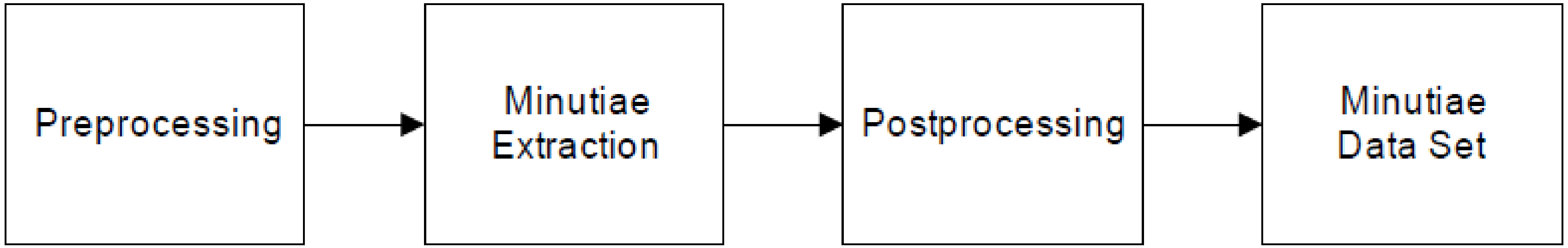
Fingerprint recognition system minutiae extraction method

Minutia extraction

- Minutia extraction comes after the preprocessing of the finger print image. It involves two processes; they are ridge thinning and minutia marking.



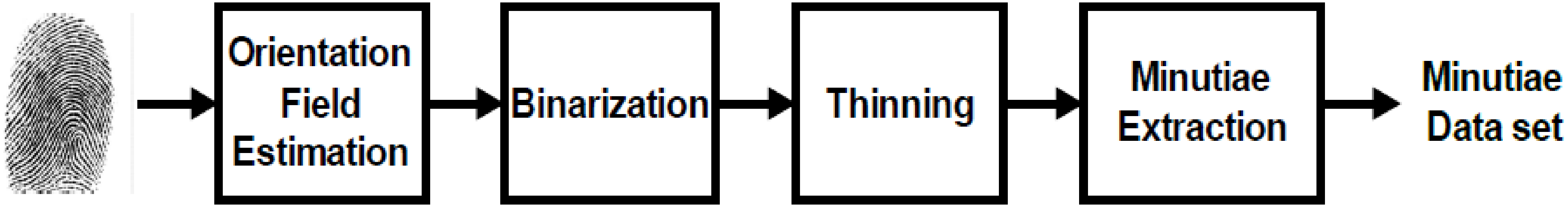
The basic concepts of each stage are:

– Preprocessing: Different operations are performed in the fingerprint image in order to prepare the image for a reliable extraction of minutiae. Examples of this techniques are noise removal and contrast enhancement algorithms.

– Minutiae extraction: In this stage a first set of minutiae candidate points is calculated from the preprocessed image.

– Post-processing: Inevitably, previous stages lead to a minutiae set that contains points that are not real minutiae (caused by bad image quality, scratches, imperfections of the algorithms...), called spurious minutiae. This points should be removed from the set, as they will be different for every acquirement of the fingerprint image and will degrade the performance of the matcher.

In 1997, Anil K. Jain et al. devised an algorithm for minutiae extraction



Estimation of the Orientation Field

In this algorithm a new hierarchical implementation of is used. It consists of the following basic steps:

- Divide the input fingerprint image in sections of size W x W.
- Compute the gradients Gx and Gy at each pixel in each block.
- Estimate the local orientation of each block through the following formula:

$$\theta_o = \frac{1}{2}\tan^{-1}\left(\frac{\sum_{i=1}^{W}\sum_{j=1}^{W} 2G_x(i,j)G_y(i,j)}{\sum_{i=1}^{W}\sum_{j=1}^{W}\left(G_x^2(i,j)-G_y^2(i,j)\right)}\right)$$

After this stage, this algorithm consists of a ridge extraction and a thinning stage.

Ridge Thinning

- Ridge Thinning is to eliminate the redundant pixels of ridges till the ridges are just one pixel wide.
- It uses an iterative, parallel thinning algorithm. In each scan of the full fingerprint image, the algorithm marks down redundant pixels in each small image window (3x3). And finally removes all those marked pixels after several scans.
- In such an iterative, parallel thinning algorithm has bad efficiency although it can get an ideal thinned ridge map after enough scans.
- This method traces along the ridges having maximum gray intensity value. Also in our testing, the advancement of each trace step still has large computation complexity although it does not require the movement of pixel by pixel as in other thinning algorithms.

Minutia post processing

- In minutia post processing the removal of false minutia is done which is followed by the process of unifying bifurcations and terminations.

False minutia removal

- The preprocessing stage does not totally heal the fingerprint image. For example, false ridge breaks due to insufficient amount of ink and ridge cross connections due to over inking are not totally eliminated.
- Actually all the earlier stages themselves occasionally introduce some artifacts which later lead to spurious minutia.
- These false minutiae will significantly affect the accuracy of matching if they are simply regarded as genuine minutia.
- Seven types of false minutia are specified in following diagrams:

False minutia removal

- m1 is a spike piercing into a valley. In the m2 case a spike falsely connects two ridges.
- m3 has two near bifurcations located in the same ridge.
- The two ridge broken points in the m4 case have nearly the same orientation and a short distance.
- m5 is alike the m4 case with the exception that one part of the broken ridge is so short that another termination is generated
- m6 extends the m4 case but with the extra property that a third ridge is found in the middle of the two parts of the broken ridge
- m7 has only one short ridge found in the threshold window only handles the case m1, m4, m5 and m6 and have not false minutia removal by simply assuming the image quality is fairly good.

False minutia removal

The procedures for removing false minutia are:

- If the distance between one bifurcation and one termination is less than D and the two minutia are in the same ridge (m1 case). Remove both of them. Where D is the average inter-ridge width representing the average distance between two parallel neighboring ridges.
- If the distance between two bifurcations is less than D and they are in the same ridge, remove the two bifurcations (m2, m3 cases).
- If two terminations are within a distance D and their directions are coincident with a small angle variation and they suffice the condition that no any other termination is located between the two terminations. Then the two terminations are regarded as false minutia derived from a broken ridge and are removed. (case m4,m5, m6).
- If two terminations are located in a short ridge with length less than D, remove the two terminations (m7).

Minutia matching

- Given two set of minutia of two fingerprint images, the minutia match algorithm determines whether the two minutia sets are from the same finger or not.
- It includes two consecutive stages: one is alignment stage and the second is match stage.
- Images to be matched, choose any one minutia from each image, calculate the similarity of the two ridges associated with the two referenced minutia points. If the similarity is larger than a threshold, transform each set of minutia to a new coordination system whose origin is at the referenced point and whose x axis is coincident with the direction of the referenced point.

Alignment

- Alignment is the process of transforming two or more sets of data into a common coordinate system. For example, two fingerprint scans acquired at different times each belong to their own coordinate system; this is because of rotation, translation, and non-linear distortion of the finger.
- In order to match features between the images, a correspondence has to be established. Typically, one image (signal) is referred to as the reference and the other image is the target, and the goal is to map the target onto the reference.
- This transformation can be both linear and nonlinear based on the deformations undergone during acquisition.
- Position-invariant features, often used to avoid registration, face other concerns like robustness to local variation such as non-linear distortions or occlusion.

Alignment Stage

- 1. The ridge associated with each minutia is represented as a series of x-coordinates (x1, x2…xn) of the points on the ridge. A point is sampled per ridge length L starting from the minutia point, where the L is the average inter-ridge length. And n is set to 10 unless the total ridge length is less than 10*L. So the similarity of correlating the two ridges is derived from: $S = {}^{m}_{i=0} x_i X_i / [{}^{m}_{i=0} x_i^2 X_i^2]\text{\^{}}0.5$, where $(x_{i\sim}x_n)$ and $(X_{i\sim}X_N)$ are the set of minutia for each fingerprint image respectively. And m is minimal one of the n and N value. If the similarity score is larger than 0.8, then go to step 2, otherwise continue to match the next pair of ridges. 2. For each fingerprint, translate and rotate all other minutia with respect to the reference minutia according to the following formula:

Alignment Stage

$$\begin{pmatrix} xi\_new \\ yi\_new \\ \theta i\_new \end{pmatrix} = TM * \begin{bmatrix} (xi - x) \\ (yi - y) \\ (\theta i - \theta) \end{bmatrix}$$

where (x,y,) is the parameters of the reference minutia, and TM is

$$TM = \begin{pmatrix} \cos\theta & -\sin\theta & 0 \\ \sin\theta & \cos\theta & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

Alignment Stage

- The new coordinate system is originated at minutia F and the new x-axis is coincident with the direction of minutia F. No scaling effect is taken into account by assuming two fingerprints from the same finger have nearly the same size.
- This method uses the rotation angle by densely tracing a short ridge start from the minutia with length D. Since the minutia direction has been got already at the minutia extraction stage, obviously this method reduces the redundant calculation but still holds the accuracy. Here the approach is to transform each according to its own reference minutia and then do match in a unified x-y coordinate. Therefore, less computation workload is achieved through our method.

Alignment Stage

- The matching algorithm for the aligned minutia patterns needs to be elastic since the strict match requiring that all parameters (x, y,) are the same for two identical minutia is impossible due to the slight deformations and inexact quantization's of minutia. In this research minutia is matched by placing a bounding box around each template minutia. If the minutia to be matched is within the rectangle box and the direction discrepancy between them is very small, then the two minutiae are regarded as a matched minutia pair. Each minutia in the template image either has no matched minutia or has only one corresponding minutia. The final match ratio for two fingerprints is the number of total matched pair over the number of minutia of the template fingerprint. The score ranges from 0 to 100. If the score is larger than a pre-specified threshold, the two fingerprints are from the same finger.