Extract from:

D. Maltoni, D. Maio, A.K. Jain, S. Prabhakar
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3.6: Singularity and Core Detection

(extract)

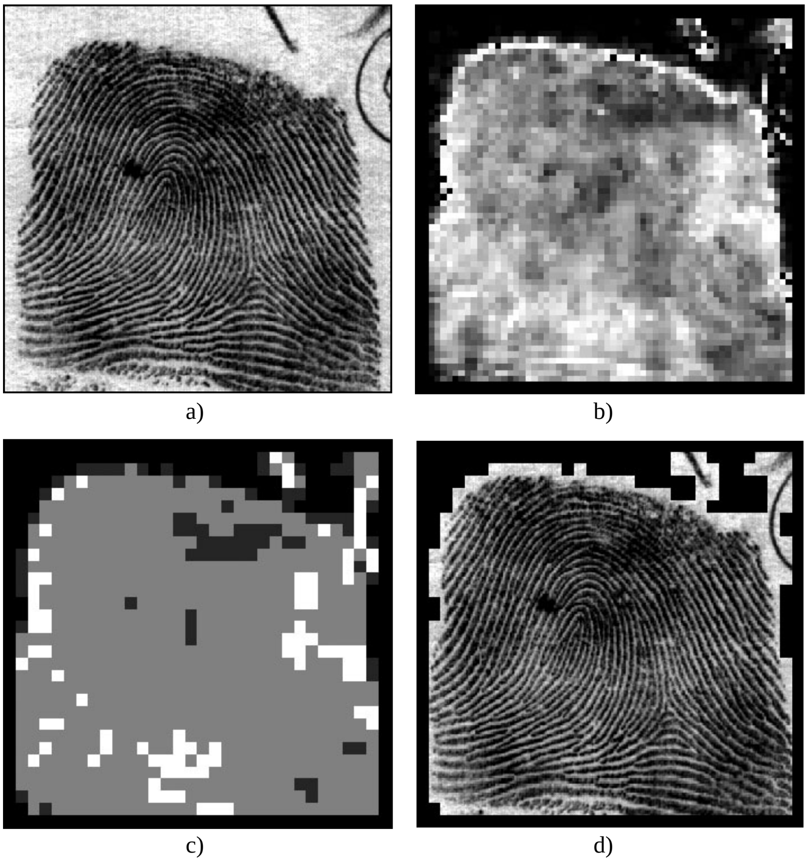

Figure 3.13. Segmentation of a fingerprint image as proposed by Ratha, Chen, and Jain (1995): a) original image; b) variance field; c) quality image derived from the variance field: a quality value "good," "medium," "poor" or "background" is assigned to each block according to its variance; d) segmented image. ©Elsevier.

3.6 Singularity and Core Detection

Most of the approaches proposed in the literature for singularity detection operate on the fingerprint orientation image. In the rest of this section, the main approaches are coarsely classified and a subsection is dedicated to each family of algorithms.

Poincaré method index

An elegant and practical method based on the Poincaré index was proposed by Kawagoe and Tojo (1984). Let **G** be a vector field and *C* be a curve immersed in **G**; then the Poincaré index $P_{\mathbf{G},C}$ is defined as the total rotation of the vectors of **G** along *C* (see Figure 3.14).

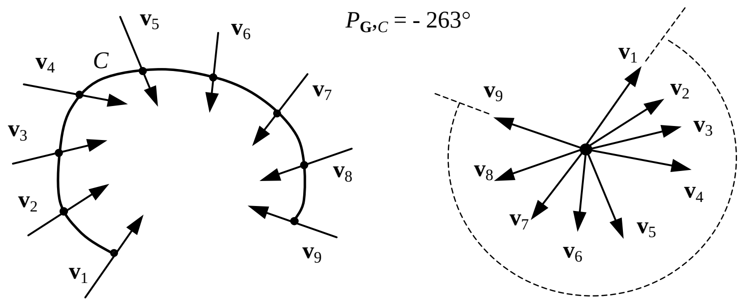

Figure 3.14. The Poincaré index computed over a curve *C* immersed in a vector field **G**.

Let **G** be the field associated with a fingerprint orientation image[1] **D** and let $[i,j]$ be the position of the element θ_{ij} in the orientation image; then the Poincaré index $P_{\mathbf{G},C}(i,j)$ at $[i,j]$ is computed as follows.

- The curve *C* is a closed path defined as an ordered sequence of some elements of **D**, such that $[i,j]$ is an internal point;
- $P_{\mathbf{G},C}(i,j)$ is computed by algebraically summing the orientation differences between adjacent elements of *C*. Summing orientation differences requires a direction (among the two possible) to be associated at each orientation. A solution to this problem is to randomly select the direction of the first element and assign the direction closest to that of the previous element to each successive element. It is well known and can be easily shown that, on closed curves, the Poincaré index assumes only one of the discrete values: 0°, ±180°, and ±360°. In the case of fingerprint singularities:

$$P_{\mathbf{G},C}(i,j)=\begin{cases} 0^\circ & \text{if } [i,\,j] \text{ does not belong to any singular region} \\ 360^\circ & \text{if } [i,\,j] \text{ belongs to a whorl type singular region} \\ 180^\circ & \text{if } [i,\,j] \text{ belongs to a loop type singular region} \\ -180^\circ & \text{if } [i,\,j] \text{ belongs to a delta type singular region.} \end{cases}$$

1 Note that a fingerprint orientation image is not a true vector field inasmuch as its elements are unoriented directions.

Figure 3.15 shows three portions of orientation images. The path defining C is the ordered sequence of the eight elements $\mathbf{d}_k$ (k = 0..7) surrounding [i,j]. The direction of the elements $\mathbf{d}_k$ is chosen as follows: $\mathbf{d}_0$ is directed upward; $\mathbf{d}_k$ (k = 1..7) is directed so that the absolute value of the angle between $\mathbf{d}_k$ and $\mathbf{d}_{k-1}$ is less than or equal to 90°. The Poincaré index is then computed as

$$P_{\mathbf{G},C}(i,j) = \sum_{k=0..7} angle\left(\mathbf{d}_k, \mathbf{d}_{(k+1) \bmod 8}\right).$$

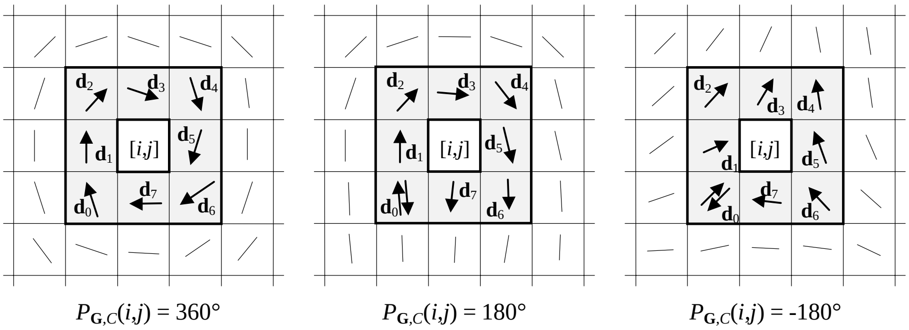

Figure 3.15. Example of computation of the Poincaré index in the 8-neighborhood of points belonging (from the left to the right) to a whorl, loop, and delta singularity, respectively. Note that for the loop and delta examples (center and right), the direction of $\mathbf{d}_0$ is first chosen upward (to compute the angle between $\mathbf{d}_0$ and $\mathbf{d}_1$) and then successively downward (when computing the angle between $\mathbf{d}_7$ and $\mathbf{d}_0$).

An example of singularities detected by the above method is shown in Figure 3.16.a.

An interesting implementation of the Poincaré method for locating singular points was proposed by Bazen and Gerez (2002b): according to Green's theorem, a closed line integral over a vector field can be calculated as a surface integral over the rotation of this vector field; in practice, instead of summing angle differences along a closed path, the authors compute the "rotation" of the orientation image (through a further differentiation) and then perform a local integration (sum) in a small neighborhood of each element. Bazen and Gerez (2002b) also provided a method for associating an orientation with each singularity; this is done by comparing the orientation image around each detected singular point with the orientation image of an ideal singularity of the same type.

Singularity detection in noisy or low-quality fingerprints is difficult and the Poincaré method may lead to the detection of false singularities (Figure 3.17). Regularizing the orientation image through a local averaging, as discussed in Section 3.3, is often quite effective in preventing the detection of false singularities.

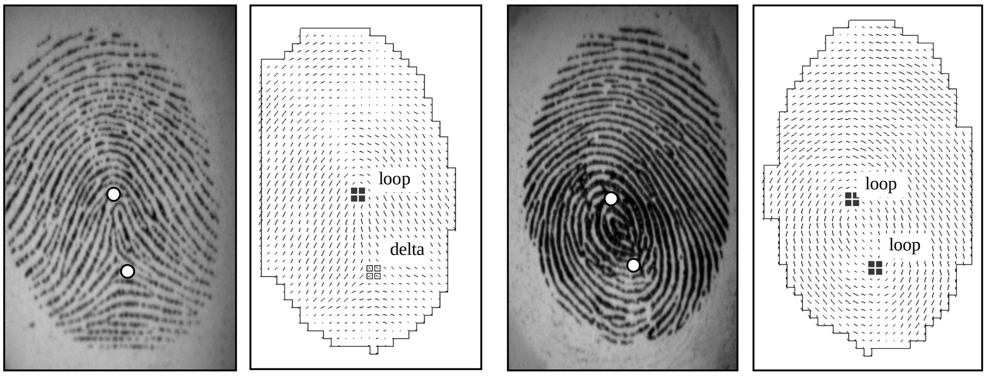

Figure 3.16. Singularity detection by using the Poincaré index method. The elements whose Poincaré index is 180° (loop) or -180° (delta) are enclosed by small boxes. Usually, more than one point (four points in these examples) is found for each singular region: hence, the center of each singular region can be defined as the barycenter of the corresponding points.

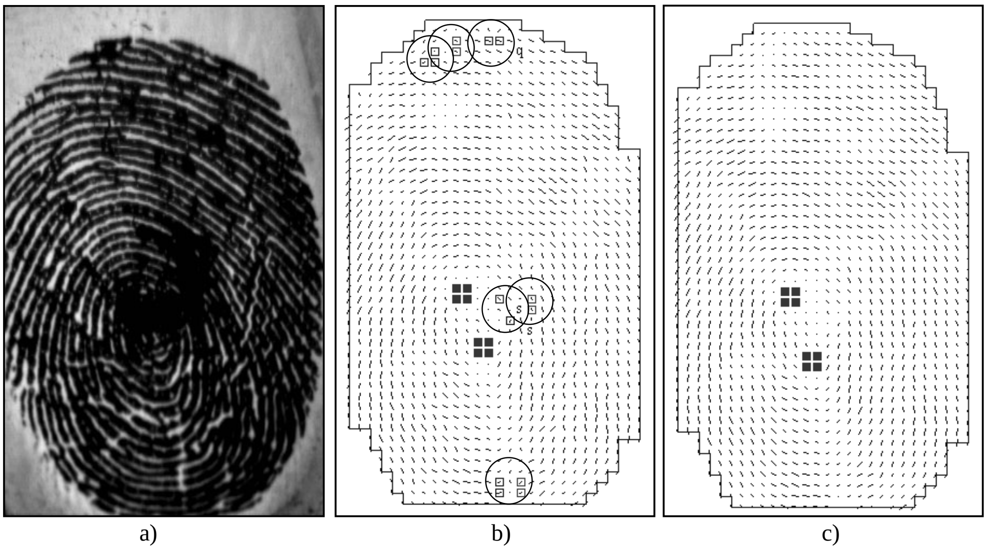

Figure 3.17. a) A poor quality fingerprint; b) the singularities of the fingerprint in a) are extracted through the Poincaré method (circles highlight the false singularities); c) the orientation image has been regularized and the Poincaré method no longer provides false alarms.