A Fault–Tolerant Approach for Detection of Singular Points in Noisy Fingerprint Images

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Abstract

Singular point detection is one of the most crucial processes in fingerprint recognition systems. Singular points are used for fingerprint classification, matching and alignment. This paper presents a method for reliable detection of singular points, which is largely insensitive to the degradation of fingerprint quality. The approach involves two phases, wherein, first phase detects the singular points, which operates on the quadrant change information. The second phase involves the analysis and extraction of the locations having high probability of the existence of singular points. The second phase uses orientation reliability measure of the filtered fingerprint image. The spurious singular points are detected, and thereby eliminated. This model is tested on selected noisy images from a publicly available (Cross Match Verifier 300 sensor) fingerprint database scanned at 500 dpi. The experimental results show that the approach effectively eliminates the spurious singular points in the noisy images.

Keywords: *Singular Points, Spurious, Quadrant Change, Reliability, Minimum Inertia, Maximum Inertia, Euclidean Distance.*

1. Introduction

Although the performance of fingerprint recognition systems has greatly improved, it is still influenced by many factors. One of such factors is the inaccurate detection of singular points (core and delta points). Poor-quality and noisy fingerprint images mostly result in spurious or missing singular points(SPs), which generally results in degradation of the overall performance of the recognition systems. So, this paper proposes a scheme, which primarily deals with the detection and elimination of spurious SPs. The scheme comprises two phases, which are based on different principles for detecting and extracting the SPs. Finally, a new set of SPs is generated, which is basically an intersection of two sets of SPs from two phases. The two techniques employed herein for detection and extraction of SPs are: i) Quadrant Change method and ii) Orientation Reliability Measure based method. They are explained in section 2. Experimental results are discussed in Sections 3, followed by conclusion in section 4.

2. Fault–Tolerant Approach for Detection of Singular Points

This approach primarily focuses on the detection and removal of SPs in low contrast and noisy fingerprint images. Also, the adopted methods in two phases, as compared with their original counterparts, are modified and made more effective towards localization of SPs. This is achieved in two phases, as shown in Fig. 7. These are explained in detail in sub-sections 2.1, 2.2 and 2.3.

2.1 Quadrant Change Method: Phase I

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 directions 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]:

ISSN (Online): 1694-0814
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$$\begin{bmatrix} PM_x \\ PM_y \end{bmatrix} = \begin{bmatrix} \begin{cases} \wedge_{(\overline{G_x'})\neq 0} PM_x = sign(\overline{G_x'}) \\ \wedge_{(\overline{G_x'})=0} PM_x = 1 \end{cases} \\ \begin{cases} \wedge_{(\overline{G_y'})\neq 0} PM_y = sign(\overline{G_y'}) \\ \wedge_{(\overline{G_y'})=0} PM_y = 1 \end{cases} \end{bmatrix} \qquad (1)$$

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]:

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

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, as shown in Fig. 1.

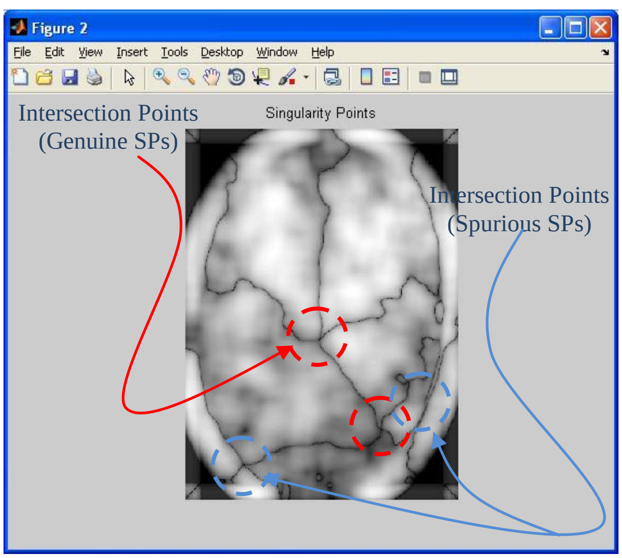

Figure 1.Horizontal and Vertical Maps (045_5_7.tif).

This method works well with good quality gray images, but the moment image quality degrades, it starts resulting in spurious SPs and goes ineffective, as shown in Fig. 2. Also, the method is modified in case of images from ARCH classes and the images from rest of the classes too, where the two quadrant change boundaries don't exactly intersect and they just pass through a point closest to both of them. ARCH class by definition holds images with no Core and Delta points, but generally obtaining a unique and unambiguous reference point becomes necessary to facilitate the alignment of fingerprint images for reliable matching. In case of images from other classes, sometimes, presence of noise results in loss of gradient information, thus the two boundaries just pass through a point closest to them, instead of intersecting each other. We have resolved such cases by employing a method based on Euclidean distance calculation, wherein, we find out such points, where they are suppose to intersect. If the distance remains below certain empirically determined optimum threshold value, such points are considered as the point of intersection, and thus either they are just used as a reference point in case of ARCH class, or considered as a true SP(s).

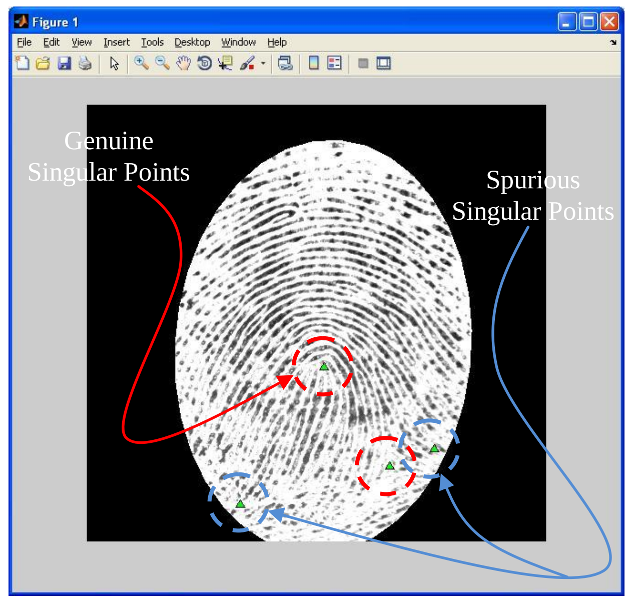

Figure 2.SPs as Outcome of Phase I (045_5_7.tif).

2.2 Orientation Reliability Measure: Phase II

In this phase, the fingerprint image is first filtered using Gabor filter, as explained in [4]. We then calculate 'reliability' of ridge orientation map, followed by calculating the area of moment of inertia about the orientation axis found (this will be the minimum inertia) and an axis perpendicular (which will be the maximum inertia), as given in Eqs. (1) and (2) [7]:

min_inertia(x, y) =
((Gyy + Gxx) - (Gxx - Gyy) * φ'$_x$) - (Gxy * φ'$_y$))/2 (1)

max_inerita(x, y) = Gyy + Gxx – min_inertia(x, y) (2)

where, φ'$_x$ and φ'$_y$ are cosine and sine of doubled angles (ridge orientations), as in [1][4]. The reliability measure is given by Eq. (3) [7]:

1.0 – min_inertia/max_inertia (3)

ISSN (Online): 1694-0814
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The reasoning is being that if the ratio of the minimum to maximum inertia is close to one, we have little orientation information [7]. This is how we measure the reliability of the orientations in ridge orientation map. As shown in Fig. 3, as the reliability changes across the orientation image, the color changes [7][8]. The bright and blue colored zones represent least reliable areas, which can be possible SPs, noisy sections or minutiae points, as orientation changes drastically around these areas. The deep red sections represent good quality regions of the image, as the orientations change in such areas are smooth, as shown in Fig. 3.

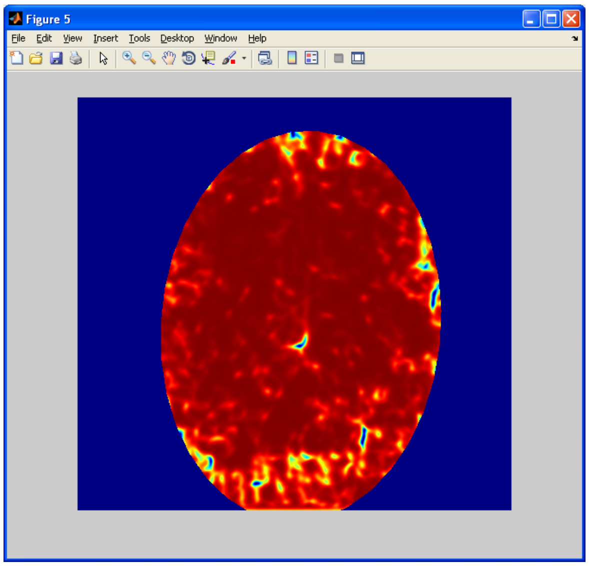

Figure 3.Reliability Image (045_5_7.tif).

The reliability values remain between 0 and 1. In our case, a value above 0.045 is considered 'reliable'. The thresholded image is shown in Fig. 4, where deep blue regions indicate the least reliable areas, possible representing the candidate SPs. This method also goes unperformant as the severity level increases in the images, resulting in many spurious minutiae, as shown in Fig. 5.

2.3 Proposed Method

As explained in Fig.7, the proposed method takes opinion from both the phases by referring to both the sets of SPs. It then draws a small bounding box (2D) around each SP from phase I to check the neighborhood of the respective SPs. In our case, we have considered 11x11 box. If any SP from phase II appears in the local neighborhood of a particular SP in phase I, SP is considered genuine and marked, or else discarded, as shown in Fig. 6.

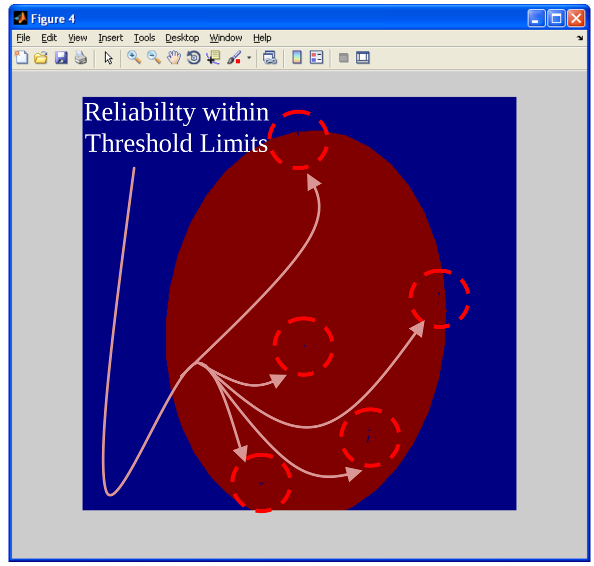

Figure 4. Thresholded Reliability Image (045_5_7.tif).

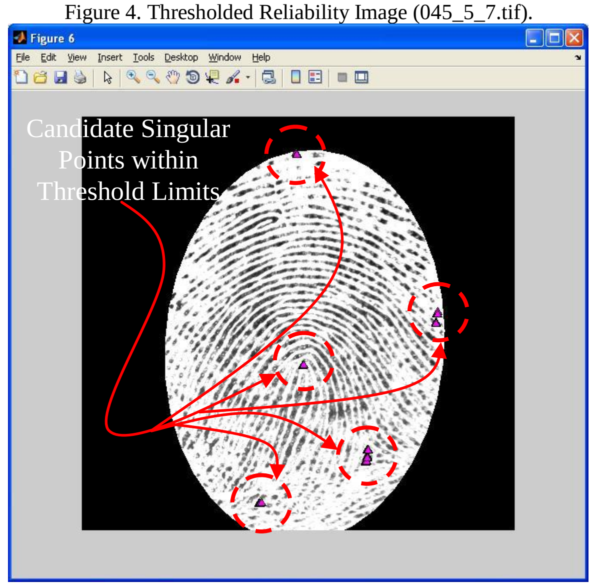

Figure 5.SPs as Outcome of Phase II (045_5_7.tif).

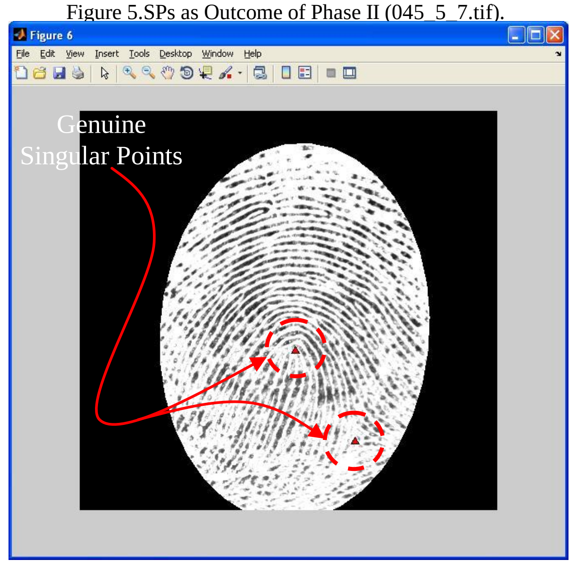

Figure 6.Genuine SPs as Outcome of Proposed Scheme (045_5_7.tif).

3. Experimental Results

Publicly available dataset, Cross Match Verifier 300 sensor [6], has been chosen as test data to evaluate the impact of the proposed cascaded scheme for elimination of spurious singular points, refer to Table 1 for details. The scheme is implemented in MATLAB. The experimental results show that this approach significantly improves the accuracy of detection of correct singular points in noisy and low contrast fingerprint images. Only, typical, noisy images have been chosen to measure the effectiveness of the approach. Few of them are presented in Fig. 8 and 9.

Table 1: Fingerprint Datasets

Publicly Available	
Cross Match Dataset	
Series	
027_3_6.tif	076_7_6.tif
027_5_2.tif	076_7_8.tif
045_3_4.tif	076_8_1.tif
045_5_2.tif	076_8_8.tif
045_5_7.tif	Total: 14
076_7_1.tif	
076_7_2.tif	
076_7_3.tif	
076_7_4.tif	
076_7_5.tif	

4. Conclusions

In this paper, a fault–tolerant approach is proposed for detection of genuine singular points, especially in noisy fingerprint images. Genuine singular points are very crucial towards the high accuracy and performance of many of the other modules of the system, like: fingerprint classification, alignment, matching etc., thus spurious singular points need to be completely removed. Experimental results clearly show that the two methods in combination could effectively remove the spurious singular points. However, the scheme is tested only against some select noisy cases, and needs needs to be further tested over full range of other publicly available large datasets.

Acknowledgments

We wish to extend our sincere thanks to the Department of Information Technology (DIT), Ministry of Communications and Information Technology, Govt. of India, for assigning us a biometric project: "BharatiyaAFIS". This work is carried out as a part of the same project.

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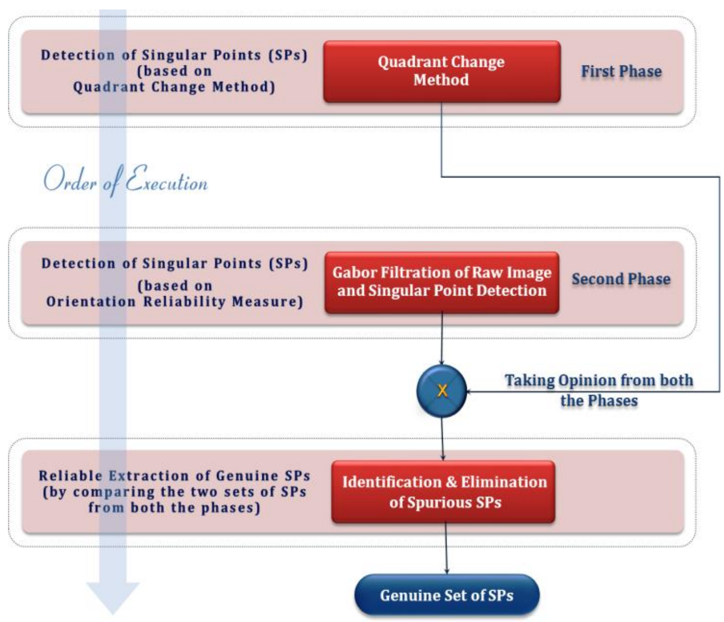

Figure 7. Proposed Scheme.

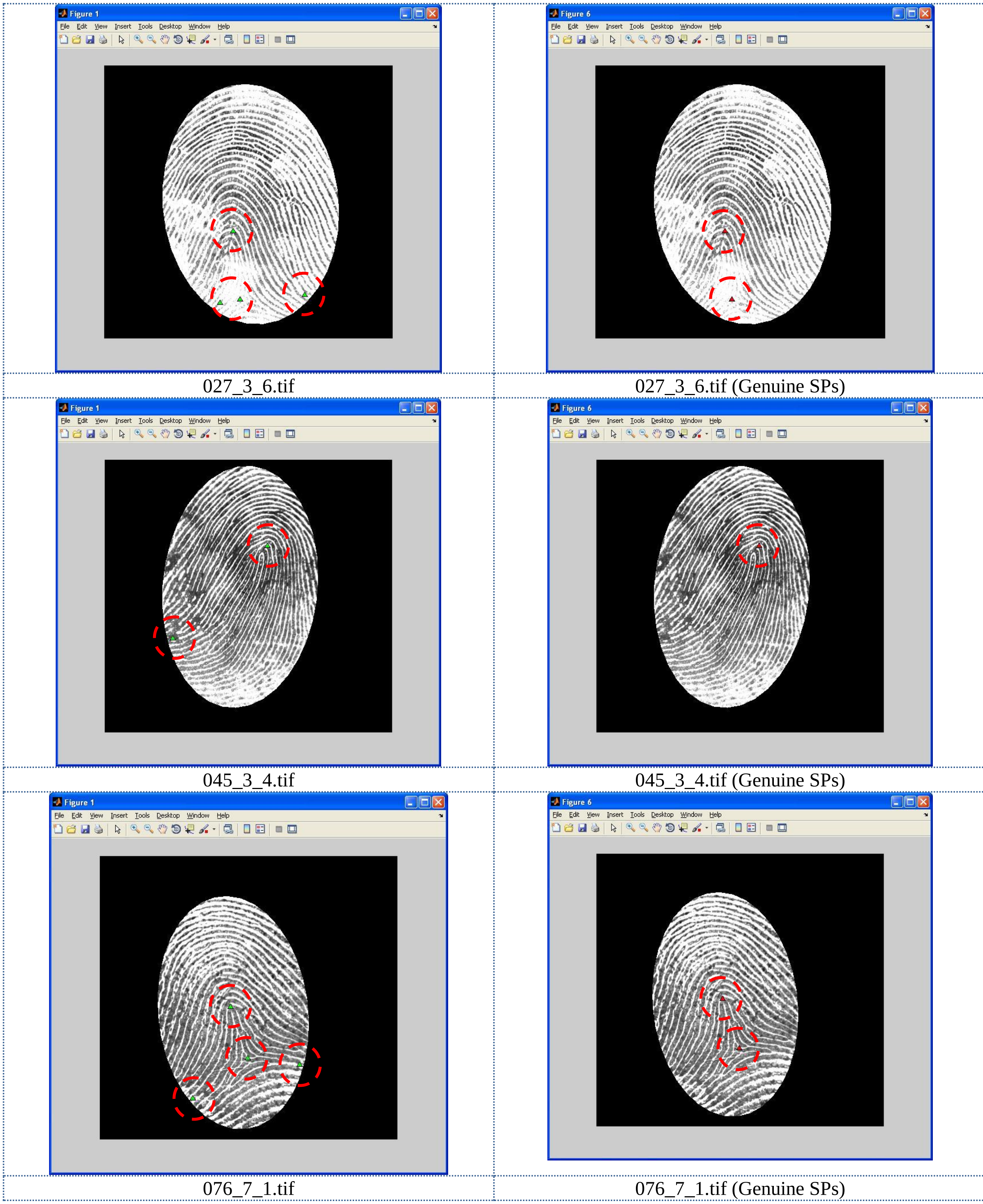

Fig. 8 Few cases from experimental results: SPs from Quadrant Change method (left) and Genuine SPs from Proposed Method (right).

ISSN (Online): 1694-0814
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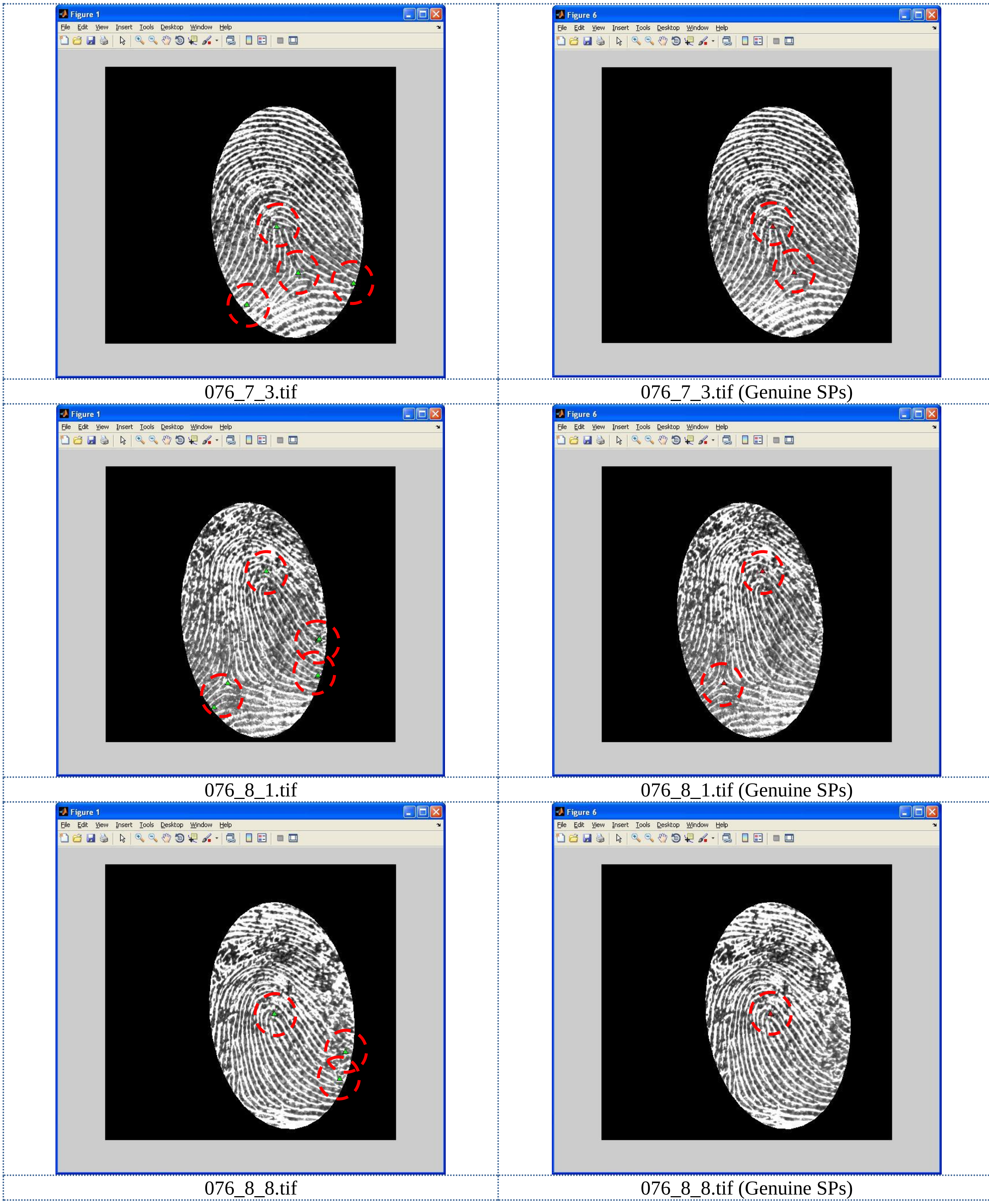

Fig. 9 Few cases from experimental results: SPs from Quadrant Change method (left) and Genuine SPs from Proposed Method (right).