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AMENDMENT 1
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Information technology — Biometric data interchange formats —

Part 2: Finger minutiae data

AMENDMENT 1: Detailed description of finger minutiae location, direction, and type

Technologies de l'information — Formats d'échange de données biométriques —

Partie 2: Données du point caractéristique du doigt

AMENDEMENT 1: Description détaillée du point caractéristique du doigt, direction et type

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Foreword

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International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of the joint technical committee is to prepare International Standards. Draft International Standards adopted by the joint technical committee are circulated to national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO and IEC shall not be held responsible for identifying any or all such patent rights.

Amendment 1 to ISO/IEC 19794-2:2005 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 37, *Biometrics*.

Information technology — Biometric data interchange formats —

Part 2: **Finger minutiae data**

AMENDMENT 1: Detailed description of finger minutiae location, direction, and type

IMPORTANT — The electronic file of this document contains colours which are considered to be useful for the correct understanding of the document. Users should therefore consider printing this document using a colour printer.

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Insert the following new annex after D.3:

Annex E
(informative)

Detailed description of finger minutiae location, direction, and type

E.1 Scope

Even if all conform to this part of ISO/IEC 19794, different minutiae data blocks extracted from the same finger image may differ not only in the exact locations, the directions, and the types of those minutiae that they have in common, but also in the number of minutiae they contain, especially in blurred fingerprint regions where even the "manual" detection of minutiae is hard. The description of the minutia location in 6.4 refers to a single-pixel-wide skeleton of the friction ridges. The minutia direction is defined in 6.4, based on tangents to the skeleton. The skeletonisation algorithm itself is not described and also the method to determine the tangents is left open.

The scope of this informative annex is to provide a more precise definition of location, direction, and type of minutiae in gray-scale finger images and a detailed description of the quality field. It enhances the readability of this part of ISO/IEC 19794 and decreases the possibility of misinterpretation. The standardisation of algorithms is out of scope of this informative annex. This informative annex does not supersede the existing standard.

E.2 Terms and definitions

For the purposes of this informative annex, the following terms and definitions apply.

E.2.1
4-neighbour of a pixel *p*
pixel that is the top, bottom, left, or right neighbour of *p*

EXAMPLE The pixels *e*, *f*, *g*, and *h* in Figure E.1 are 4-neighbours of pixel *p*.

a	e	b
h	p	f
d	g	c

Figure E.1 — 4- and 8-neighbours of a pixel *p*

E.2.2
4-path from pixel p_0 to pixel p_n
sequence of pixels (p_0, p_1, p_2, …, p_n) such that p_i is a 4-neighbour of p_{i-1}

E.2.3
4-connected set of pixels
set *S* of pixels such that for any two pixels $p, q \in S$ there exists a 4-path from *p* to *q*

E.2.4
8-neighbour of a pixel *p*
pixel that is a 4-neighbour or a diagonal (top-left, top-right, bottom-left, or bottom-right) neighbour of *p*

EXAMPLE The pixels *a*, *b*, *c*, *d*, *e*, *f*, *g*, and *h* in Figure E.1 are 8-neighbours of pixel *p*.

E.2.5
8-path from pixel p_0 to pixel p_n
sequence of pixels (p_0, p_1, p_2, …, p_n) such that p_i is an 8-neighbour of p_{i-1}

E.2.6
8-connected set of pixels
set *S* of pixels such that for any two pixels $p, q \in S$ there exists an 8-path from *p* to *q*

E.2.7
border ∂S of a set of pixels *S*
subset $\partial S = \{x \in S : x \text{ is 4-neighbour of } q, q \notin S\}$ of pixels of *S* that are 4-neighbours of pixels outside *S*

E.3 Minutiae detection strategy

E.3.1 "Liberal-conservative" spectrum

Minutia detection algorithms may use different discriminative practices in the minutia detection strategy. A liberal minutia detection strategy is supposed to detect a large number of minutiae which will increase the probability to include spurious minutiae while a conservative strategy will detect only a few minutiae and increase the probability to miss some. The following subclauses provide an explanation of some types of spurious (false) minutiae which may result from the use of a 'liberal' strategy but which may not be detected if a more 'conservative' strategy is employed.

The following images show examples of applying a conservative or liberal minutia detection strategy to the same sample images. These examples are not meant to suggest a liberal or conservative strategy. The best detection strategy for a particular application depends on the business processes and their associated security requirements that the biometric components of the system are designed to support or enable.

Figure E.2 — Liberal minutia detection (left) versus conservative minutia detection (right)

Figure E.3 — Liberal minutia detection (left) versus conservative minutia detection (right)

Figure E.4 — Liberal minutia detection (left) versus conservative minutia detection (right)

Figure E.5 — Liberal minutia detection (left) versus conservative minutia detection (right)

Figure E.6 — Liberal minutia detection (left) versus conservative minutia detection (right)

E.3.2 Fingerprint boundary

No minutia should be set outside the fingerprint boundary.

Minutiae may be set below the first phalange, even it is not the usual case.

E.3.3 Sweat pore

No minutia should be set at a sweat pore. A pore could happen to lie at the position of the forking of a friction ridge (bifurcation, see Figure E.16 below), but a sweat pore without connectivity to three legs must not be misinterpreted as a minutia.

E.3.4 Touching ridges

No minutia should be set where thick ridges touch each other.

E.3.5 Incipient ridge

No minutia should be set at an incipient (very short and thin) ridge.

E.3.6 Crease

No minutia should be set at a crease (accidental interruption of ridges).

E.3.7 Core

No minutia should be set at a core.

A core represents a singularity in the direction field, hence a proper angle value cannot be assigned to this location.

NOTE Information about cores can be expressed in a standardised way in the extended data block (see 8.5.3).

E.3.8 Delta

No minutia should be set at a delta.

A delta represents a singularity in the direction field, hence a proper angle value cannot be assigned to this location.

NOTE Information about deltas can be expressed in a standardised way in the extended data block (see 8.5.3).

E.4 Minutia characteristics

E.4.1 Rationale

This document shall not standardize certain algorithms as laid down in the scope. The guidelines to find the best minutia position and location require some methodology in description. Examples of two independent methods for determining the location and orientation of minutiae are presented in this document. The first is commonly known as the ridge gradient method while the second is referred to as the valley skeletal bifurcation method, which is popular in the AFIS industry. Without loss of generality, the ridge gradient method will focus on ridge ends and ridge bifurcations and the valley skeletal bifurcation method will describe valley bifurcations and ridge bifurcations in this document, i.e. the choice of the method finally depends on the specific format type to be used.

E.4.2 Minutia type

The minutia type cannot be determined reliably in some occasions.

EXAMPLE Due to varying contact pressure while acquiring the fingerprint and due to different image binarisation approaches, a ridge ending may join an adjacent ridge, giving the impression of a ridge bifurcation.

The minutiae type “other” should only be used if neither of the other two minutiae types, “ridge ending” and “ridge bifurcation”, can reliably be assigned to a minutia.

E.4.3 Minutia location tools

E.4.3.1 Consideration of the resolution of the underlying finger image

For the minutiae location, a correct handling of the resolution of the underlying finger image is important. The minutiae extraction algorithm should be able to determine the resolution of the underlying finger image in a reliable way (e.g. from a fingerprint-sensor configuration file). For minutiae data in the finger minutiae record format, this resolution shall be stored in the X and Y resolution fields within the record header. For minutiae data in the on-card-biometric-comparison format, the resolution of the underlying finger image shall be used when calculating the X and Y coordinates of the location in the prescribed metric dimension units out of their pixel values. For conversion between format types, the resolution shall be taken from, or stored in, the X and Y resolution fields within the record header.

E.4.3.2 Image binarisation

Every gray scale fingerprint image can be transformed into a binary image. This is common practice in image processing. Every pixel is assigned black if its gray scale value is darker than a threshold (such as the average gray scale value) and white if its gray scale value is lighter than the threshold. Most professional finger image processing implementations use sophisticated methods such as location-dependent thresholds to come to a binary image. A binary image separates the image pixels into two categories: ridges and valleys. Without loss of generality, black pixels refer to ridges in the following text.

captured raw image

binary image (truncated)

Figure E.7 — Raw image vs. binary image

E.4.3.3 Image skeletonization

Skeletonization is a standard procedure in graphing practice. It produces a single-pixel-wide skeleton from a binary image. Several skeletonization methods are reported in literature. The process yields either a 4-connected or 8-connected skeleton. Figure E.8 shows a sample image and its skeleton.

Figure E.8 — Binary image and ridge skeleton, from [14]

As valley skeletons will also be used in this standard, Figure E.9 depicts the valley skeleton of the same image.

Figure E.9 — Binary image and valley skeleton, from [14]

E.4.3.4 Ridge Flow Direction

Every fingerprint image has a well defined directional image expressing the local dominant ridge flow direction. Methods to compute a directional image are reported in literature, e.g. [12]. Figure E.10 shows a fingerprint image and its directional image.

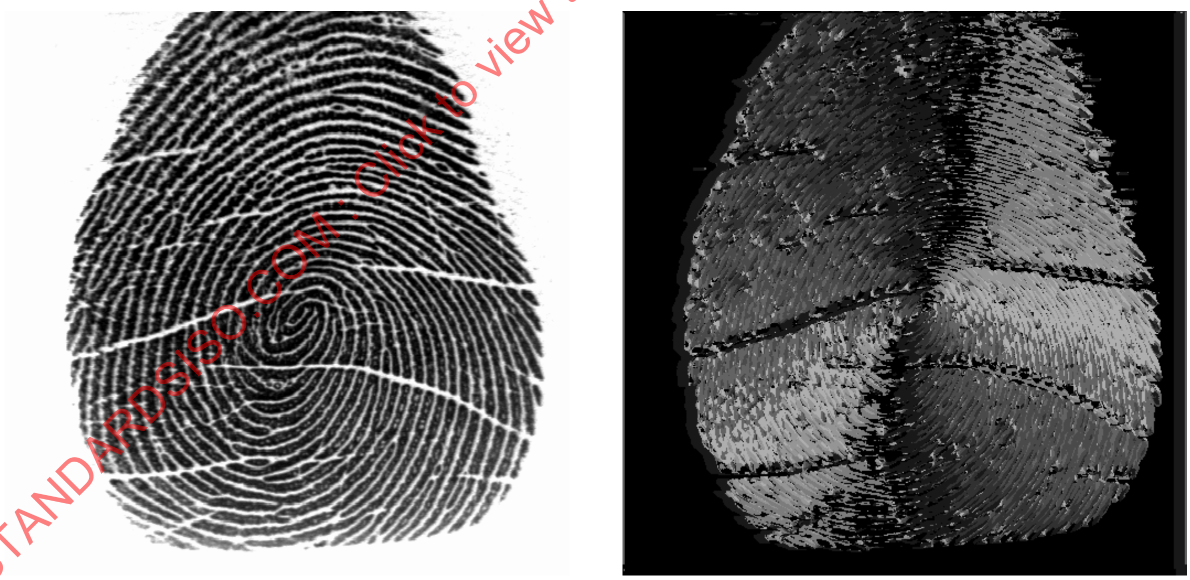

Figure E.10 — Raw image and pixel-wise directional image, from [14]

Most current fingerprint minutiae detection algorithms are working with a block-wise directional image rather than a pixel-wise. The original directional image is therefore divided into blocks and the most common orientation within a block becomes the orientation for the whole block. Figure E.11 shows the block directional image.

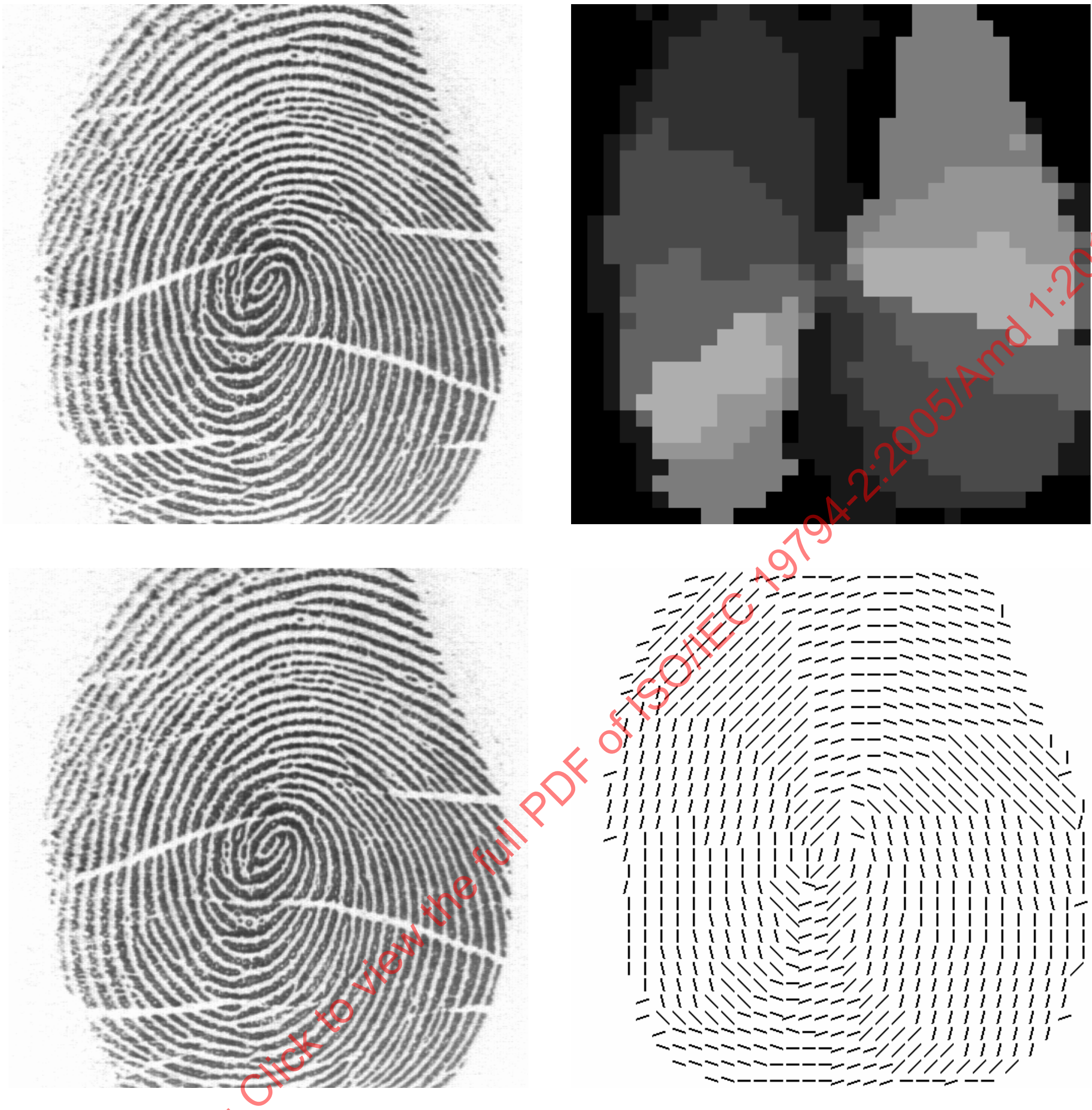

Figure E.11 — Raw image and block-wise directional image, from [14]

E.4.4 Ridge gradient method

The ridge gradient method relies on moving along the ridge line until a minutia condition occurs, which is either forking or ending of the ridge. It was originally reported for gray-scale images [13], but is described here for binary images to simplify the procedure, which has only a descriptive nature in this part of ISO/IEC 19794.

E.4.4.1 Minutia location at a ridge skeleton endpoint

Friction ridges in a binary image have a well defined border: Black pixels with at least one white pixel as 4-neighbour are border pixels of a friction ridge. This ensures that the border is at least 8-connected. The border of a ridge skeleton endpoint is depicted in Figure E.12.

Figure E.12 — Border of a ridge skeleton endpoint

Skeletonisation algorithms should reduce the friction ridges of a binary fingerprint image to a single pixel wide skeleton. Instead of discussing how the skeletonisation algorithm should work, another approach to describing where to place the minutiae is preferred. Every ridge has a dominant ridge flow direction. The dominant ridge flow direction (see E.4.3.4) line meets the border of the ridge in a single pixel of the binary image. This pixel is considered the optimal minutia location. See Figure E.13.

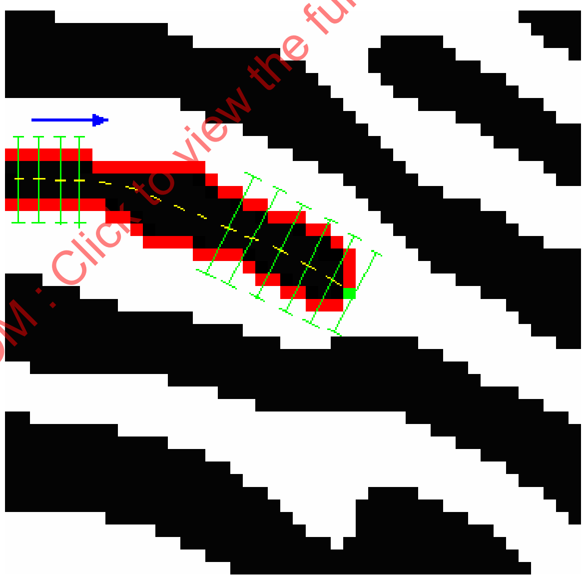

Figure E.13 — Minutia location on a ridge skeleton endpoint

E.4.4.2 Minutia location at a ridge skeleton bifurcation point

The border at a ridge bifurcation is well defined. The three parts of the border are not necessarily connected. The border of a ridge skeleton bifurcation point is depicted in Figure E.14.

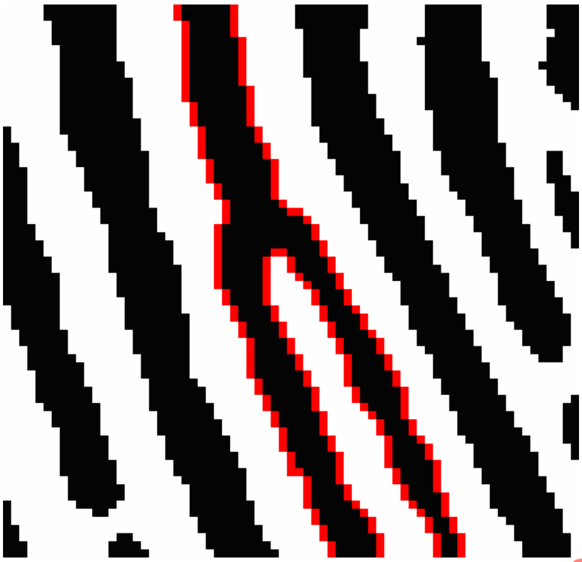

Figure E.14 — Border of a ridge skeleton bifurcation point

The dominant ridge flow direction lines along all three legs meet in a single point or form a small triangle within the ridge. The single intersecting point is considered the optimal minutia location. It is most likely half a ridge width from the border pixel where an acute angle is enclosed by neighbouring legs. It could happen rarely and depending on the image resolution that the three legs do not intersect in a single pixel but form a small triangle at intersection. In this case, the optimal minutia position is the center of mass of the triangle. See Figure E.15.

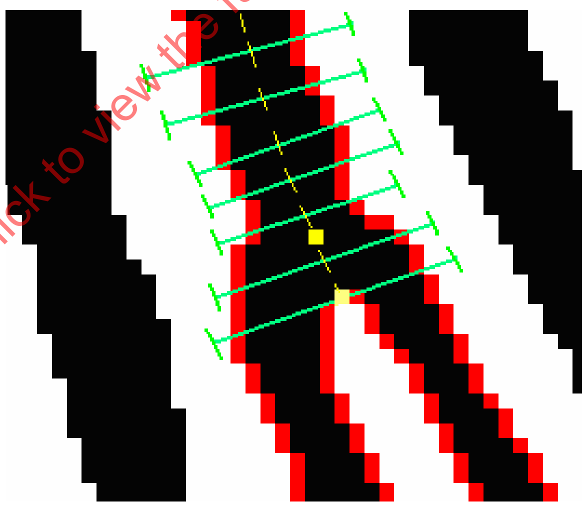

Figure E.15 — Minutia location on a ridge skeleton bifurcation point

E.4.4.3 Minutia location at a valley skeleton bifurcation point

Analogical rules as for ridge skeleton bifurcation points apply also for valley skeleton bifurcation points. The valley skeleton birfurcation point is described in detail in the section using the valley skeletal bifurcation method to determine minutia position and orientation.

E.4.4.4 Minutia direction at a ridge skeleton endpoint

This part of ISO/IEC 19794 defines the minutia direction at a ridge skeleton endpoint as the angle measured counter-clockwise from the positive X axis to the tangent to the skeleton, at the ridge skeleton endpoint. There are several methods to determine the tangent to a curve. The following procedure is a recommended method to find the tangent: A circle is drawn around the minutia point. The radius should be 1,63 mm (This is equivalent to 32 pixels at 19,69 ppmm/500 ppi and approximately the average width of 3 ridges of adult persons). The circle hits the skeleton of the ridge on which the minutia resides in a single pixel. If the ridge skeleton is not available, the intersection of the ridge with the circle has a well-defined centre to approximate. A line is drawn form the minutia point through the intersection respectively its centre point. It approximates the tangent to the ridge.

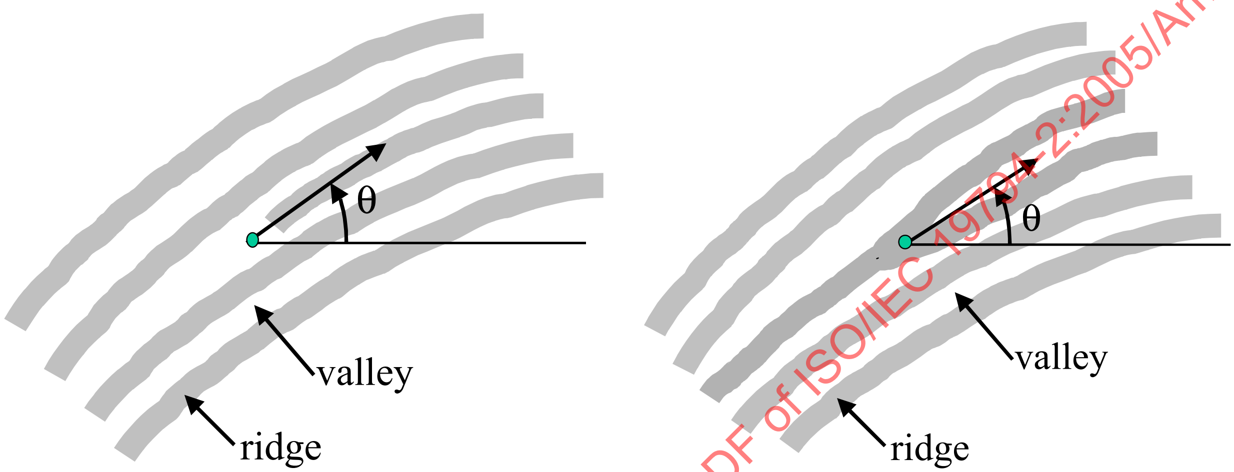

Figure E.16 — Minutia direction on a ridge skeleton endpoint and bifurcation point, equivalent to Figure 3 and Figure 4 from ISO/IEC 19794-2:2005

E.4.4.5 Minutia direction at a ridge skeleton bifurcation point

A circle shall be drawn around the minutia. The radius shall be 1,63 mm (average width of 3 ridges of adult persons). The circle hits the skeleton of the ridge bifurcation on which the minutia resides in three pixels. Alternatively, the circle crosses every leg of the bifurcation once and with a well-defined centre. The intersecting points respectively centres of intersections are connected with the minutia. The connections define three angles, including only one acute angle. The angle measured counter-clockwise from the positive X axis to the bisecting line of this acute angle is the minutia direction.

E.4.4.6 Minutia direction at a valley skeleton bifurcation point

Analogical rules as for ridge skeleton bifurcation points apply also for valley skeleton bifurcation points. Valley skeleton bifurcation points will be discussed in the valley skeletal bifurcation extraction method.

E.4.5 Valley skeletal bifurcation method

The valley skeletal bifurcation method determines both the ridge and valley skeleton and works on this data to determine the position, type and orientation of ridge bifurcations and valley bifurcations (representing ridge ends).

The position or location of a minutia representing a medial valley ridge ending shall be the point of forking of the medial skeleton of the valley area immediately in front of the ridge ending. If the three legs of the valley area were thinned down to a single-pixel-wide skeleton, the point of the intersection is the location of the minutia. Similarly, the location of the minutia for a bifurcation shall be the point of forking of the medial skeleton of the ridge. If the three legs of the ridge were each thinned down to a single-pixel-wide skeleton, the point where the three legs intersect is the location of the minutia.

After all ridge endings have been converted to bifurcations, all of the minutiae of the fingerprint image are represented as bifurcations. The X and Y pixel coordinates of the intersection of the three legs of each minutia can be directly formatted. Determination of the minutia direction can be extracted from each skeleton bifurcation. The three legs of every skeleton bifurcation must be examined and the endpoint of each leg determined. Figure E.17 illustrates the three methods used for determining the end of a leg. The ending is established according to the event that occurs first.

- A distance of 1,63 mm.
- The end of skeleton leg that occurs between a distance of 0,50 mm and 1,63 mm; legs shorter than 0,5 mm are not used. This applies to both naturally short legs and those legs that fall into the background region.
- A second bifurcation is encountered within a distance of 1,63 mm.

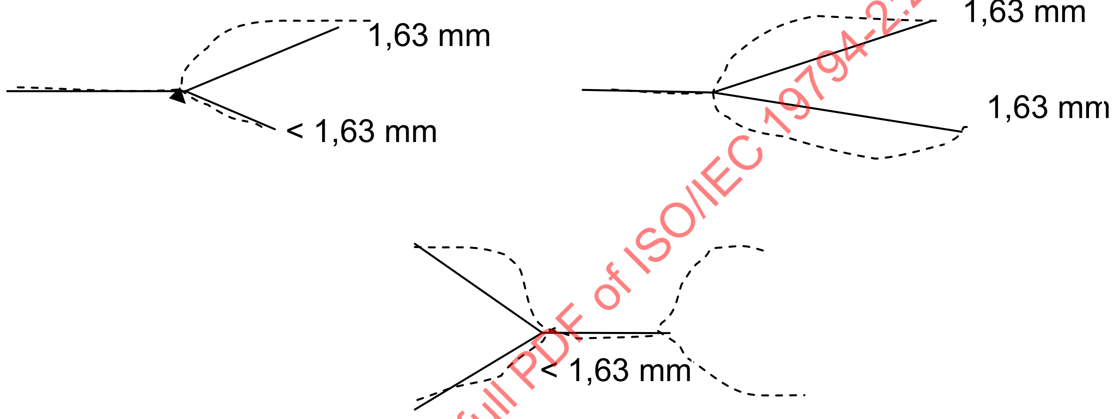

Figure E.17— Minutia direction on a ridge skeleton endpoint and bifurcation point, equivalent to Figure 3 and Figure 4 from 19794-2:2005

The angle of the minutiae is determined by constructing three virtual rays originating at the bifurcation point and extending to the end of each leg. The smallest of the three angles formed by the rays is bisected to indicate the minutiae direction.

E.4.5.1 Minutia location at a valley skeleton bifurcation

The minutia for a ridge ending shall be defined as the point of forking of the medial skeleton of the valley area immediately in front of the ridge ending (refer to Figure E.19 below). If the valley area were thinned down to a single-pixel-wide skeleton, the point where the three legs intersect is the location of the minutia. In simpler terms, this is the point where the valley "Y"'s, or (equivalently) where the three legs of the thinned valley area intersect. A Ridge Ending shall be encoded only if all of the legs used to calculate the minutiae angle length (as defined in E.4.5.3 – Angle of a Ridge Ending) are ⩾ 0,50mm in length.

E.4.5.2 Minutia location at a ridge skeleton bifurcation

The minutia for a ridge bifurcation shall be defined as the point at which a ridge splits into two ridges. The ridge bifurcation is located at the center of the intersection of three ridges. If a thinned image is considered, it is the location of the pixel with three neighbors. A Ridge Bifurcation shall be encoded only if the legs used to calculate the minutiae angle (as defined in E.4.5.4 Angle of a Ridge Bifurcation) are ⩾ 0,50mm in length.

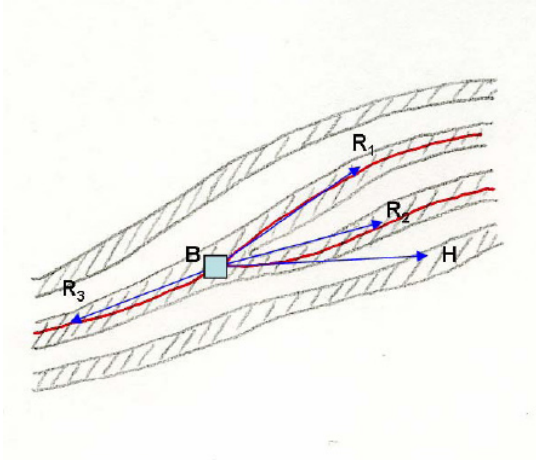

Figure E.18 — Minutia location on a ridge bifurcation

E.4.5.3 Angle of a Ridge Ending

Determination of the minutia direction can be extracted from each skeleton bifurcation. The three legs of every skeleton bifurcation must be examined and followed for 1,63 mm; special cases are outlined below. The angle of the minutiae is determined by constructing three virtual rays originating at the bifurcation point and extending to the end of each leg. The smallest of the three angles formed by the rays is bisected to indicate the minutiae direction.

Four cases are possible; see Figure E.19 through Figure E.22. In these figures, the shaded regions represent fingerprint ridges, the red lines represent the valley skeleton, and the blue lines represent the legs and horizontal axis.

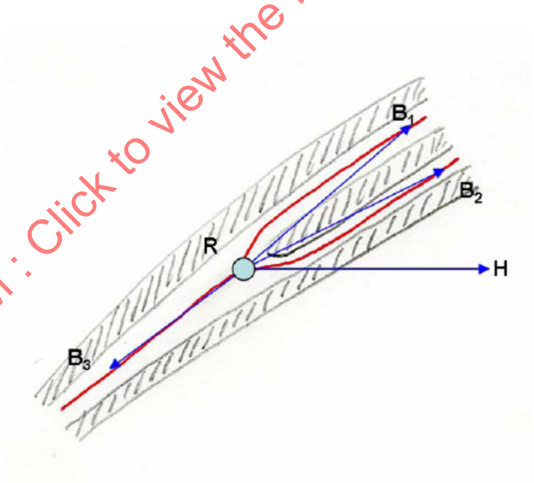

Figure E.19 — Case 1: Three legs of valley bifurcation with length ⩾ 1,63 mm

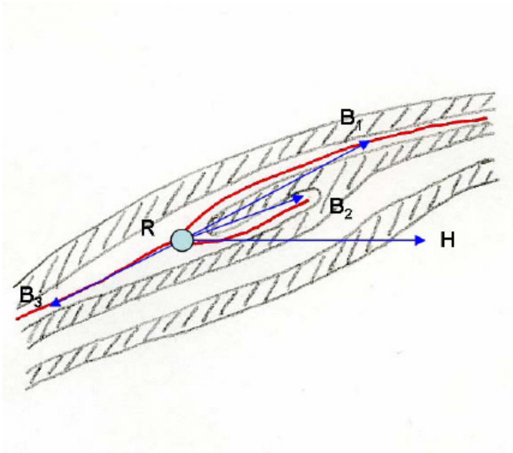

Figure E.20 — Case 2: One leg of valley bifurcation with length < 1,63 mm but ⩾ 0,50 mm

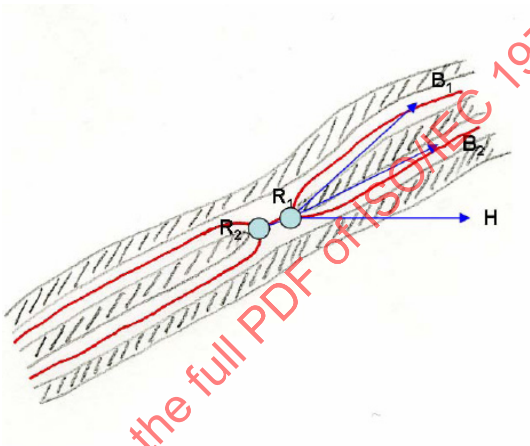

Figure E.21 — Case 3: Third leg meets opposite valley bifurcation with length < 1,63 mm but ⩾ 0,50 mm

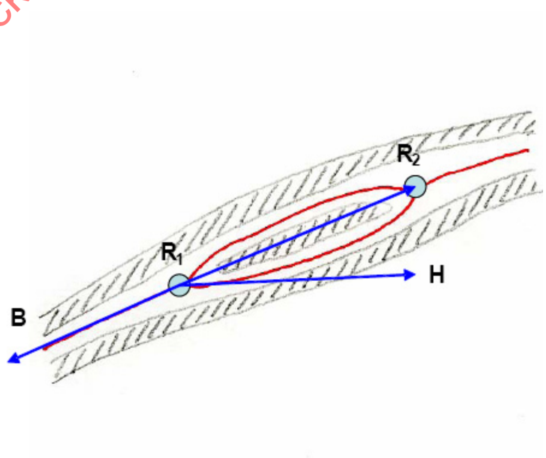

Figure E.22 — Case 4: Ridge with length < 1,63 mm but ⩾ 0,50 mm

NOTE While the formulas for cases (1) and (2) are identical, the cases are shown separately to illustrate how to calculate the angle for a ridge ending when it is not possible to follow a leg for 1,63 mm.

(1) Figure E.19 illustrates the case where the lengths of three legs, RB_1, RB_2, and RB_3, ⩾ 1,63 mm. The angle of the ridge ending, R, is defined as:

Angle of R = (Angle B_1RH + Angle B_2RH) / 2, where the line RH parallels the horizontal axis.

If the line RH bisects the legs RB_1 and RB_2, the angle of the ridge ending, R, is defined as:

Angle of R = [(Angle B_1RH + Angle B_2RH) / 2] - 180º, where angles outside the range of 0º–359º shall be normalized to fall within this range.

(2) Figure E.20 illustrates a case similar to (1), but the length of one of the legs of the paralleled valley bifurcation, RB_2, is < 1,63 mm, but ⩾ 0,50 mm. The angle of the ridge ending, R, is defined as:

Angle of R = (Angle B_1RH + Angle B_2RH) / 2, where the line RH parallels the horizontal axis.

If the line RH bisects the legs RB_1 and RB_2, the angle of the ridge ending, R, is defined as:

Angle of R = [(Angle B_1RH + Angle B_2RH) / 2] - 180º, where angles outside the range of 0º–359º shall be normalized to fall within this range.

(3) Figure E.21 illustrates a case similar to (1), but with the lengths of two legs, $R_1B_1$and R_1B_2, of the paralleled valley bifurcation ⩾ 1,63 mm, but the third leg, R_1R_2, meets the other valley bifurcation and the length R_1R_2 < 1,63 mm, but ⩾ 0,50 mm. The angle of the ridge ending, R1, is defined as:

Angle of R_1 = (Angle B_1R_1H + Angle $B_2 R_1H$) / 2, where the line RH parallels the horizontal axis.

If the line R_1H bisects the legs R_1B_1 and R_1B_2, the angle of the ridge ending, R_1, is defined as:

Angle of R_1 = [(Angle B_1R_1H + Angle $B_2 R_1H$) / 2] - 180º, where angles outside the range of 0º–359º shall be normalized to fall within this range.

(4) Figure E.22 illustrates the case where two paralleled valleys meet together at a valley bifurcation and the length of both legs are < 1,63 mm, but ⩾ 0,50 mm and the length of the third leg ⩾ 1,63 mm. The angle of the ridge ending, R1, is defined as:

Angle of R_1 = Angle R_2R_1H, where the line R_1H parallels the horizontal axis.

If the line R_1H intersects R_2, the angle of the ridge ending, R_1, is 0º.

Figure E.23 illustrates (1) above, where point R is a valley bifurcation while points B_1, B_2, and B_3 represent the end points that lie on thinned valley skeleton lines, at a distance of 1,63 mm from each end point in the direction into the enclosed ridge ending, R. The angle of the ridge ending R is the average of the angles B_1RH and B_2RH.

Figure E.24 illustrates (2) above, where point R is a ridge ending while points B_1, B_2, and B_3 represent the nearest valley end points. The distance between R and B_2 is < 1,63 mm, but ⩾ 0,50 mm while the lengths of the other two legs, RB_1 and RB_3, ⩾ 1,63 mm. The angle of ridge ending R is the average of the angles B_1RH and B_2RH.

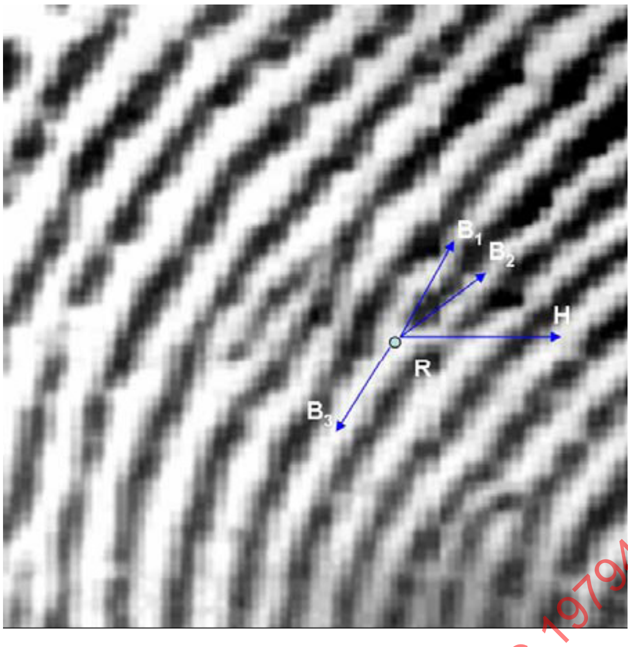

Figure E.23 — Valley bifurcation location and angle with the length of segment ⩾ 1,63 mm

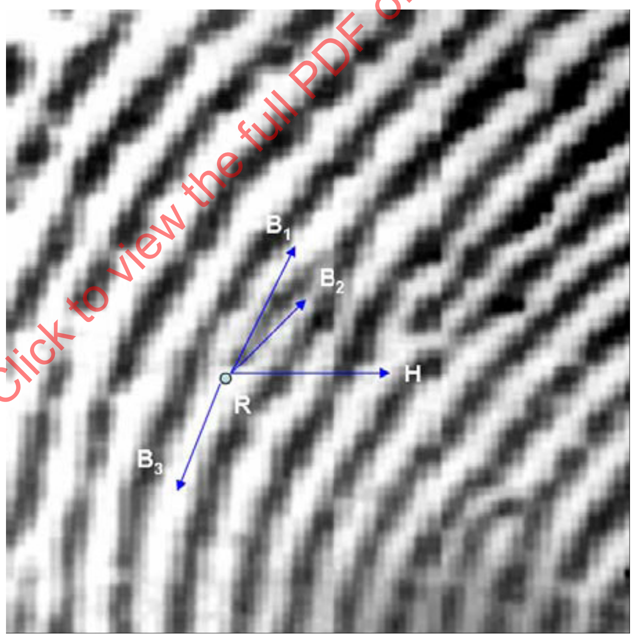

Figure E.24 — Valley bifurcation location and angle with the length of segment < 1,63 mm

E.4.5.4 Angle of a Ridge Bifurcation

Determination of the minutia direction can be extracted from each skeleton bifurcation. The three legs of every skeleton bifurcation must be examined and followed for 1,63 mm; special cases are outlined below. The angle of the minutiae is determined by constructing three virtual rays originating at the bifurcation point and extending to the end of each leg. The smallest of the three angles formed by the rays is bisected to indicate the minutiae direction.

Four cases are possible; see Figure E.25 through Figure E.28. In these figures, the shaded regions represent fingerprint ridges, the red lines represent the ridge skeleton, and the blue lines represent the legs and horizontal axis.

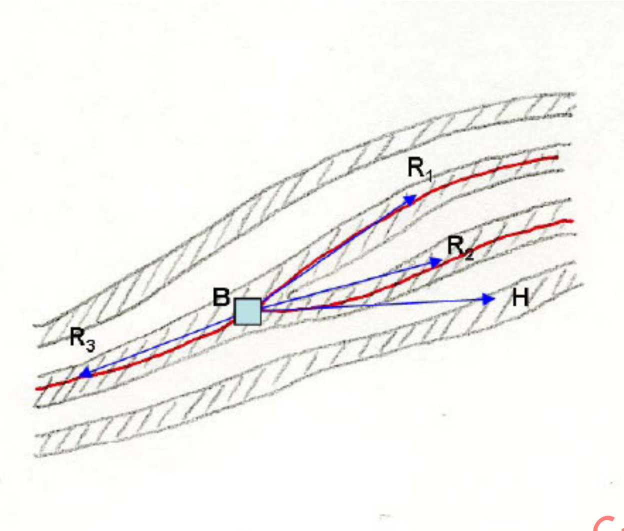

Figure E.25 — Case 1: Three legs of ridge bifurcation with length ⩾ 1,63 mm

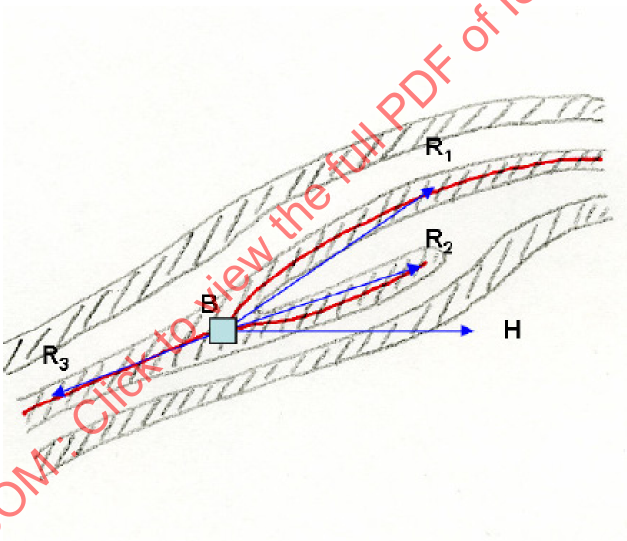

Figure E.26 — Case 2: One leg of the ridge bifurcation with length < 1,63 mm but ⩾ 0,50 mm

