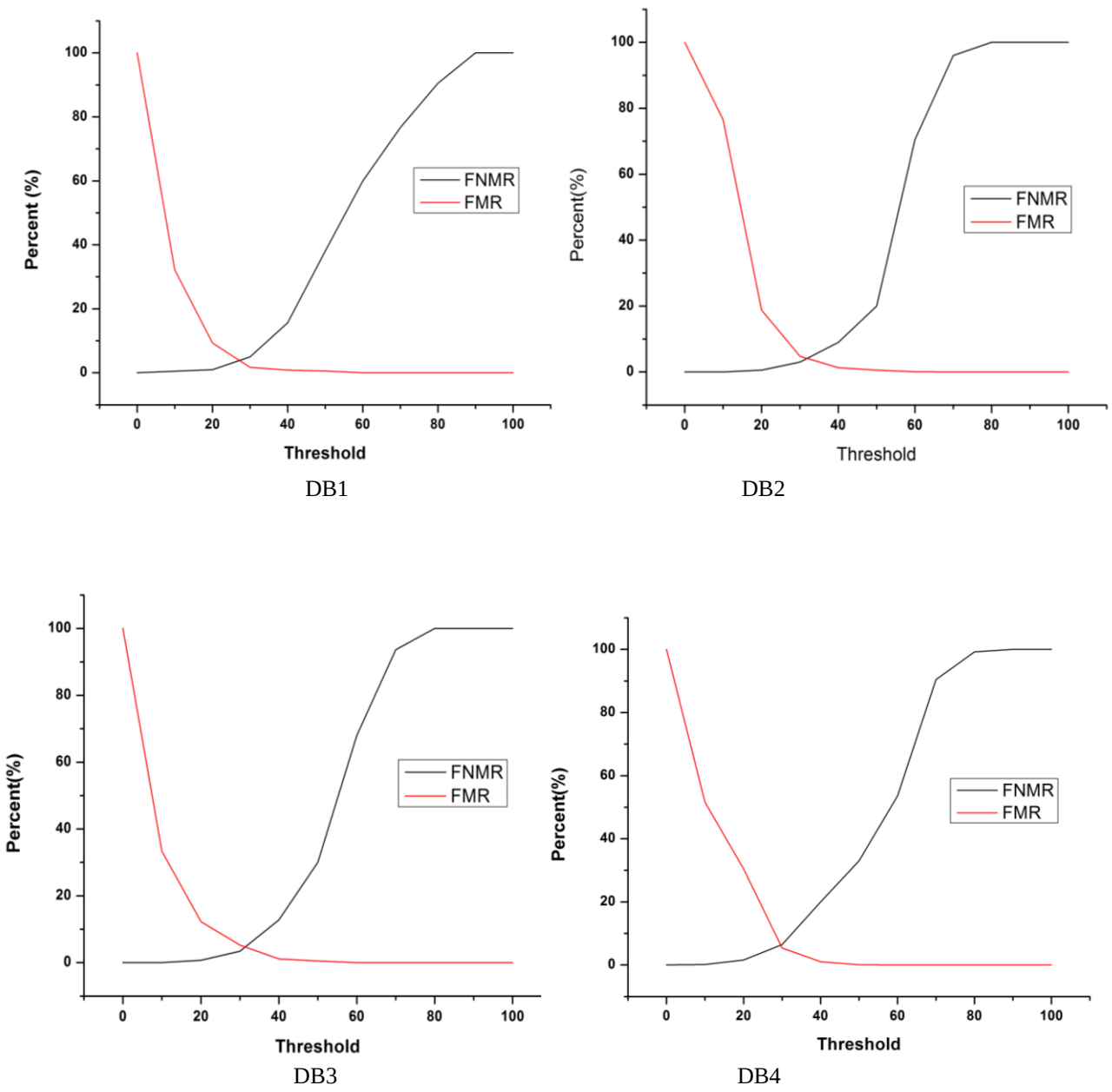
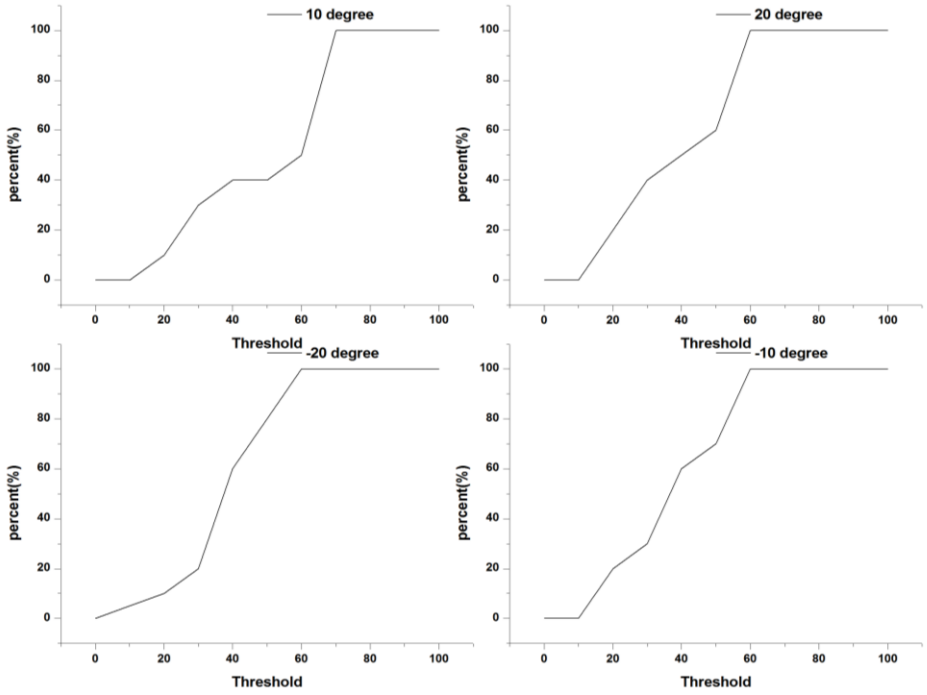
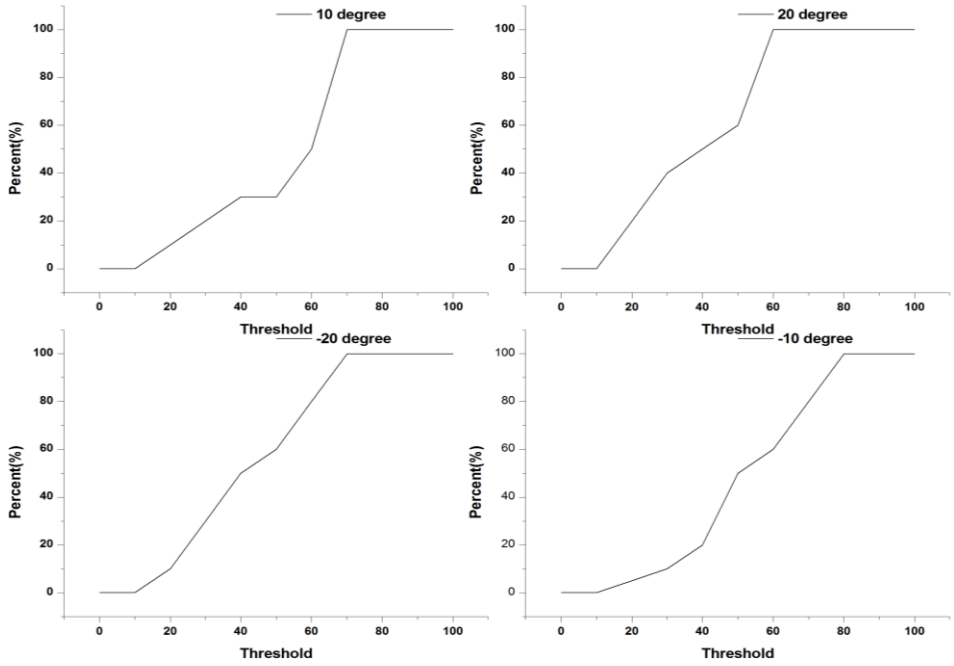



**Fig 8.3: Showing graph of FNMR and FMR against matching threshold using FVC2002 database.**

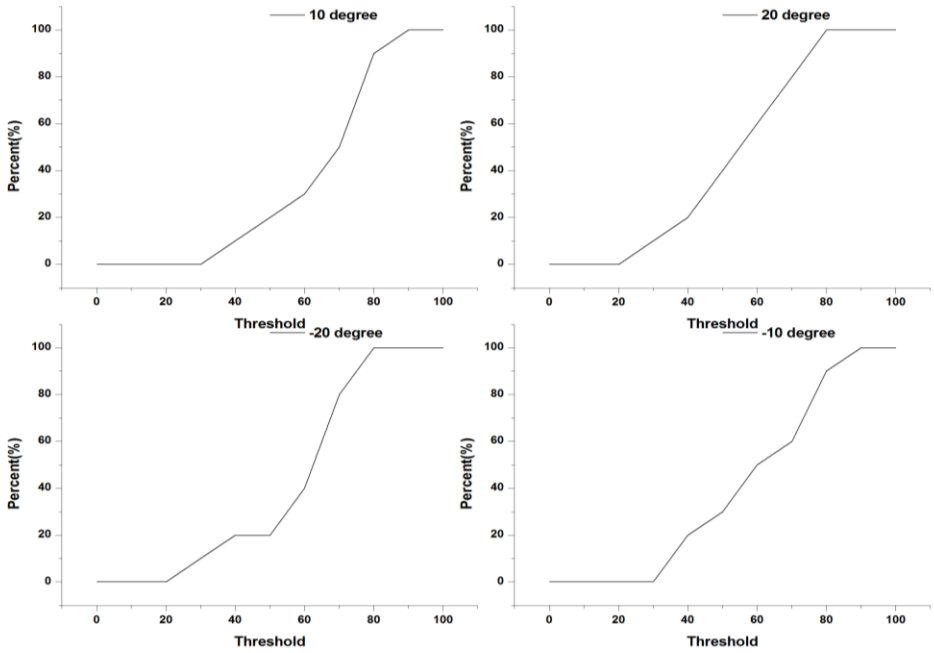
The experimental results of the dry image, dark image, and normal image are shown in Fig. 8.4. From this figure, we can observe that the normal and dark images give better results, for comparison, than the dry images with respect to Error rate and threshold values.




(i) Dry Image




(ii) Dark image




(iii) Normal Image

**Fig 8.4: Showing graph of different quality of images at different degree of rotation.**

The proposed algorithm is prone to error if the fingerprint image acquired is partial where the core point is hard to detect. Some images from FVC2002 dataset is given in Fig. 8.5 of this nature.

Fingerprint Core point

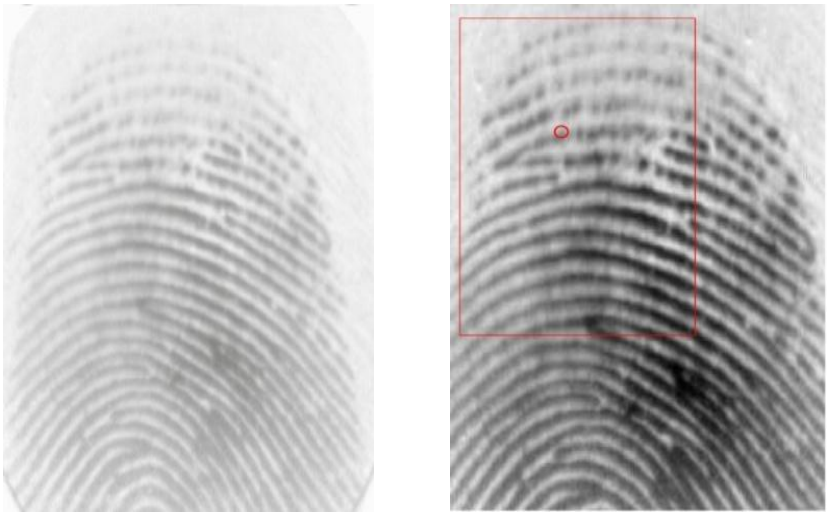


**Fig 8.5 Showing original image and false core point of the fingerprint image.**

## 8.4. Comparison on Fingerprint Matching

The proposed system compares with [69] and [70] and yields better results in terms of EER as shown in table 8.3.

**Table 8.3. Comparison with respect to EER**

| Matching Algorithm | EER |
|---|---|
| Memetic Fingerprint Matching [69] | 3.6 |
| Fingerprint matching using spiral partitioning scheme [70] | 1.98 |
| Proposed algorithm | 1.44 |

## 8.5 Experimental Results on Fingerprint Database Indexing

The proposed algorithm is tested in three possible attacks, namely rotation, noise and scaling:

***Rotation :*** It is tested in four degrees, namely -10 degree, -5 degree, 5 degree and 10 degree.

***Gaussian noise :*** It is also tested in four different levels: 0.1, 0.3, 0.5 and 0.7 respectively.

***Scaling :*** For scaling test 1.1, 1.2, 1.3 and 1.4 values were used.

The indexing algorithm also consider error tolerance which is observed by using two parameters i.e. False Matching Rate (FMR) and False Non Matching Rate (FNMR). The intersection point of the two parameters is obtained at the threshold value of 18, which is the error tolerance and is shown in figure 8.6.

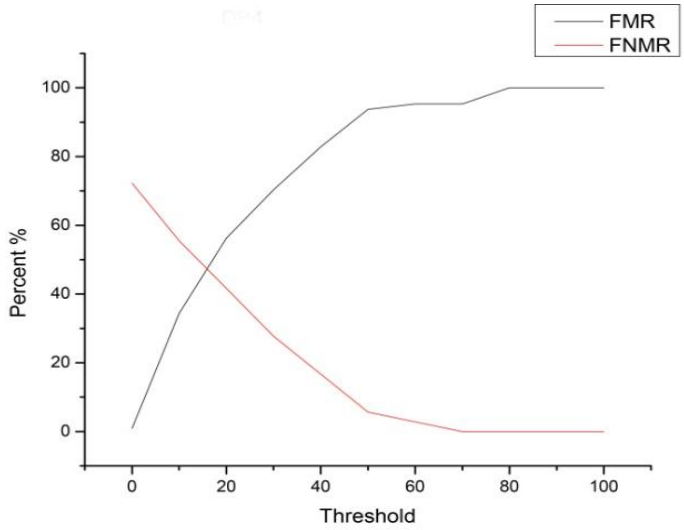
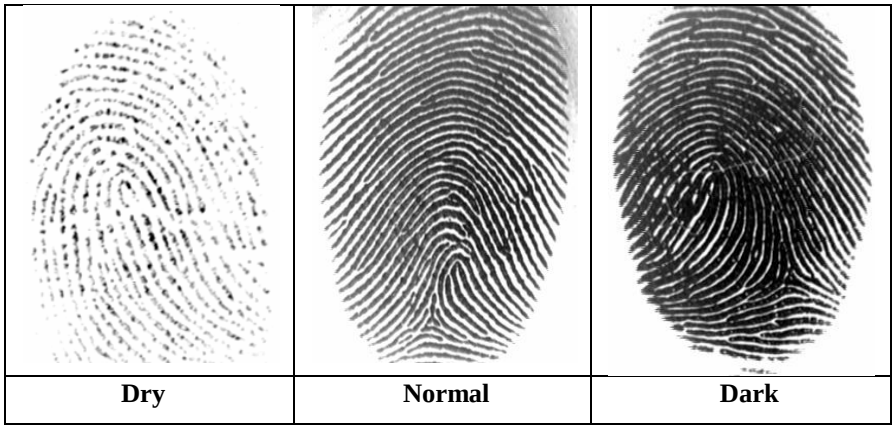



**Fig.8.6. Showing error tolerance 'K'**

***Evaluation:*** The performance of database indexing can be measured by hit rate and penetration rate. The hit rate represents the correct selection candidate list from the fraction of the set of selected candidates and the penetration rate represents the average length of the candidate list retrieved for each probe.

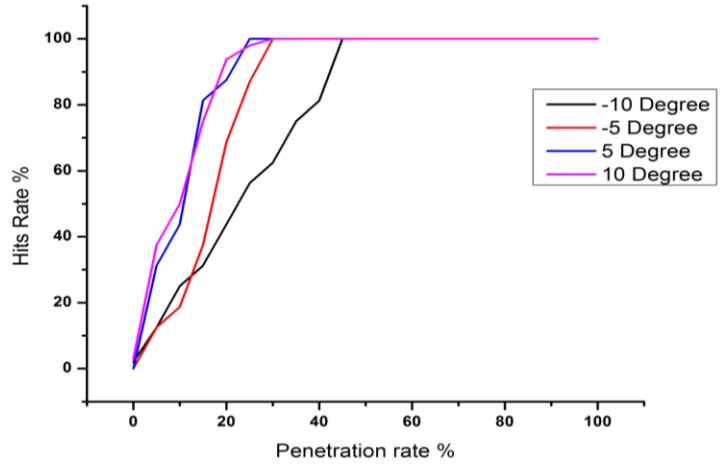
### 8.5.1 Experimentation on DB1

The sample fingerprint images of DB1 contain three quality viz, dry images, normal images and dark images as shown in figure 8.7. The experimental results are shown in figure 8.8.

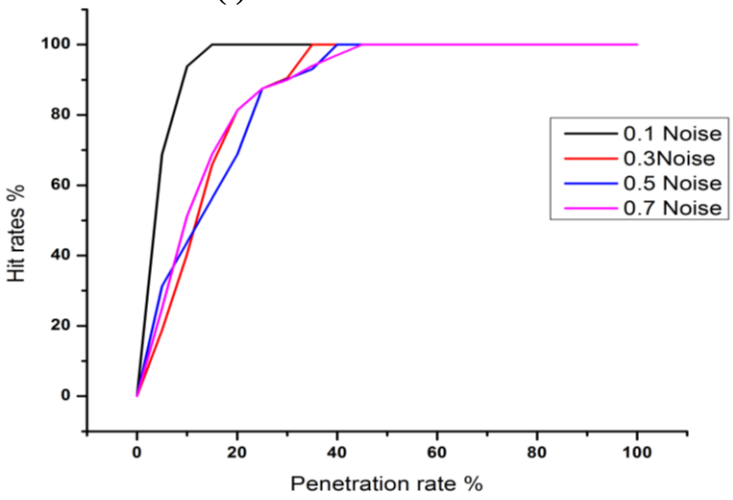


| Dry | Normal | Dark |
|---|---|---|

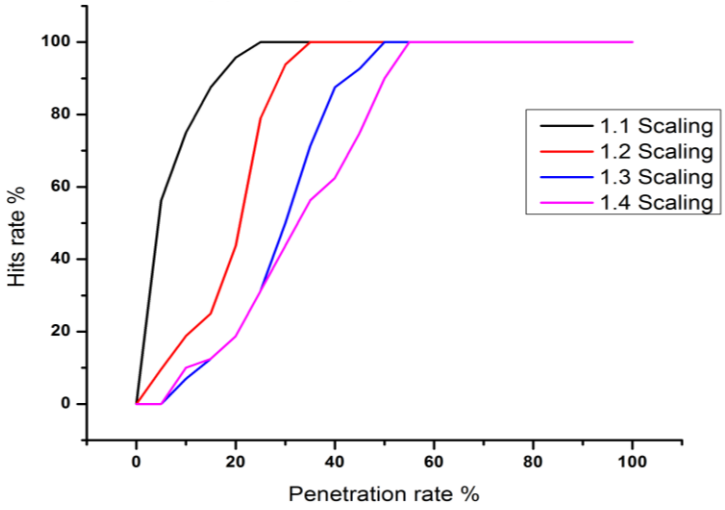
**Fig 8.7. DB1 Sample images**




(i) DB1 Rotation Test




(ii) DB1 Noise Test




(iii) DB1 Scaling Test

**Fig. 8.8 Performance on rotation, noise and scaling test using DB1 FVC 2002 Dataset**

From the figure 8.8, it is observed that, in rotation test, the penetration rate at the hit rate of 100% varies from 25% to 45 %. In noise test, the penetration rate at the hit rate of 100% varies from 15% to 43%. In Scaling test, the penetration rate at the hit rate of 100% varies from 20% to 52%.

### 8.5.2 Experimentation on DB2

The sample fingerprint images of DB2 are shown in figure 8.9. The experimental results of rotation test, noise test and scaling test are shown in figure 8.10.

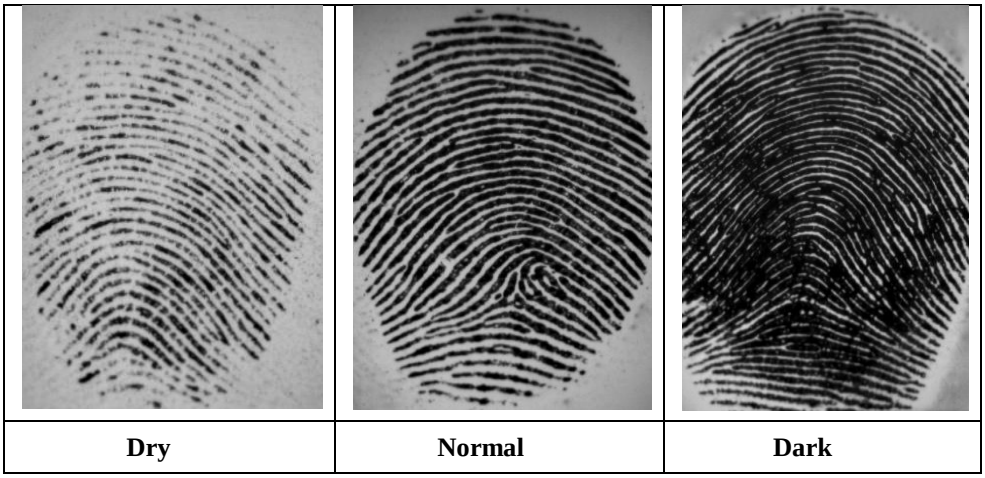
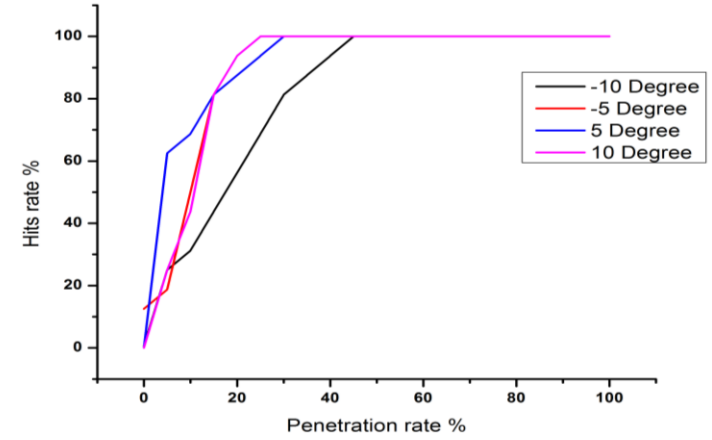
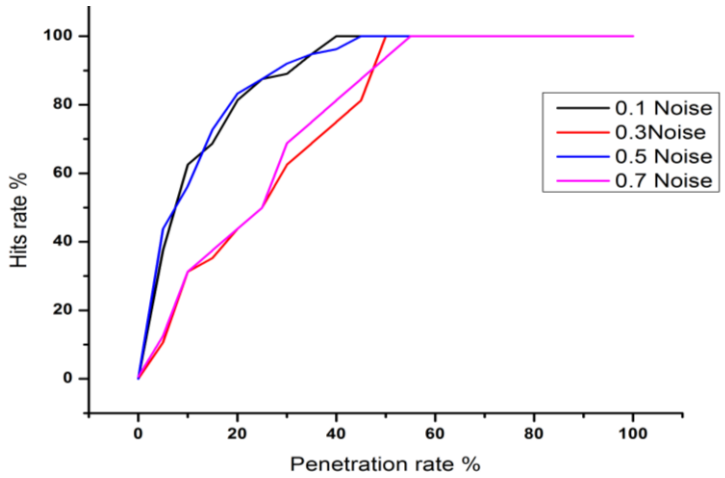



**Fig.8.9 DB2 Sample images**

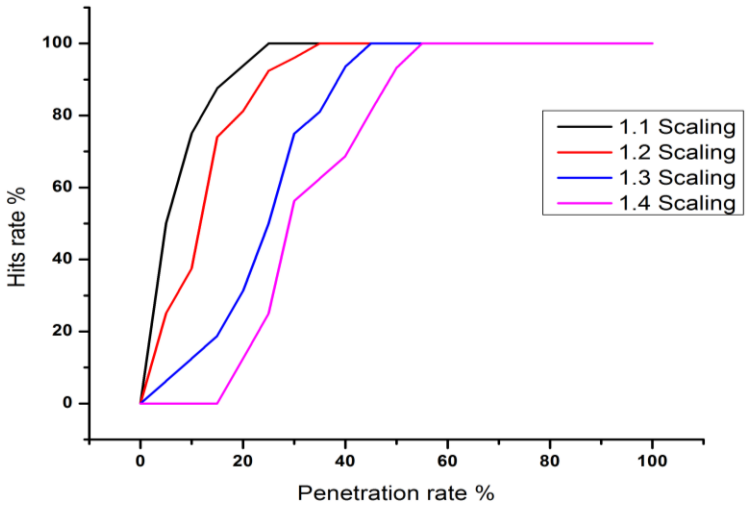
From the figure 8.10, it is observed that the rotation test of penetration rate is at a hit rate of 100% which varies from 25% to 45%. In noise test, the penetration rate is at the hit rate of 100%, which varies from 35% to 52%. In scaling test, the penetration rate is at the hit rate of 100%, which varies from 25% to 50 %.




(i) DB2 Rotation Test




(ii) DB2 Noise Test




(iii) DB 2 Scaling Test

**Fig. 8.10 Performance on rotation, noise and scaling test using DB2 FVC 2002 Dataset**.

### 8.5.3 Experimentation on DB3

The sample fingerprint images of DB3 and their different quality is shown in figure 8.11. The experimental results of rotation test, noise test and scaling test are shown in figure 8.12.

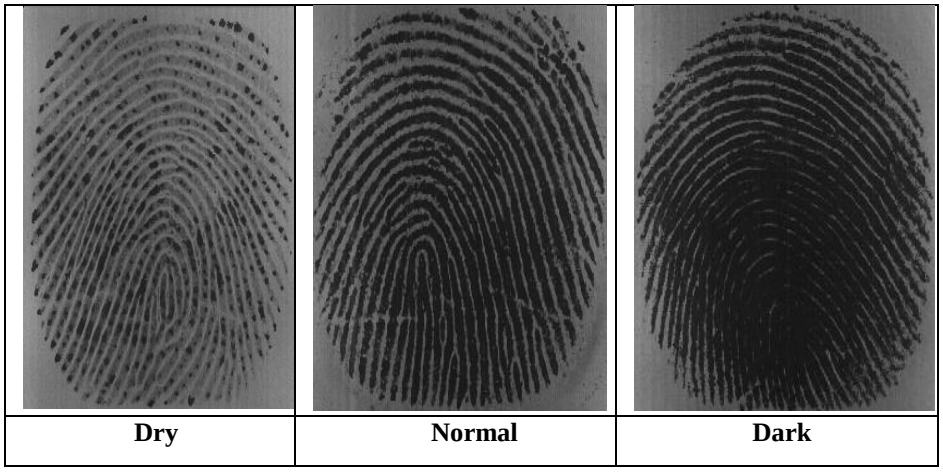
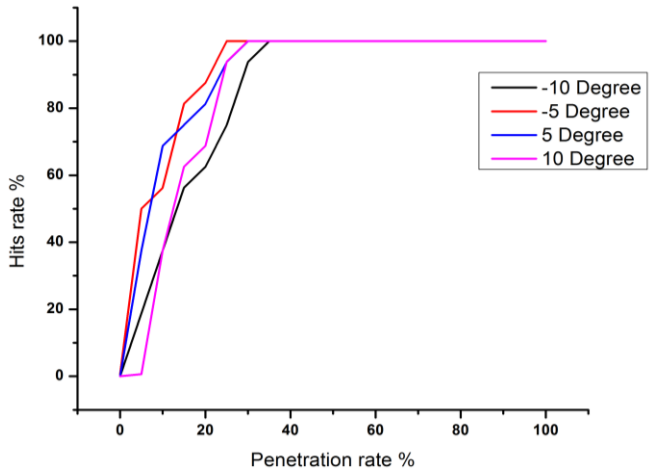
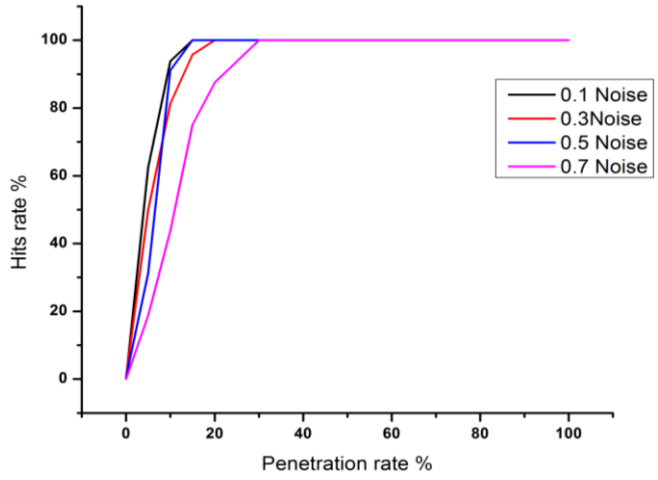



**Fig. 8.11 DB3 Sample image**

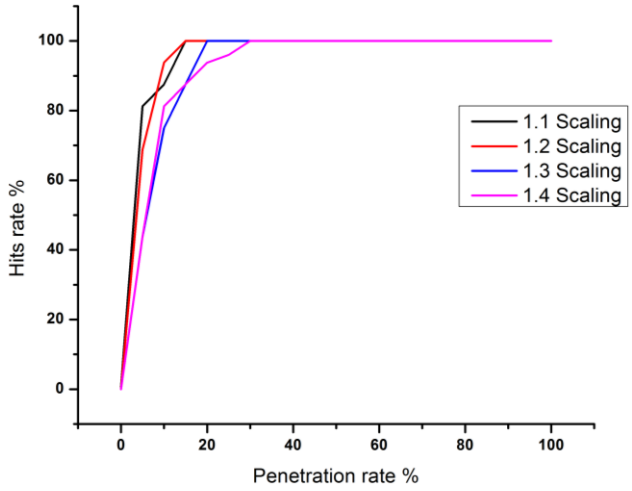
The figure 8.12 shows the penetration rate on rotation test at a hit rate of 100%, which varies from 25% to 35%. In noise test, the penetration rate is at a hit rate of 100%, which varies from 15% to 30%. In scaling test, the penetration rate is at a hit rate of 100%, which varies from 15% to 30%.




(i) DB3 Rotation Test




(ii) DB3 Noise Test

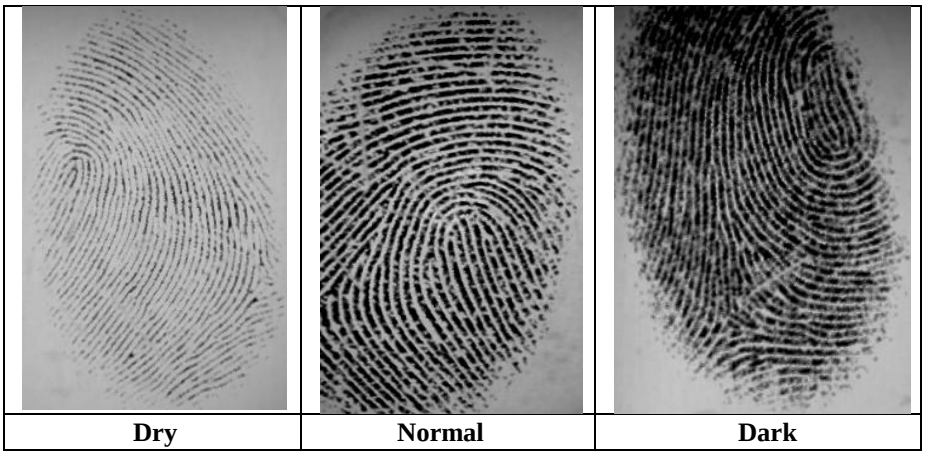



(iii) DB3 Scaling Test

**Fig.8.12 Performance on rotation, noise and Scaling test using DB3 FVC 2002 Dataset**

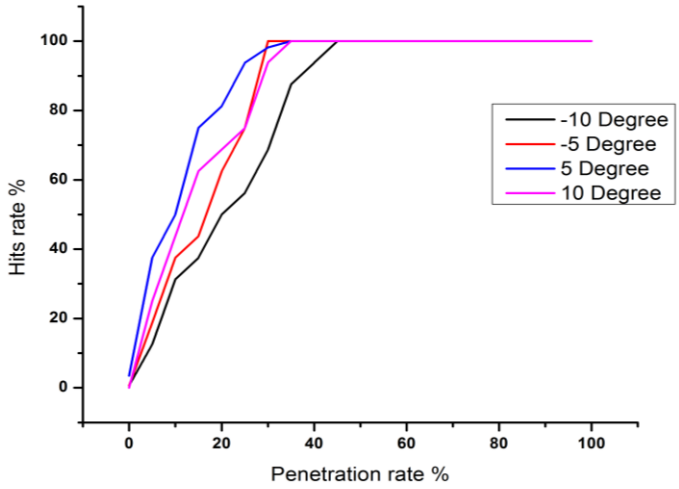
### 8.5.4 Experimentation on DB4

The sample fingerprint images of DB4 and their different qualities are shown in figure 8.13. The experimental results of rotation test, noise test and scaling test are shown below figure 8.14. Here, penetration rate of rotation test at a hit rates of 100% are in the range from 30% to 45%. Penetration rates of noise test and scaling test at a hit rate of 100% are in the range from 20% to 40% and 20% to 38% respectively.

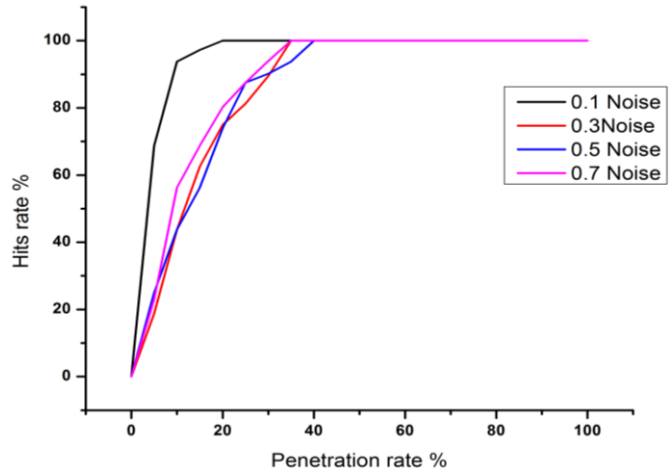


| Dry | Normal | Dark |
|---|---|---|

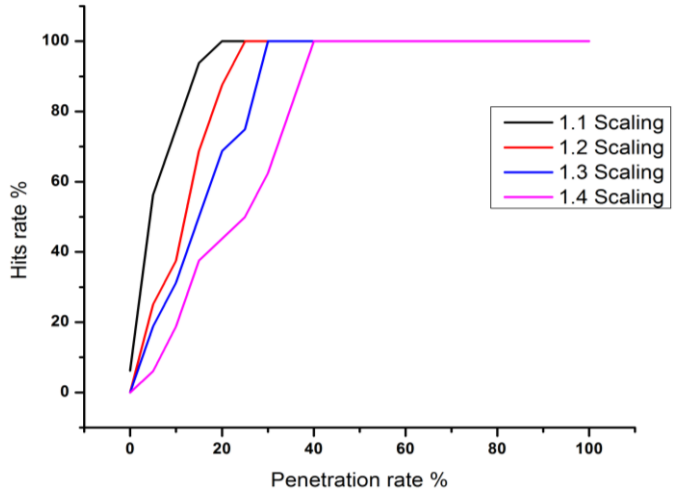
**Fig 8.13. DB4 Sample images**




(i) DB4 Rotation Test




(ii) DB4 Noise Test




(iii) DB4 Scaling Test

**Fig. 8.14 Performance on rotation, noise and scaling test using DB4 FVC 2002 Dataset**

From the experimentation using all the database of FVC2002, it shows that the proposed algorithm has a robustness property to some certain degree of rotation, noise and scaling. And it also performs consistently on different quality of fingerprint images, i.e, dry, dark and normal fingerprint images. The average penetration rate and hit rate for the proposed system using FVC2002 dataset is shown in figure 8.15.

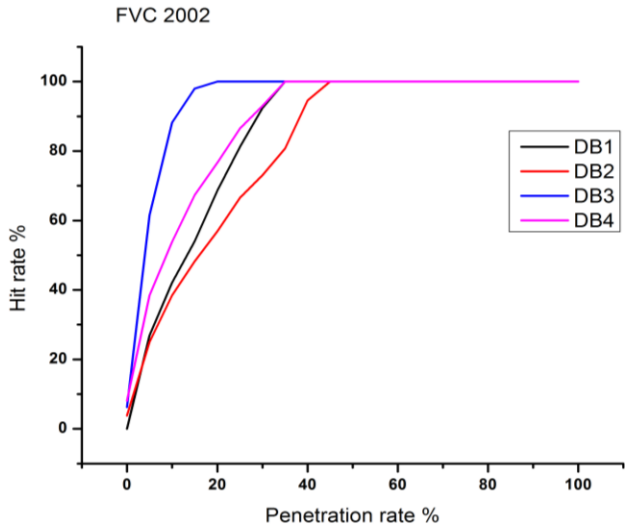



**Fig. 8.15. Performance of proposed indexing algorithm on FVC2002 Database.**

## 8.5 Comparison on Database Indexing

The proposed algorithm is compared with Minutiae triplets [84] and minutiae neighborhood [76]. The table 8.4 shows the comparison between them with a penetration rate at 95% and 100% hit rate. At 95% hit rate, minutiae triplets perform better than the proposed algorithm, but at 100% hit rate, the proposed algorithm performs better than both the minutiae triplets and minutiae neighbourhood algorithms.

**Table 8.4. Comparison for indexing performance: Penetration rate at 95% and 100% hit rate.**

| Algorithm | FVC 2002 DB1 | |
|---|---|---|
| | **95% hit rate** | **100% hit rate** |
| Minutiae Triplets [84] | **7.2%** | 38.1% |
| Minutiae neighborhood [76] | 14% | 57% |
| Distance feature | 28% | **35%** |

## 8.6. Chapter Summary

This Chapter explained about the standard fingerprint database and also discussed about the experimental results of the proposed preprocessing and post processing stages, heap based fingerprint matching algorithm and fingerprint indexing using distance feature. The results are well explained using figures, tables and graphs. It also shows the comparison with other related works available in the literature.