Fingerprint Recognition

Lưu Nam Đạt

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Figure 1: Source Image

1. Preprocessing

1.1. Normalization

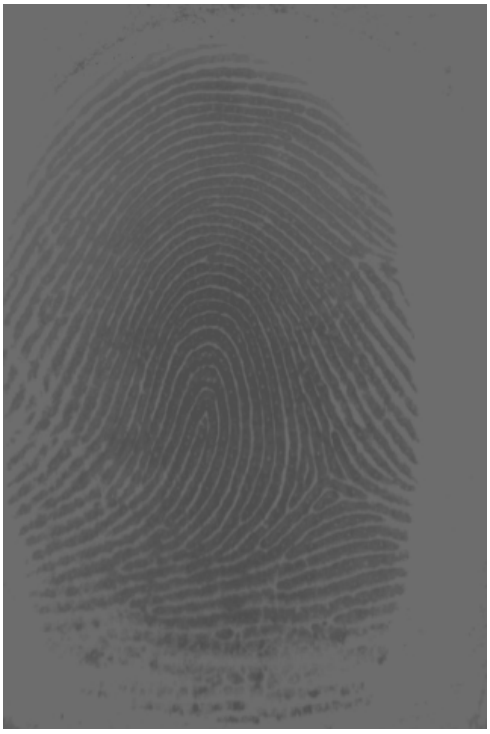


Figure 2: Normalization

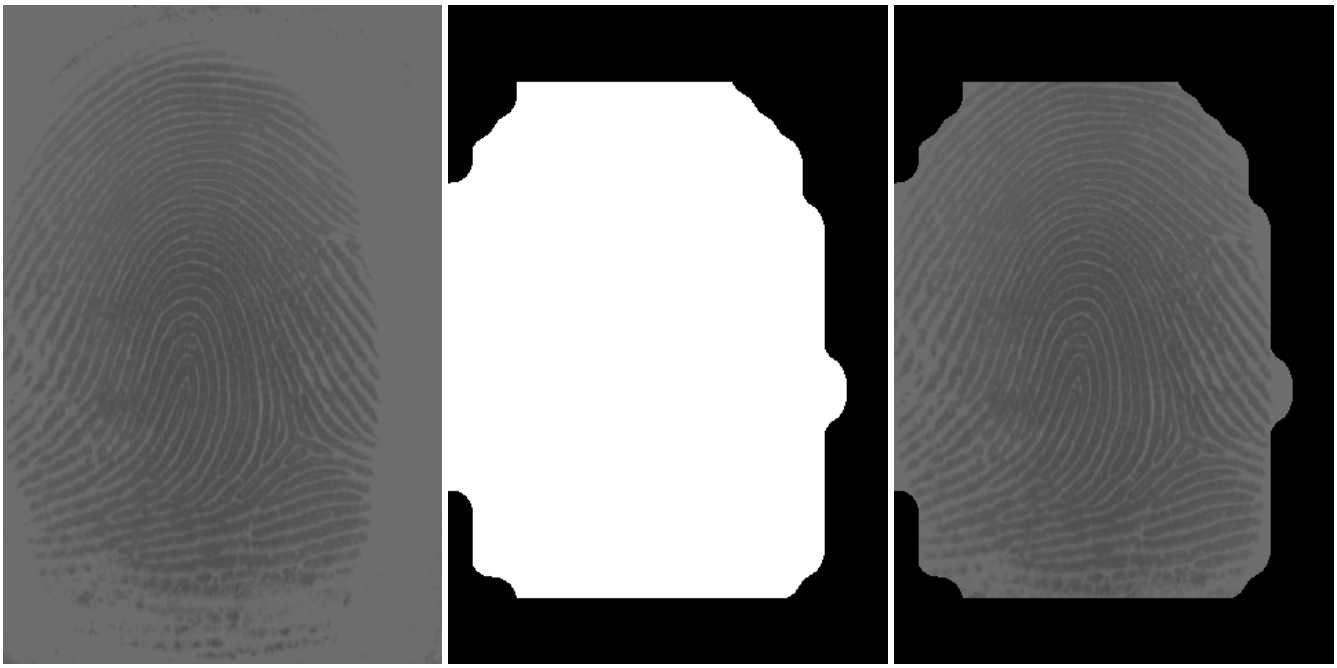
$$A(M) = \frac{\sum M_{ij}}{Size(M)}$$

$$S = Std(M) = \sqrt{\frac{\sum((M_{ij} - A(M))^2)}{Size(M)}}$$

$$\delta = \frac{\sqrt{S_0 \times (M_{ij} - A(M))^2}}{S}$$

$$M_{ij} = \begin{cases} A_0 - \delta, & \text{if } M_{ij} \geq A(M) \\ A_0 + \delta, & \text{if } M_{ij} < A(M) \end{cases}$$

1.2. Segmentation



A block K in image M is background if:

$$Std(K) \leq Std(M) \times \text{threshold}$$

Dilation, followed by Erosion are performed to unify the blocks.

Then, erosion followed by dilation are performed to exclude insignificant blocks.

1.3. Orientation

(The third image is only used for visualization only. It does not take part in any computing process.)

Sobel Operator is used for detect gradient along Ox and Oy.

Then, for each pixel in image, we can calculate the gradient angle:

$$\theta = \tan^{-1} \frac{|\overrightarrow{Gx}|}{|\overrightarrow{Gy}|}$$

Then we can calculate the gradient angle for each block.

1.4. Ridges' Frequency

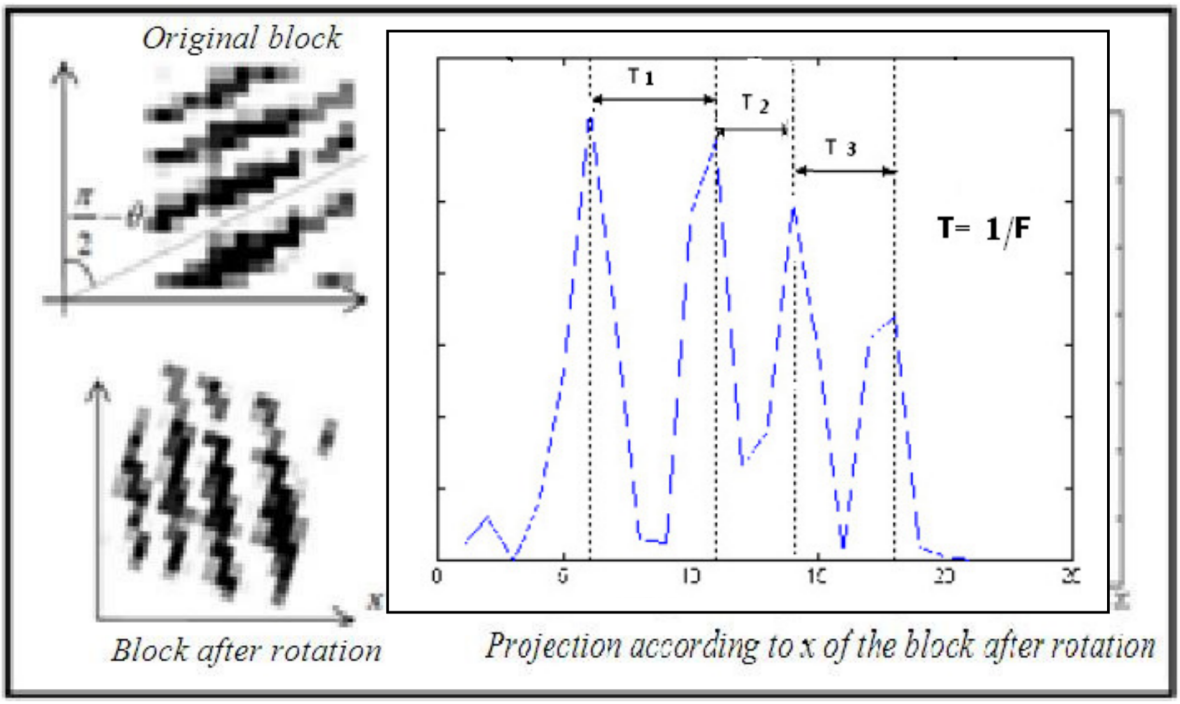
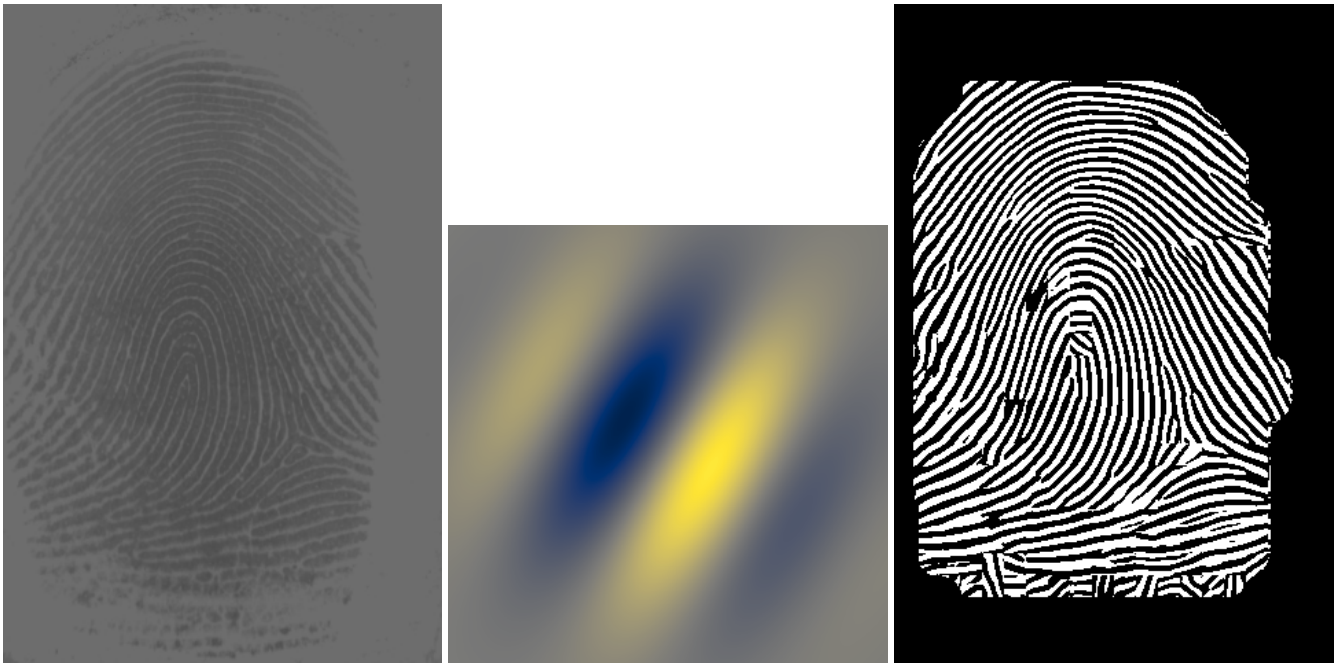


Figure 3: Calculating Ridges' Frequency

θ is calculated in the *Orientation* step.

1.5. Gabor filter



The size of the filter is determined by *ridge frequency*.

The Rotation of the filter is determined by *block orientation*.

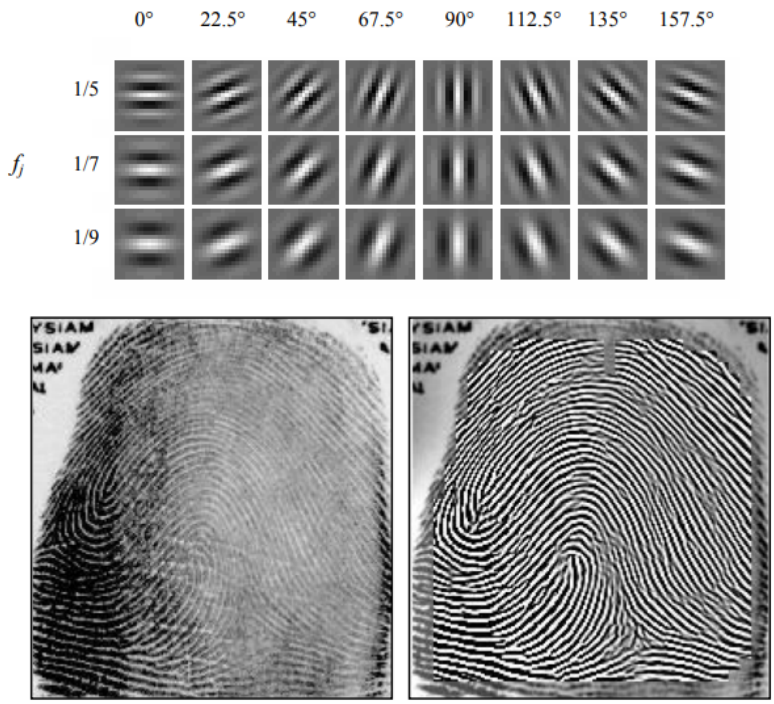


Figure 4: Another Example

1.6. Skeletonization

Figure 5: Skeletonization

1.7. Singularities and Keypoints

$$P_{\mathbf{G},C}(i,j) = \sum_{k=0\ldots7} angle\left(\mathbf{d}_k, \mathbf{d}_{(k+1) \bmod 8}\right).$$

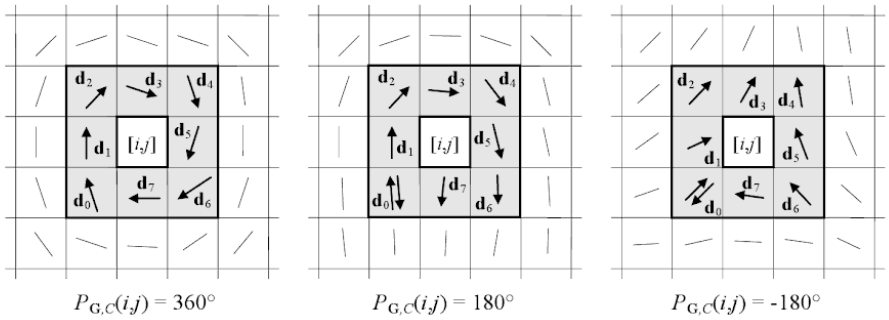


Figure 6: Detect Singularities

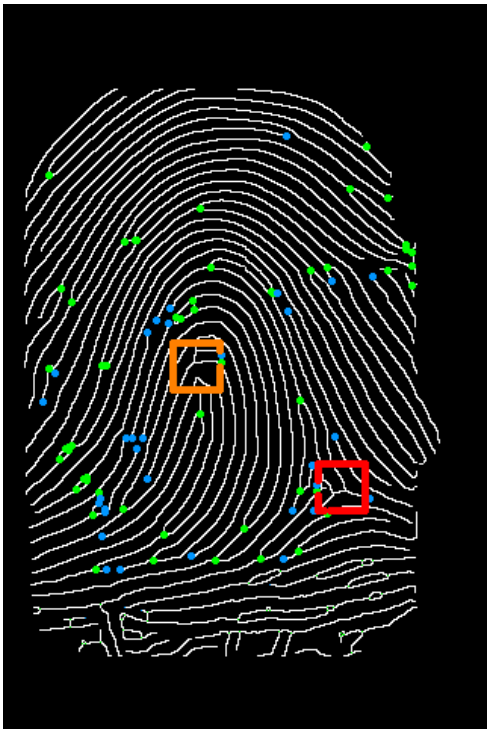
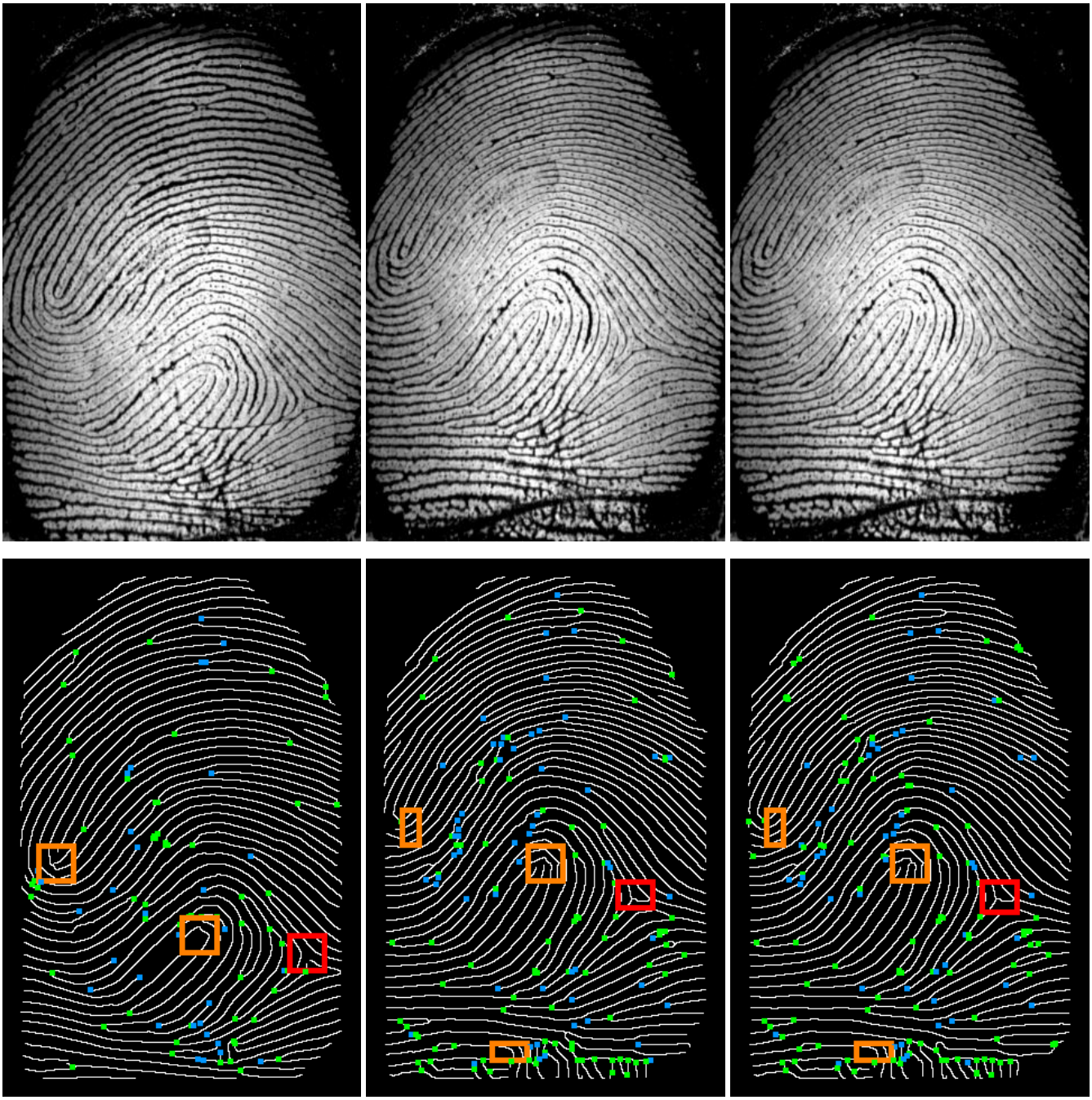


Figure 7: Singularities and Keypoints

2. Comparing

Verdict: Match



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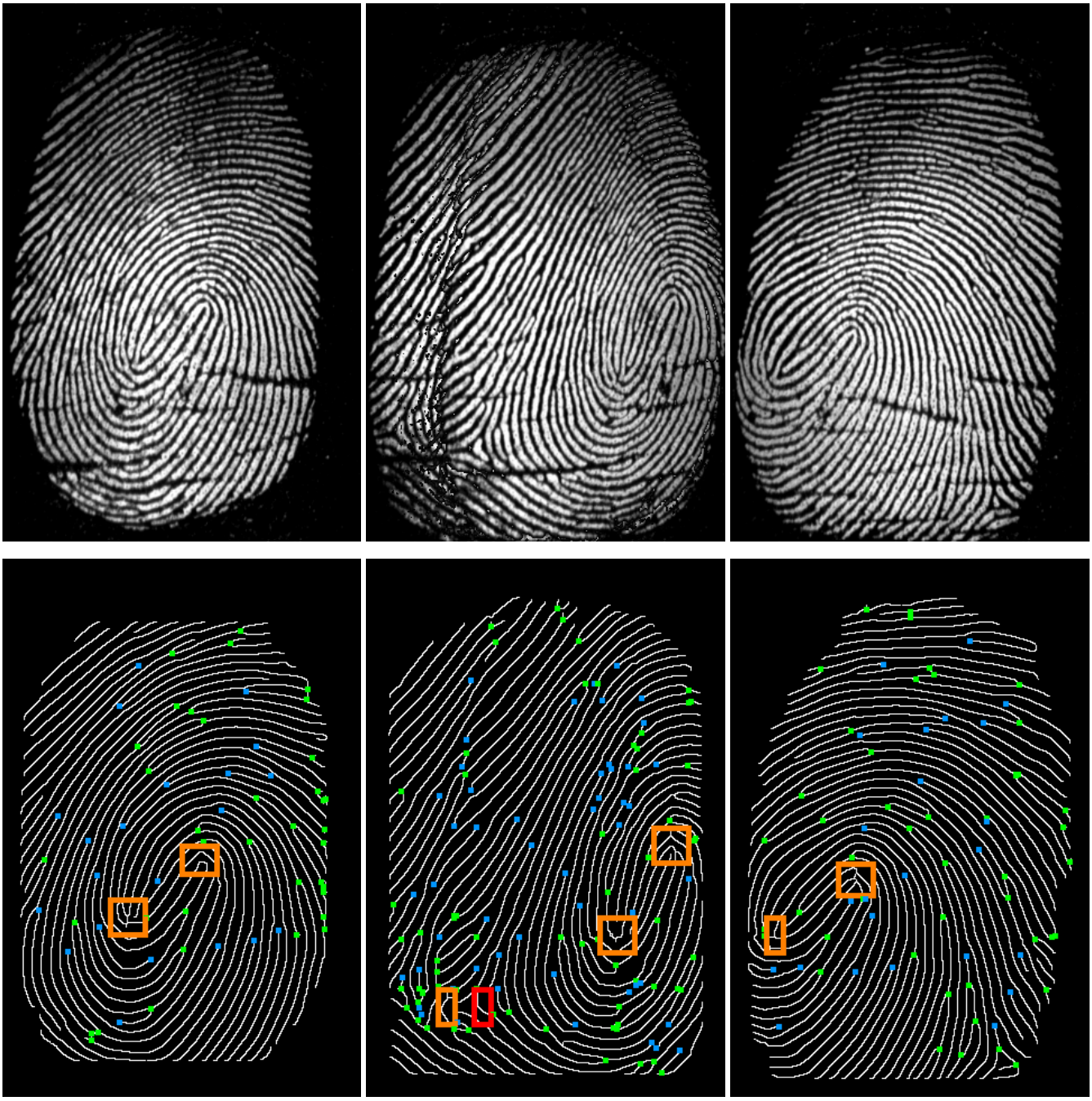
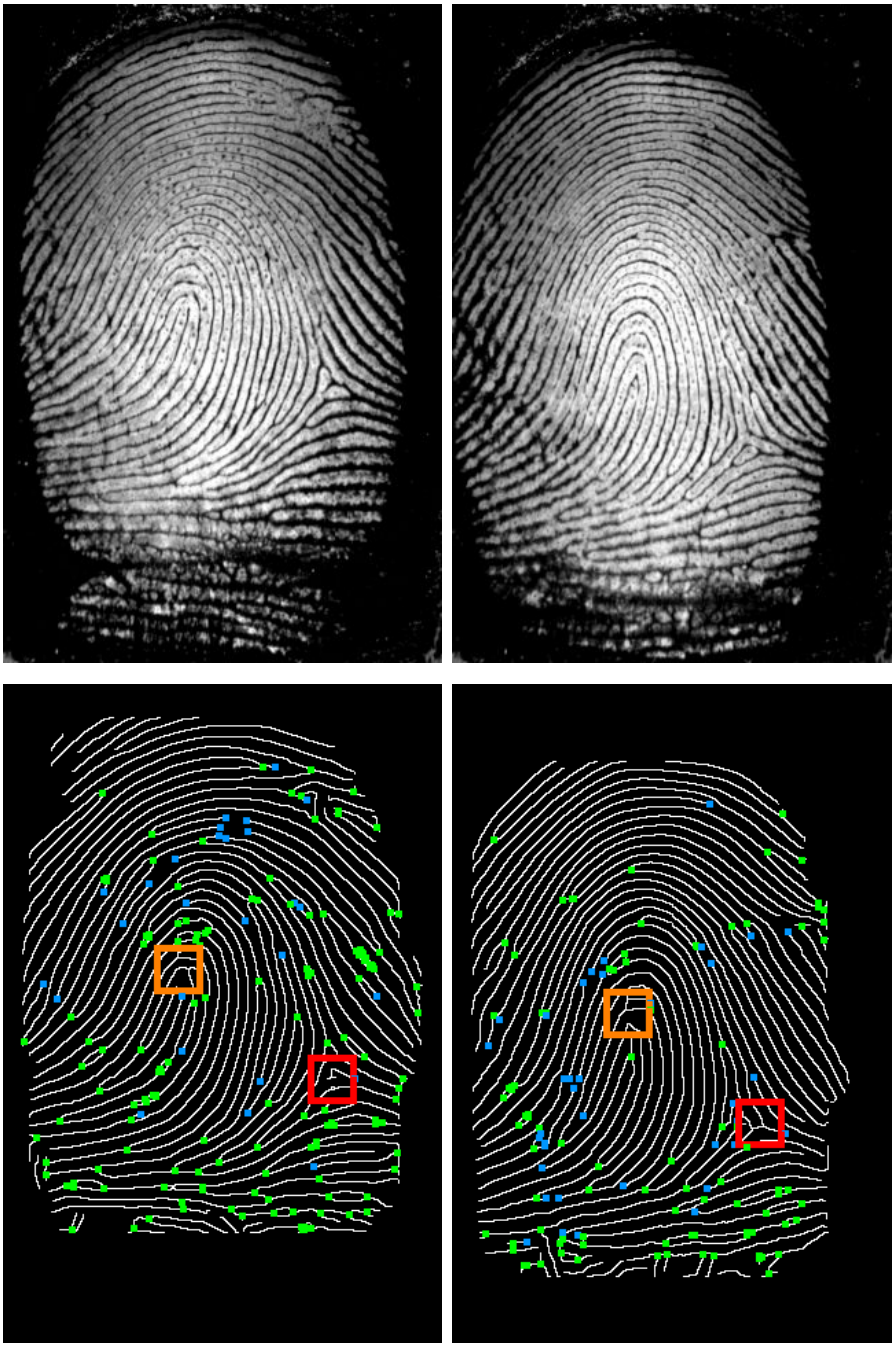
Comparing 1 and 9: MMScore = 0.02355706937779257 [True]
Comparing 1 and 10: MMScore = 0.03147042916615236 [True]
```

Verdict: Match



```
Comparing 11 and 13: MMScore = 0.06850775829491 [True]
Comparing 11 and 14: MMScore = 0.057465974475778385 [True]
```

Verdict: Mismatch



Comparing 0 and 4: Ridge MMScore = 0.11450558858066591 [False]

Verdict: Mismatch

```
Comparing 16 and 21:
CA = (268, 155), CB = (259, 183);
Ridge MMScore = 0.2133995812504585;
Singu MMScore = 0.5;
MMScore = 0.7133995812504585 [False]
```