# A Cascaded Fingerprint Quality Assessment Scheme for Improved System Accuracy

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**Abstract**

Poor-quality images mostly result in spurious or missing features, which further degrade the overall performance of fingerprint recognition systems. This paper proposes a reconfigurable scheme of quality checks at two different levels: i) at raw image level and ii) at feature level. At first level, ellipse properties are calculated through analysis of statistical attributes of the captured raw image. At second level, the singularity points (core & delta) are identified and extracted (if any). These information, as quality measures, are used in a cascaded manner to block/pass the image. This model is tested on both publicly available (Cross Match Verifier 300 sensor) as well as proprietary (Lumidigm Venus V100 OEM Module sensor) fingerprint databases scanned at 500 dpi. The experimental results show that this cascaded arrangement of quality barricades could correctly block poor quality images and hence elevated the overall system accuracy: with quality checks, both FNMR and FMR significantly dropped to 9.52% & 0.26% respectively for Cross Match Dataset and 2.17% & 2.16% respectively for Lumidigm Dataset.

***Keywords:*** *Fingerprint Image Quality, Elliptical ROI, Singularity Points, Euclidean Distance.*

## 1. Introduction

Although the performance of fingerprint recognition systems has greatly improved, it is still influenced by many factors. Among these, fingerprint image quality has had the greatest impact on matching performance. Poor-quality images mostly result in spurious or missing features, which further degrade the overall performance of the recognition systems [3]. Knowing the fingerprint quality in advance proves useful towards improving the performance of fingerprint recognition systems. So, in this paper, a quality assessment scheme is proposed, which analyzes the fingerprint image being fed into the system. Upon analysis, the image is either blocked (and hence rejected) or allowed to pass through for further processing, as per the case. The two quality assessment techniques employed herein are: i) assessment at raw image level through ellipse modeling and ii) assessment at feature level through singular point detection. They are explained in section 2. Experimental results are discussed in Sections 3, followed by conclusion in section 4.

## 2. Cascaded Scheme for Fingerprint Quality Assessment

Two quality barricades/quality checks (QCs) are employed in series to deal with the poor quality fingerprint images. Images need to be analyzed and blocked at the earliest to ensure the reliable matching performance and higher accuracy of the fingerprint recognition systems. As shown in figure 4, at first quality check (QC1), the raw image is analyzed and an ellipse is modeled. Properties of ellipse are measured and decision is taken whether to block or pass the raw image. If allowed to pass through to the next level (QC2), singular point features are identified and extracted. If finger is not placed properly over the scanner platen, QC2 will declare the core points either missing or unacceptable (if shifted to the boundaries of the platen). So, if core point(s) not detected in and around center of the image, QC2 will block the image with a prompt/message. They are explained in detail in sub-sections 2.1 and 2.2.

### 2.1 Quality Assessment at Raw Image Level: First Quality Barricade

This approach is primarily based on Ellipse modeling, wherein, the statistical properties (like: moments, especially the normalized second central moment) of the raw fingerprint image are measured. Based on these region properties, an ellipse is modeled, as shown in figure 1,

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which is a smooth closed curve symmetric about its horizontal and vertical axes. Once an ellipse is modeled, ellipse properties, viz. area of ellipse, major and minor axes, eccentricity, are used to assess the quality of the fingerprint image.

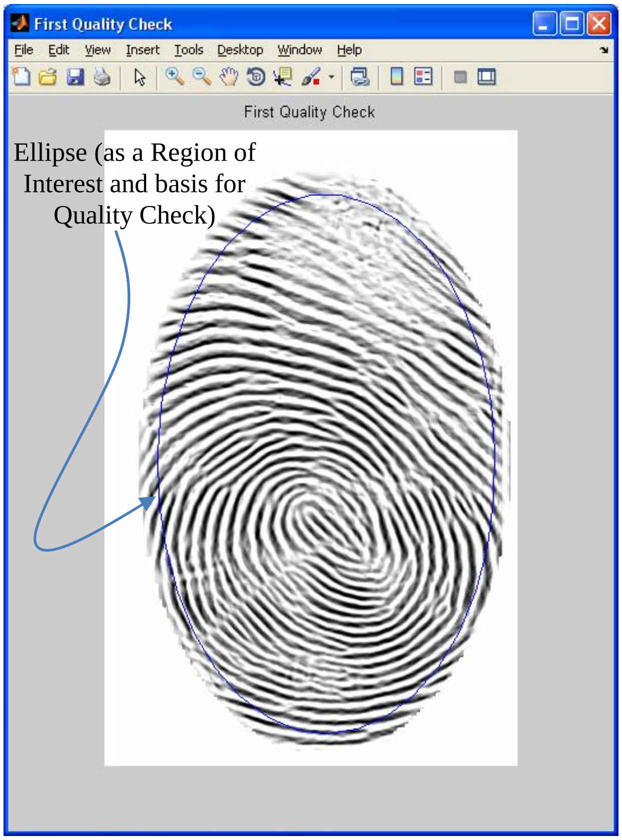


Figure 1. Raw fingerprint image modeled as an ellipse at QC1.

Elements of ellipse: The semi-major axis (denoted by *a* in the figure 2) and the semi-minor axis (denoted by *b* in the figure 2) of the ellipse are one half of the major and minor diameters, respectively. The foci of the ellipse are two special points $F_1$ and $F_2$ on the ellipse's major axis and are equidistant from the center point. The sum of the distances from any point P on the ellipse to those two foci is constant and equal to the major diameter ( $PF_1 + PF_2 = 2a$ ). Each of these two points is called a focus of the ellipse. The eccentricity of an ellipse, usually denoted by $\varepsilon$ or $e$, is the ratio of the distance between the two foci, to the length of the major axis or $e = 2f/2a = f/a$. For an ellipse the eccentricity is between 0 and 1 ($0<e<1$). When the eccentricity is 0 the foci coincide with the center point and the figure is a circle. As the eccentricity tends toward 1, the ellipse gets a more elongated shape.

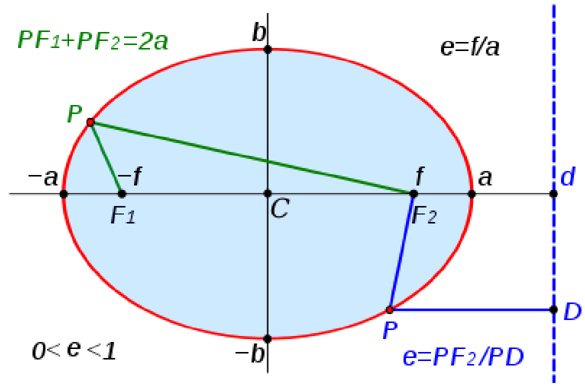


Figure 2. Elements of an ellipse.

In mathematics, a moment is, loosely speaking, a quantitative measure of the shape of a set of points. The "second moment", for example, is widely used and measures the "width" (in a particular sense) of a set of points in one dimension or in higher dimensions measures the shape of a cloud of points as it could be fit by an ellipsoid. The second central moment about the mean is the variance, the positive square root of which is the standard deviation $\sigma$ [8] (the second central moment $\mu 2$ is the variance: $\sigma^2 = \mu 2$ [7]).The normalized central moments are dimensionless quantities, which represent the distribution independently of any linear change of scale [8].

## 2.2 Quality Assessment at Feature Level: Second Quality Barricade

This sub-section deals with the second quality barricade, which, in principle, is based on identification and extraction of singularity point(s) features: cores and/or deltas. Presence of at least one such singular point, in and around the center of the image, is treated as an indicator of proper placement of finger on the scanner platen, and absence indicates improper placement. In absence of any such singular point, the image is blocked (not allowed to pass through for further processing and matching) with a prompt/message.

Working principle: a singular point is the location where the general ridge orientation becomes discontinuous. Informally this can be stated as the area where ridges oriented rightwards change to leftwards and those that were oriented upwards turn downwards, and opposite. This information can be extracted from the quadrant change of the averaged square gradients [1][2]. The orthogonal gradient components in the x and y direction are considered separately. In general, each pair of corresponding gradient components manifests the gradient quadrant change by the change of sign. The sign maps PMx and PMy are computed using Eq. (1) [2]:

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$$\begin{bmatrix} PM_x \\ PM_y \end{bmatrix} = \begin{bmatrix} \begin{cases} \wedge_{(\overline{G_x'})\neq 0} PM_x = sign(\overline{G_x'}) \\ \wedge_{(\overline{G_x'})=0} PM_x = 1 \end{cases} \\ \begin{cases} \wedge_{(\overline{G_y'})\neq 0} PM_y = sign(\overline{G_y'}) \\ \wedge_{(\overline{G_y'})=0} PM_y = 1 \end{cases} \end{bmatrix} \quad (1)$$

The points in whose respective local ridge gradient changes sign in both x and y directions. Those points are found by computing the union of the two sets of such points for which the sign of the y-directional and x-directional (respectively) gradient component changes (Eq. 2) [2]:

$$[x_{sp}, y_{sp}] = \langle x, y : edge(PM_x) \rangle \cap \quad (2)$$
$$\cap \langle x, y : edge(PM_y) \rangle$$

The operator *edge* in Eq. 2 denotes any edge detector that works on binary images, and [$x_{sp}$, $y_{sp}$] are the points where two quadrant change boundaries intersect.

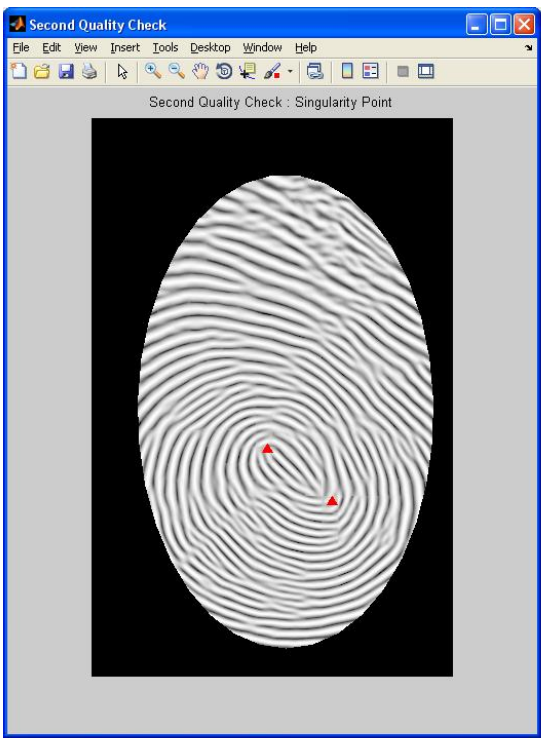


Figure 3.Detection of singular points at QC2.

In case of fingerprint image from ARCH class, which has no singular points(s), care should be taken to deal with it separately, or else such an image will also get blocked even if it is of good/acceptable quality. We overcome this problem through our approach, wherein, we find out the closest point (possible intersection point) the two quadrant change boundaries pass through. This is based on Euclidean distance approach. Other improvements include separation of core and delta points, thereupon, making decisions based on only core points and not delta points. Also, few more barricades need to be added based on local quality analysis approaches, like Local FFT and Contrast, as in [9].

## 3. Experimental Results

Publicly available [6] (Cross Match Verifier 300 sensor) and a proprietary (Lumidigm Venus V100 OEM Module sensor) fingerprint databases (@ 500 dpi) have been chosen as test data to evaluate the impact of the proposed cascaded scheme on system's performance, refer to Table 1 for details. The scheme is implemented in MATLAB. The experimental results show that this approach significantly improves the overall system accuracy: FNMR and FMR dropped to 9.52% & 0.26% respectively for Cross Match Dataset and 2.17% & 2.16% respectively for Lumidigm Dataset. Few cases from experimental results in the form of comparison charts are presented in Fig. 9 and 10. The corresponding graphs are shown in Fig. 5, 6, 7 and 8.

Table 1: Fingerprint Datasets

| **Publicly Available** | | **Proprietary** | |
|---|---|---|---|
| Cross Match Dataset | | Lumidigm Dataset | |
| Series | Images | Series | Images |
| 012_3 | 8 | 001_5 | 11 |
| 013_4 | 8 | 002_5 | 11 |
| 022_3 | 8 | 003_5 | 11 |
| 022_4 | 8 | 004_5 | 11 |
| 022_6 | 8 | 006_5 | 10 |
| 022_7 | 8 | 007_5 | 11 |
| 022_8 | 8 | --- | --- |
| **Total** | **56** | **Total** | **65** |

## 4. Conclusions

In this paper, we have proposed a cascaded scheme to assess the fingerprint image quality at raw image and feature levels, so that poor quality images can get identified and thus sidelined to ensure reliable matching and much higher system accuracy. Experimental results clearly show that the quality barricades in combination could effectively block poor quality fingerprint images, thereby, strengthen the performance of the matcher.

Though the scheme could perform extremely well over the small datasets presented here, it needs to be confirmed and tested rigorously over full range of FVC2004 and other publicly available large datasets.

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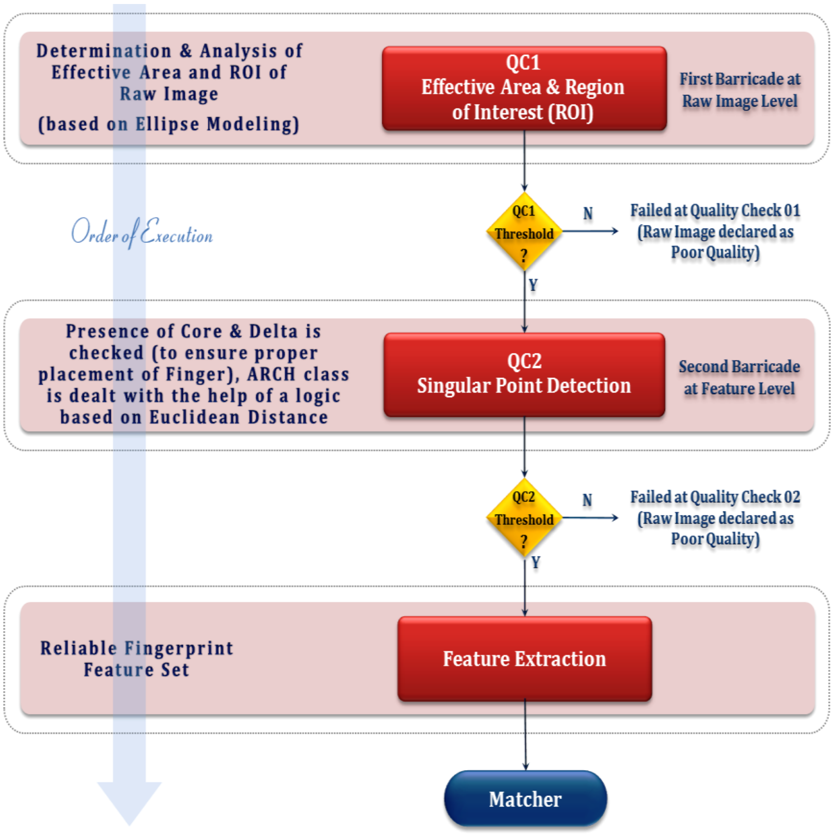


Figure 4. Cascaded fingerprint quality assessment scehme.

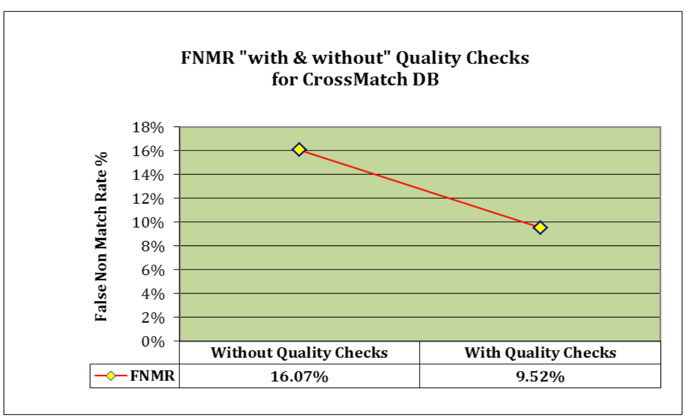


Figure 5. FNMR: Cross Match Dataset.

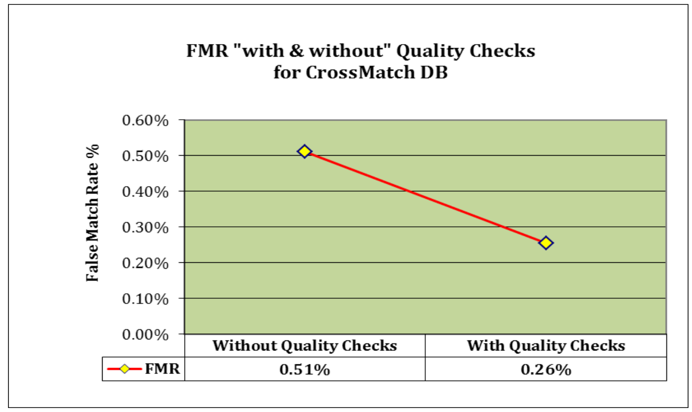


Figure 6. FMR: Cross Match Dataset.

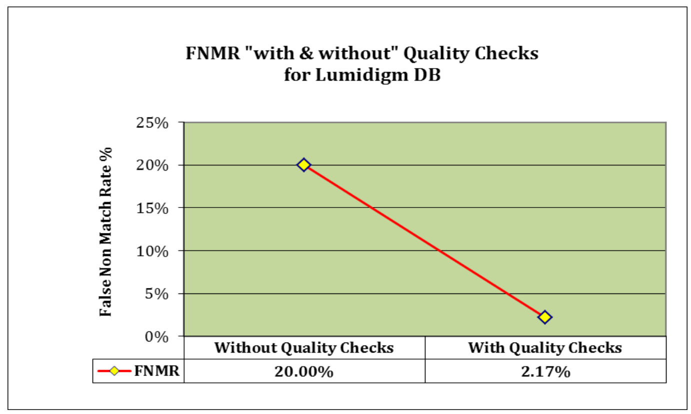


Figure 7. FNMR: Lumidigm Dataset.

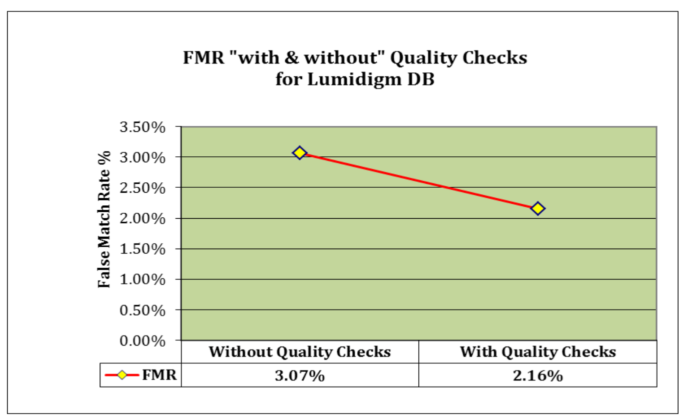


Figure 8. FNMR: Lumidigm Dataset.

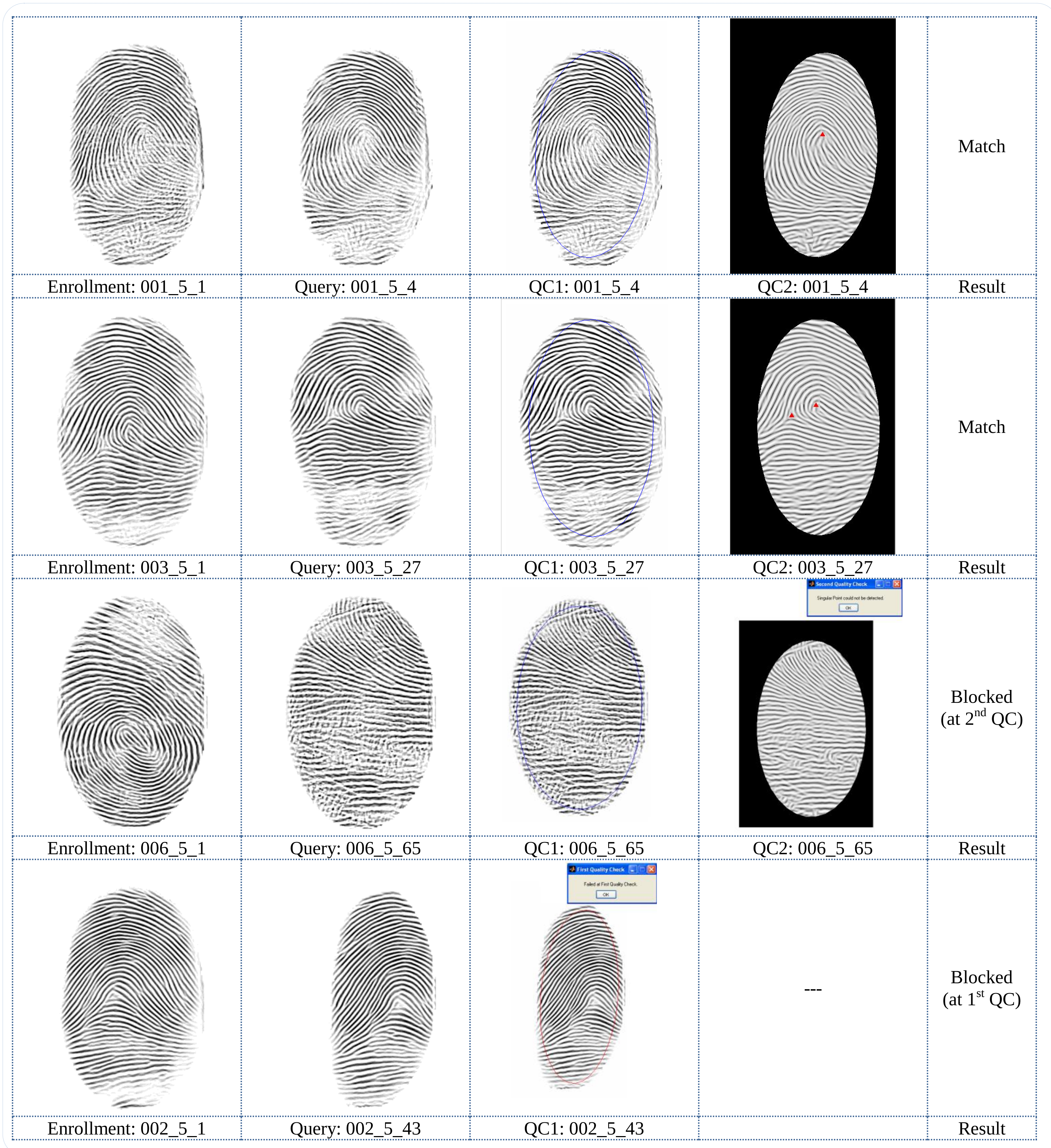


Fig. 9 Few cases from experimental results.

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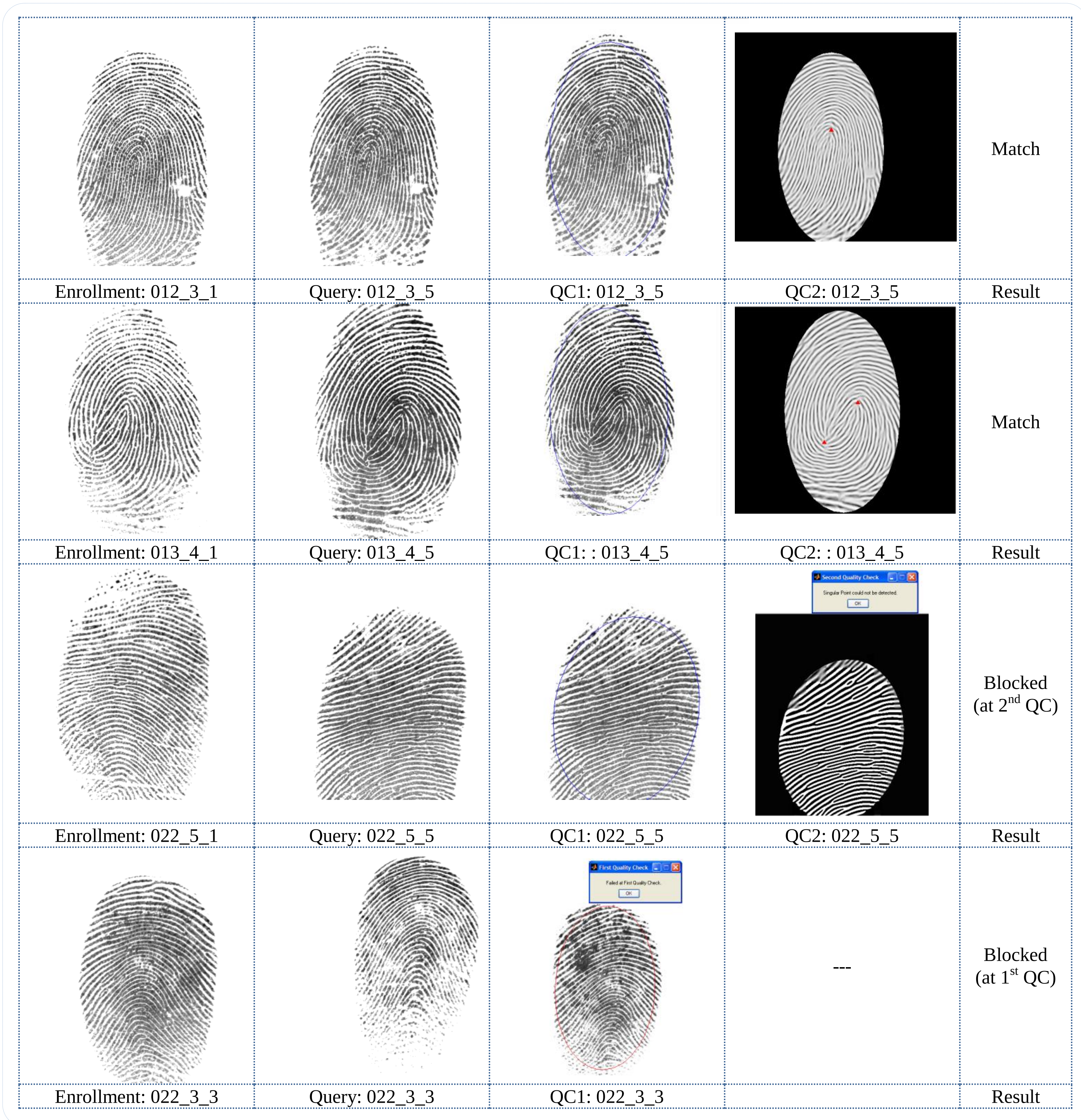


Fig. 10 Few cases from experimental results.