# Enhancement, and Minutias Detection

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**Acknowledgments: Xavier Palathingal, Andrzej Drygajlo, Handbook of Fingerprint Recognition**

# Minutiae Detection

- Reliable minutiae extraction is extremely important
  - Binarization
  - Thinning
  - Post processing – filling holes, linking breaks, removing bridges

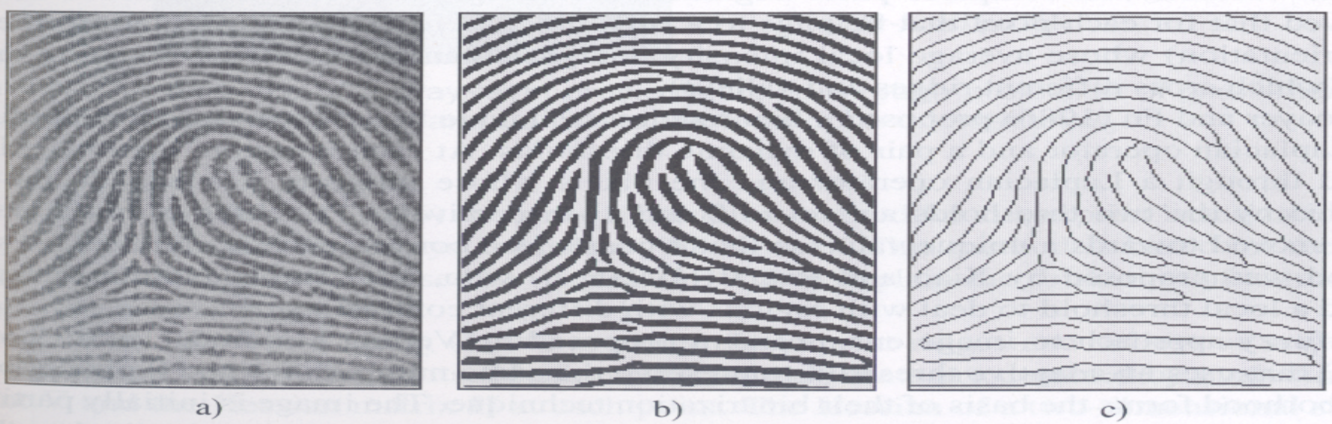



Figure 3.31. a) A fingerprint gray-scale image; b) the image obtained after a binarization of the image in a); c) the image obtained after a thinning of the image in b). Reprinted with permission from Maio and Maltoni (1997). ©IEEE.

# Binarization-based methods

– Simplest method - global threshold
– Local threshold technique
– Fingerprint specific solutions necessary

- Binarization is the output of Contextual Filtering: **enhance2ridgevalley.m**

```
binaryBlkSize = 20;
imReconstruct = blkproc(imReconstruct, [binaryBlkSize
   binaryBlkSize], @binarizeimage);

function  Iout = binarizeimage(Iin)
level = graythresh(Iin); %Otsu method
Iout = im2bw(Iin, level);
```

laboratory Gerstner

# Threshold computation: Otsu I

- Otsu's method: *N. Otsu (1979). "A threshold selection method from gray-level histograms". IEEE Trans. Sys., Man., Cyber. 9: 62–66*
  - *http://en.wikipedia.org/wiki/Otsu%27s_method*
  - *http://homepages.inf.ed.ac.uk/rbf/CVonline/LOCAL_COPIES/MORSE/threshold.pdf*
- minimizes the intra-class variance – for each threshold T lot's of work

$$\sigma^2_{\text{Within}}(T) = n_B(T)\sigma^2_B(T) + n_O(T)\sigma^2_O(T)$$

$$n_B(T) = \sum_{i=0}^{T-1} p(i)$$

$$n_O(T) = \sum_{i=T}^{N-1} p(i)$$

$\sigma^2_B(T)$ = the variance of the pixels in the background (below threshold)

$\sigma^2_O(T)$ = the variance of the pixels in the foreground (above threshold)

- between-class variance:

$$\begin{aligned}\sigma^2_{\text{Between}}(T) &= \sigma^2 - \sigma^2_{\text{Within}}(T)\\ &= n_B(T)\left[\mu_B(T) - \mu\right]^2 + n_O(T)\left[\mu_O(T) - \mu\right]^2\end{aligned}$$

where $\sigma^2$ is the combined variance and $\mu$ is the combined mean

# Threshold computation: Otsu II

- Compute histogram and probabilities of each intensity level
- Set up initial $n_b(0)$ and $n_o(0)$ and $\mu_b(0)$, $\mu_o$ (0)
- Step through all possible thresholds T=1.... maximum intensity
  - Update $n_b(T)$,$n_o(T)$
  - Compute $\sigma_{between}(T)$
- Desired threshold corresponds to the maximum $\sigma_{between}(T)$

# Minutiae detection

- A simple image scan allows the pixel corresponding to minutiae to be detected
- *crossing number* of a pixel p
- **DEMO: Fp1 = cleanskeleton(Fp1);**

$$cn(\mathbf{p}) = \frac{1}{2}\sum_{i=1..8} \left| val(\mathbf{p}_{i \bmod 8}) - val(\mathbf{p}_{i-1}) \right| ,$$

where $\mathbf{p}_0, \mathbf{p}_1, \ldots, \mathbf{p}_7$ are the pixels belonging to an ordered sequence of pixels defining the 8-neighborhood of $\mathbf{p}$ and $val(\mathbf{p}) \in \{0,1\}$ is the pixel value. It is simple to note (Figure 3.36) that a pixel $\mathbf{p}$ with $val(\mathbf{p}) = 1$:

- is an intermediate ridge point if $cn(\mathbf{p}) = 2$;
- corresponds to a termination minutia if $cn(\mathbf{p}) = 1$;
- defines a more complex minutia (bifurcation, crossover, etc.) if $cn(\mathbf{p}) \geq 3$.

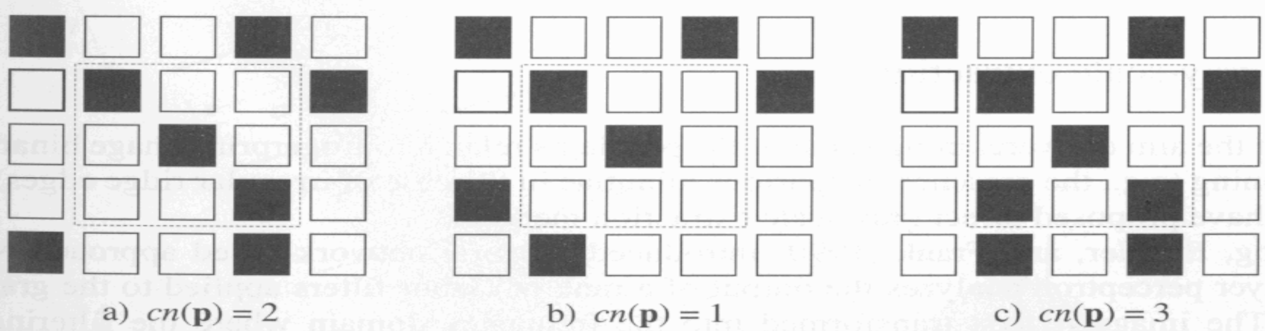



Figure 3.36. a) intra-ridge pixel; b) termination minutia; c) bifurcation minutia.

# Examples of minutiae extraction

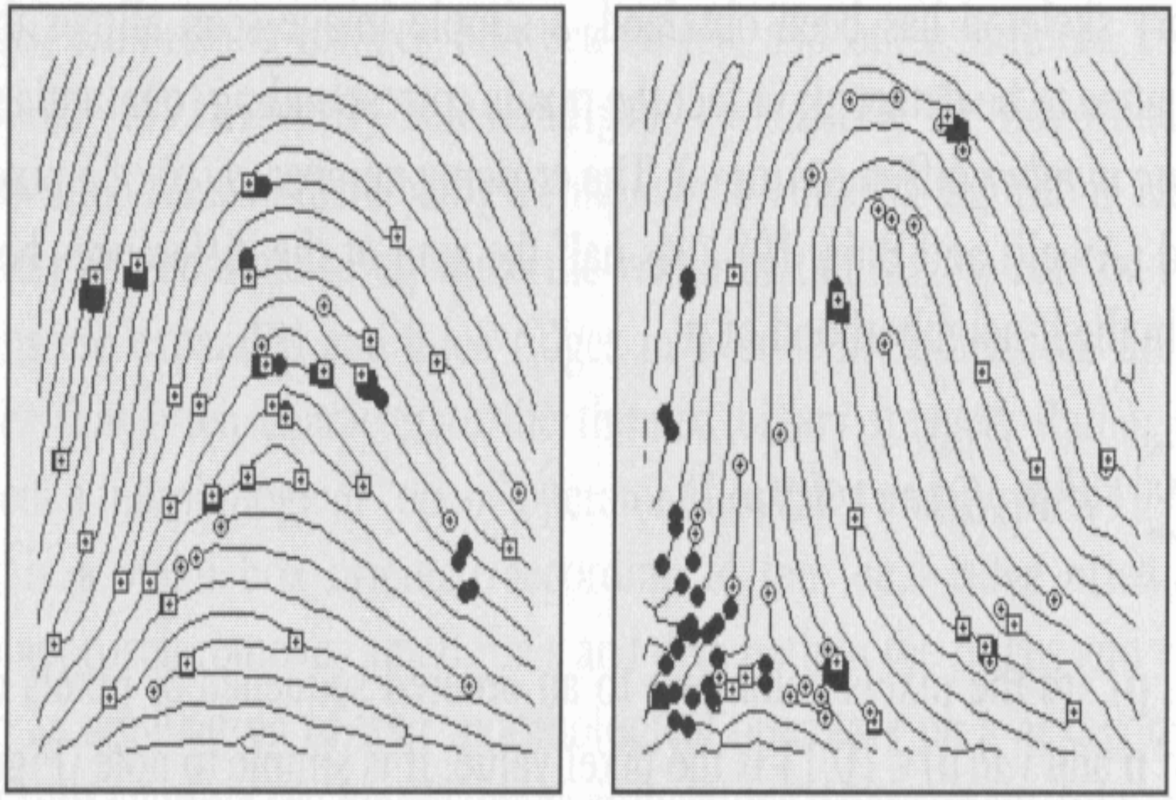
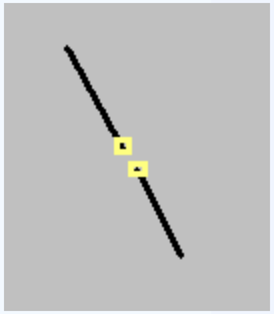


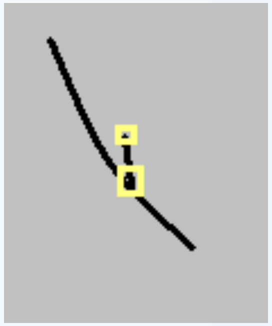
Figure 3.37. Examples of minutiae detection on binary skeletons. White circles and white boxes denote terminations and bifurcations, respectively; black circles and black boxes denote filtered minutiae (see Section 3.9).

# Minutiae Filtering

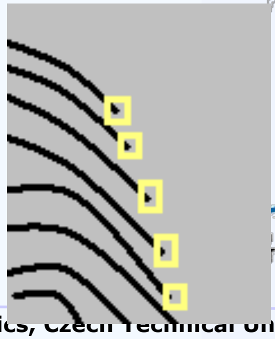
- Post-processing stage is useful for removing spurious minutiae [already present or introduced by previous steps]
- Two main post-processing types:
  - Structural post-processing
  - Minutiae filtering in the gray-scale domain



- Ridge breaks (insufficient ink or moist)



- Ridge cross-connections (over-ink, over-moist)



- Boundaries

# Example

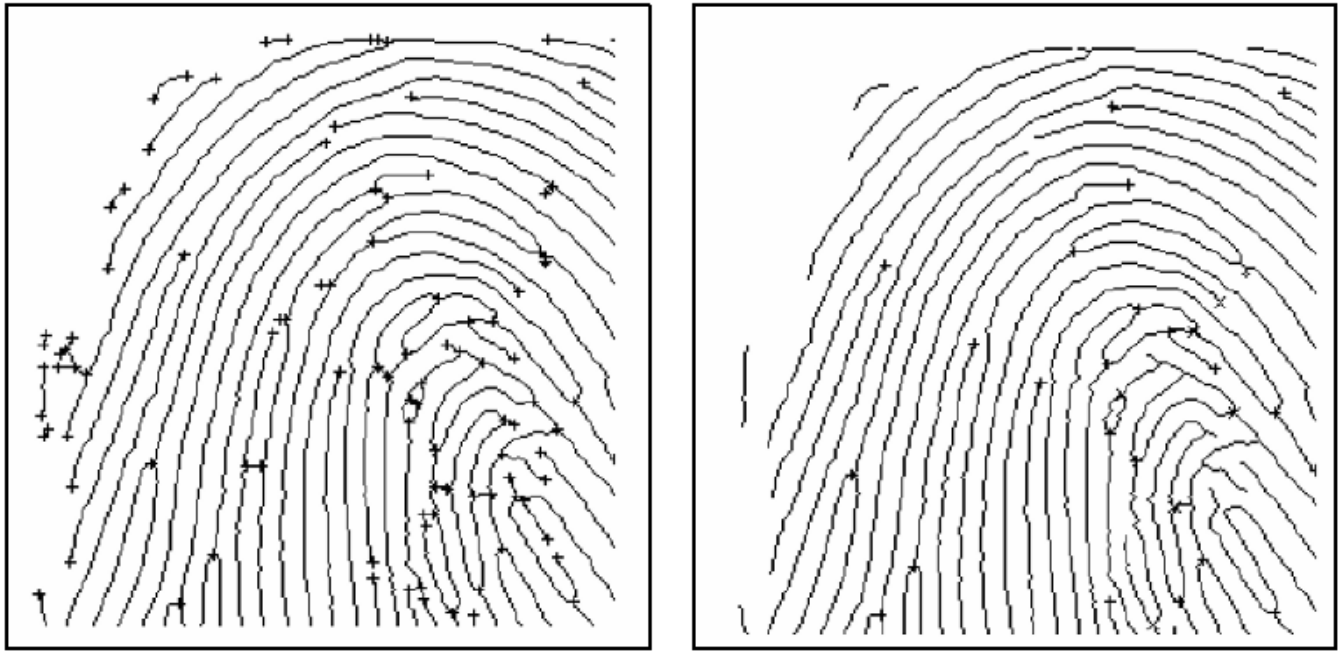


Figure 3.51. Minutiae post-processing according to Farina, Kovacs-Vajna, and Leone (1999). On the right, most of the false minutiae present in the thinned binary image (on the left) have been removed. © Elsevier.