

BS ISO/IEC 19794-8:2011+A1:2014

Incorporating corrigendum April 2012



BSI Standards Publication

Information technology — Biometric data interchange formats

Part 8: Finger pattern skeletal data

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National foreword

This British Standard is the UK implementation of ISO/IEC 19794-8:2011+A1:2014, incorporating corrigendum April 2012. It supersedes BS ISO/IEC 19794-8:2011 which is withdrawn.

The start and finish of text introduced or altered by amendment is indicated in the text by tags. Tags indicating changes to ISO/IEC text carry the number of the ISO amendment. For example, text altered by ISO/IEC amendment 1 is indicated by A1 A1.

The UK participation in its preparation was entrusted to Technical Committee IST/44, Biometrics.

A list of organizations represented on this committee can be obtained on request to its secretary.

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31 May 2014	Implementation of ISO/IEC amendment 1:2014

**Information technology — Biometric data
interchange formats —**

**Part 8:
Finger pattern skeletal data**

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

Partie 8: Données des structures du squelette de l'empreinte



Reference number
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Case postale 56 • CH-1211 Geneva 20
Tel. + 41 22 749 01 11
Fax + 41 22 749 09 47
E-mail copyright@iso.org
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Foreword

ISO (the International Organization for Standardization) and IEC (the International Electrotechnical Commission) form the specialized system for worldwide standardization. National bodies that are members of ISO or IEC participate in the development of International Standards through technical committees established by the respective organization to deal with particular fields of technical activity. ISO and IEC technical committees collaborate in fields of mutual interest. Other international organizations, governmental and non-governmental, in liaison with ISO and IEC, also take part in the work. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

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.

ISO/IEC 19794-8 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 37, *Biometrics*.

This second edition cancels and replaces the first edition (ISO/IEC 19794-8:2006), Clauses 6, 7 and 8 and Annex B of which have been technically revised. It also incorporates the Technical Corrigendum ISO/IEC 19794-8:2006/Cor.1:2011.

ISO/IEC 19794 consists of the following parts, under the general title *Information technology — Biometric data interchange formats*:

- *Part 1: Framework*
- *Part 2: Finger minutiae data*
- *Part 3: Finger pattern spectral data*
- *Part 4: Finger image data*
- *Part 5: Face image data*
- *Part 6: Iris image data*
- *Part 7: Signature/sign time series data*
- *Part 8: Finger pattern skeletal data*
- *Part 9: Vascular image data*
- *Part 10: Hand geometry silhouette data*
- *Part 11: Signature/sign processed dynamic data*

The following parts are under preparation:

- *Part 13: Voice data*
- *Part 14: DNA data*

Introduction

With the interest of implementing interoperable personal biometric recognition systems, this part of ISO/IEC 19794 establishes a data interchange format for pattern-based skeletal fingerprint recognition algorithms. Pattern-based algorithms process sections of biometric images. Pattern-based algorithms have been shown to work well with the demanding, but commercially driven, fingerprint sensor formats such as small-area and swipe sensors.

The exchange format defined in this part of ISO/IEC 19794 describes all characteristics of a fingerprint in a small data record. Thus it allows for the extraction of both spectral information (orientation, frequency, phase, etc.) and features (minutiae, core, ridge count, etc.). Transformations like translation and rotation can also be accommodated by the format defined in this part of ISO/IEC 19794.

With this part of ISO/IEC 19794 for pattern-based skeletal representation of fingerprints:

- interoperability among fingerprint recognition vendors based on a small data record is allowed;
- proliferation of low-cost commercial fingerprint sensors with limited coverage, dynamic range, or resolution is supported;
- a data record that can be used to store biometric information on a variety of storage mediums (including, but not limited to, portable devices and smart cards) is defined;
- adoption of biometrics in applications requiring interoperability is encouraged.

Note that it is recommended that biometric data protection techniques in ANSI X9.84 or ISO/IEC 15408 be used to safeguard the biometric data defined in this part of ISO/IEC 19794 for confidentiality, integrity and availability.

A1 Annex A to document addresses the conformance testing to be used for interchange format defined in this part of ISO/IEC 19794. This Annex A is distinct from the ISO/IEC 29109-8, which addressed conformance testing only of the first, 2007, edition of the ISO/IEC 19794-8 standard. **A1**

Information technology — Biometric data interchange formats —

Part 8: Finger pattern skeletal data

BS ISO/IEC 19794-8:2011+A1:2014
ISO/IEC 19794-8:2011+A1:2014 (E)

1 Scope

This part of ISO/IEC 19794 specifies the interchange format for the exchange of pattern-based skeletal fingerprint recognition data. The data format is generic in that it can be applied and used in a wide range of application areas where automated fingerprint recognition is involved.

This part of ISO/IEC 19794 also specifies elements of conformance testing methodology, test assertions, and test procedures as applicable to the interchange format for the exchange of pattern-based skeletal fingerprint recognition data.

This part of ISO/IEC 19794 establishes

- test assertions of the structure of the finger pattern skeletal data format as specified in this part of ISO/IEC 19794 (Type A Level 1 as will be defined in ISO/IEC 19794-1:2011/Amd.2),
- test assertions of internal consistency by checking the types of values that may be contained within each field (Type A Level 2 as will be defined in ISO/IEC 19794-1:2011/Amd.2).

This part of ISO/IEC 19794 does not establish

- test of conformance of CBEFF structures required by this part of ISO/IEC 19794,
- test of consistency with input biometric data record (Level 3),
- test of other characteristics of biometric products or other types of testing of biometric products (e.g. acceptance, performance, robustness, security),
- test of conformance of systems that do not produce ISO/IEC 19794-8 records.

A1 This part of ISO/IEC 19794 also specifies elements of conformance testing methodology, test assertions, and test procedures as applicable to this part of ISO/IEC 19794. Specifically, it establishes

- test assertions of the structure of the finger pattern skeletal data format as specified in Clauses 7 and 8 of this part of ISO/IEC 19794 (Type A Level 1 as defined in ISO/IEC 19794-1:2011 AMD 1),
- test assertions of internal consistency by checking the types of values that may be contained within each field (Type A Level 2 as defined in ISO/IEC 19794-1:2011 AMD 1),
- tests of semantic assertions (Type A Level 3 as defined in ISO/IEC 19794-1:2011 AMD 1).

The conformance testing methodology specified in this part of ISO/IEC 19794 does not establish

- tests of other characteristics of biometric products or other types of testing of biometric products (e.g. acceptance, performance, robustness, security),
- tests of conformance of systems that do not produce data records conforming to the requirements of this part of ISO/IEC 19794. **A1**

2 Conformance

A biometric data record conforms to this part of ISO/IEC 19794 if it satisfies all of the normative requirements related to:

- a) its data structure, data values, and the relationships between its data elements, as specified throughout Clause 7 for the finger pattern skeletal data record format and Clause 8 for the finger pattern skeletal data card format of this part of ISO/IEC 19794;
- b) the relationship between its data values and the input biometric data from which the biometric data record was generated, as specified throughout Clause 7 for the finger pattern skeletal data record format and Clause 8 for the finger pattern skeletal data card format of this part of ISO/IEC 19794.

A system that produces biometric data records is conformant to this part of ISO/IEC 19794 if all biometric data records that it outputs conform to this part of ISO/IEC 19794 (as defined above) as claimed in the Implementation Conformance Statement (ICS) associated with that system. A system does not need to be capable of producing biometric data records that cover all possible aspects of this part of ISO/IEC 19794, but only those that are claimed to be supported by the system in the ICS.

A system that uses biometric data records is conformant to this part of ISO/IEC 19794 if it can read, and use for the purpose intended by that system, all biometric data records that conform to this part of ISO/IEC 19794 (as defined above) as claimed in the ICS associated with that system. A system does not need to be capable of using biometric data records that cover all possible aspects of this part of ISO/IEC 19794, but only those that are claimed to be supported by the system in an ICS.

A) Biometric data interchange format conformance tests conform to this part of ISO/IEC 19794 if they satisfy all of the normative requirements set forth in clauses 6, 7, and 8. Specifically, they shall use the test methodology specified in ISO/IEC 19794-1:2011 AMD 1, and all Level 1, Level 2 and Level 3 tests shall use the assertions defined in Table A.1 of Clause A.2 in this part of ISO/IEC 19794.

Implementations of this part of ISO/IEC 19794 tested according to the specified methodology shall be able to claim conformance only to those biometric data record (BDB) requirements specified in this part of ISO/IEC 19794 that are tested by the test methods established by this methodology.

In consideration of the semantic specifics in different parts of 19794, all level 1, level 2, and level 3 tests shall use the assertions defined in Table A.2 of clause A.3 of this part of 19794 in conformity with the concept and rules set in 19794-1 Annex A. **A1**

3 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO/IEC 19794-1:2011, *Information technology — Biometric data interchange formats — Part 1: Framework*

ISO/IEC 7816-6:2004, *Identification cards — Integrated circuit cards — Part 6: Interindustry data elements for interchange*

ISO/IEC 7816-11:2004, *Identification cards — Integrated circuit cards — Part 11: Personal verification through biometric methods*

4 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 19794-1 and the following apply.

4.1

sweat pore

minute opening in the dermis, allowing loss of fluid as a part of the temperature control of the body

5 Abbreviated terms

For the purposes of this document, the following abbreviated terms apply.

BER	Basic Encoding Rules
BIT	Biometric Information Template
CBEFF	Common Biometric Exchange Formats Framework
DO	Data Object
ppcm	pixels per centimetre

6 Determination of finger pattern skeletal data

This part of ISO/IEC 19794 for finger pattern interchange data is based on the skeleton representation of friction ridges. Since the result of different skeleton generation algorithms will differ at a maximum of about a quarter of the ridge width this will have no impact on interoperability. In order to get a robust skeleton of the ridges a noise reduction and regularization may take place on the raw image. The direction encoding of the skeleton line elements is included in the interchange data record. The start and endpoints of the skeleton ridgelines are included as real or virtual minutiae, and the line from start to endpoint is encoded by successive direction changes. In the following, first the minutiae characteristics and then the encoding definition for one skeleton line is described.

6.1 Minutia

Minutiae are points located at the places in the fingerprint image where friction ridges end or split into two ridges.

6.1.1 Minutia type

Each minutia point has a “type” associated with it. There are two major types of minutia: a “ridge ending” represented by the 2-bit value 01 and a “ridge bifurcation” or split point represented by 2-bit value 10. Points with three or more intersecting ridges (trifurcations, etc.) will be treated as a “ridge bifurcation” type.

Ridge skeletons require the use of both real and “virtual” minutiae. Virtual minutiae are points on the fingerprint image where a real ridge ending or a bifurcation does not exist, but a point is required to finish, or continue, a skeleton ridgeline. Virtual minutiae have thus two types: virtual endings and virtual continuations.

- Virtual endings are necessary to describe skeleton lines ending at the image boundary or at border lines to those areas where there is insufficient image quality to determine ridges and real minutiae points (see Figure C.3). They are also needed to finish the encoding of a closed loop (Table C.1). Virtual endings have been assigned the 2-bit value 00.
- In rare cases a skeleton line description will require the insertion of a virtual minutia point on a ridgeline. For example, such points will be required to begin an encoding of a closed loop for which no real minutiae exist, as well as to describe ridges with high curvature at a sufficient accuracy (see note about maximal curvature in 6.2.4). These are called “virtual continuation” and have been assigned the 2-bit value 11 (Table C.1).

6.1.2 Minutia location and coordinate system

The coordinate system used to express the position of the minutiae points of a fingerprint shall be a Cartesian coordinate system. Points shall be represented by their x and y coordinates, where x increases to the right and y increases downward (opposite of the pointing direction of the finger), when viewing on a latent print of the finger (see Figure 1). Note that this is in agreement with most imaging and image processing use. When viewing on the finger, x increases from right to left as shown in Figure 1. All x and y values are non-negative. For the skeletal pattern record format, the resolution is specified in the representation header, see 7.4. For the skeletal pattern card format, the resolution of the x and y coordinates of the minutia shall be in metric units. The granularity is one bit per five hundredth of a millimetre in the normal format and one tenth of a millimetre in the compact format:

1 unit = 0,05 mm (normal format) or 0,1 mm (compact format).

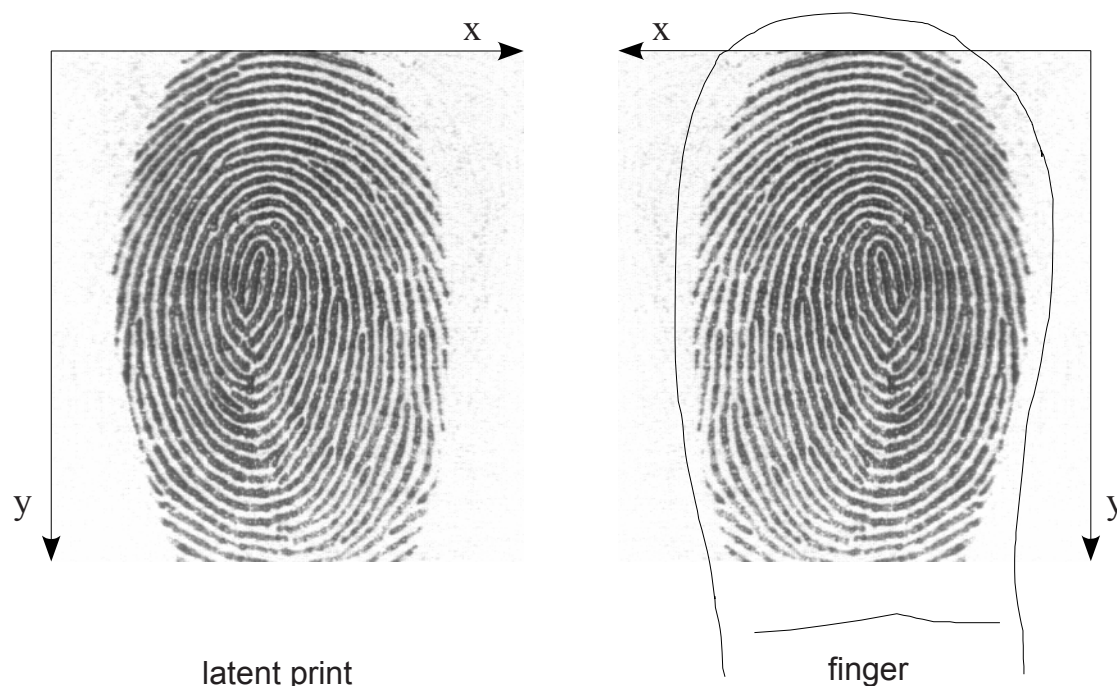


Figure 1 — Coordinate system

The position of the minutia for a ridge ending shall be defined as the coordinates of the skeleton point with only one neighbour pixel belonging to the skeleton.

NOTE In some format types of ISO/IEC 19794-2 a ridge ending refers to the point of bifurcation of the valley in front of the ridge.

The position of the minutia for a ridge bifurcation shall be defined as the point of forking of the skeleton of the ridge. In other words, the point where three or more ridges intersect is the location of the minutia.

The position of a virtual ending shall be defined like the position of a real ridge ending.

The position for the minutiae type “virtual continuation” is not evaluated by comparison algorithms, that analyse minutiae points and angles only. Minutiae of this type are only used for reconstructing the skeleton but may support subsequent classifications of the reconstructed pattern. One may assign any point on the skeleton necessary to increase the accuracy of the ridge line description (Table C.1).

6.1.3 Angle conventions

The minutiae angle is measured increasing counter clockwise starting from the horizontal axis to the right. The angle of a minutia is scaled to fit the bit width of the data field defined in the representation header.

The direction of a ridge skeleton endpoint is defined as the angle between the tangent to the ending ridge and the horizontal axis extending to the right of the ridge ending point.

A ridge skeleton bifurcation point has three intersection ridges. The two ridges enclosing the ending valley encompass an acute angle. The direction of a ridge bifurcation is defined as the mean direction of their tangents. Where each direction is measured as the angle the tangent forms with the horizontal axis to the right.

The direction of the lines starting or ending at a points with more than three arms (trifurcation, etc.) shall be defined like the direction of a real ridge ending.

The direction of a virtual ending shall be defined like the direction of a real ridge ending.

The direction for the minutia type “virtual continuation” is not evaluated by comparison algorithms, that analyse minutiae points and angles only. Minutiae of this type are only used for reconstructing the skeleton but may support subsequent classifications of the reconstructed pattern. One may assign the mean of the incoming and outgoing direction or the outgoing direction (Table C.1).

6.1.4 Differences to minutia data in ISO/IEC 19794-2 – Finger minutia data

The definition of the minutia position and direction is identical with ISO/IEC 19794-2:2005 card format (Format type ‘0006’) with

- minutia placement on a ridge bifurcation encoded as a ridge skeleton bifurcation point and
- minutia placement on a ridge endpoint encoded as a ridge skeleton endpoint.

To compare minutiae with any other definition, a position and direction correction may be necessary. There may be performance interoperability differences with the other format types of ISO/IEC 19794-2.

The angular resolution of minutiae in the finger pattern skeletal data record is defined in the header. The minimal resolution allowed is 16 directions, that is $22,5^\circ$ per least significant bit. A resolution below the recommended 64 directions ($5,625^\circ$) (Table 1: Bit-depth of direction code start and stop direction) may cause a decrease in match quality for purely minutiae based comparison algorithms. This recommendation corresponds to the angular resolution of the compact card format in finger minutiae data.

There are no virtual minutiae (type ID 00 and 11) in the finger minutiae data format.

There is no minutia type “other” (type ID 00) in the skeletal pattern data format.

Point with more than three arms (trifurcation, etc.) are not mentioned in the finger minutiae data, so they may be omitted or encoded as “other”. In the finger pattern skeletal data these structures get the type “bifurcation”.

6.2 Encoding the skeleton ridge line by a direction code

6.2.1 Direction code

Each line in the skeleton image is encoded as a polygon. Therefore, each polygon element is taken from a fixed set of line elements (defined in Clause 6.2.4). The line starts at an offset coordinate with a starting direction and the following minutia characteristics:

- minutia type (2 bits: 00 virtual ending, 01 ridge ending, 10 ridge bifurcation, 11 virtual continuation);
- minutia direction (bit-depth defined in the representation header, range: 0-360 degrees scaled according to bit-depth);
- x-coordinate (bit-depth defined in the representation header);
- y-coordinate (bit-depth defined in the representation header);
- number of direction elements following (8 bits).

The successive polygonal elements are defined by their direction change relative to the previous element or for the first element relative to the minutia direction, scaled and rounded to the direction code range and resolution (6.2.4). The length of each element is a function of the direction change (6.2.4):

- direction change (bit-depth and resolution defined in the representation header, data type is a signed integer - the smallest negative number $10\dots0$ is not used for direction change); (e.g. for bit-depth of 4 and 32 directions on 180° the signed integer range from -7 to 7 is scaled to the angle range from $-39,375^\circ$ to $+39,375^\circ$;

- or in situations of high ridge line curvature one may wish to store direction elements at higher spatial resolution. Therefore one can switch between two different resolution levels. With the smallest negative number 10...0 the resolution level is switched between normal or high. A line encoding will always start at normal resolution. On the first occurrence of 10...0 in a line code switch to high resolution level in using half the step length, on the second occurrence switch back normal resolution and full step length etc. (Table C.2).
- the direction change is repeated until the line end is reached;
- minugia type of line end (2 bits: 00 virtual ending, 01 ridge end, 10 ridge bifurcation, 11 virtual continuation).

If the skeleton line ends at a virtual ending (type number 00), the relative position of the minugia on the line element follows:

- the relative minugia position l/S_n is scaled to the range 0-3 via $\min(3, \text{floor}(4l/S_n))$ and stored as unsigned integer of length 2 bits, where l is the distance between the start of the last line element and the minugia, and S_n the step length of the last line element (Figure 2).
- If the skeleton line ends at a true minugia (type number 01 or 10) or is interrupted by a virtual continuation (type number 11) a byte-aligned minugia description follows. In order to keep the alignment overhead small it is done in the following manner: If the previously stored minugia type of the line end is already starting byte aligned, the minugia data is completed by appending its direction and position. On unaligned ending type, it is repeated at the start of the next byte followed by direction and position.

Thus the encoding continues with the following:

- If the previously stored minugia type of the line end is not starting byte aligned, it is repeated at the start of the next byte. Any unused bits caused by this alignment are filled with zeros.
- minugia direction (bit-depth defined in the representation header, range 0-360 degrees scaled according to bit-depth);
- x-coordinate (bit-depth defined in the representation header).
- y-coordinate (bit-depth defined in the representation header).

If the ending minugia is of type virtual continuation (type number 11) the line description continues with:

- the number of direction elements following (8 bits) and direction elements as described above.

Any unused bits of the last byte for each encoded line is filled with zeroes to get a byte aligned beginning for the next line encoding.

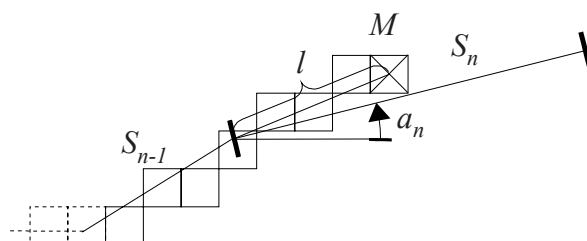


Figure 2 — The relative minugia position on a polygon line element is the ratio l/S_n , where S_n is the length of the line element passing the minugia M and l is the distance between the start of S_n and minugia M . α_n is the angle of S_n .

6.2.2 General skeleton line encoding rules

To keep the encoding size small a line shall start with a real minutia (type 01 or 10) if possible.

There are no restrictions about the use of virtual continuation minutiae or high resolution mode.

NOTE 1 Virtual continuation minutia and the high resolution mode are “tools” to describe the ridges. One may prefer one method to describe high curvature and use the other to mark a line passing a bifurcation, a core or delta or extreme values in curvature. But these additional interpretations will increase the encoding size and can only be used in a non interoperable manner.

No assumption shall be made about the order of the line encodings in the record.

The skeleton shall be encoded only for image areas where the ridge lines are displayed with a sufficient quality (Figure C.3).

NOTE 2 A one bit quality map is implicitly defined: At image areas with no encoded ridge line nearby the quality is 0 or not sufficient and at a image area with an encoded ridge line nearby the quality is 1 or sufficient. With the zonal quality data in the extended data area a multi-bit quality map may be defined in addition.

To judge the descriptive quality of the skeleton line encodings, one has to compare its reconstructed ridge lines with the fingerprint image the encoding comes from. The reconstructed ridge lines shall describe the fingerprint image in ridge position and structure, thus the following rules apply:

- The reconstructed skeleton line polygon element shall be inside the area of the ridge it is describing for most part of its length, i.e. at least 50%. A threshold in the range of 5% may be appropriate (best practice). This value depends on the reconstruction and comparison quality requirements of the application.
- The reconstructed skeleton line shall never be inside the area of any other ridge but the one it is describing.
- The reconstructed skeleton line shall preserve the topology of the ridges (see the definition of skeleton).

6.2.3 Constructing direction elements

For constructing the direction change α_i between two successive polygonal elements see Figure 3 and Figure 4. First, draw a circle, of radius equal to the polygon element length, around the current point. Obtain the intersection point between the circle and the skeleton line the in forward direction. The direction towards this point is scaled according to the bit-depth of the direction code. The difference between this direction and the previous line element is stored. The end point of this new polygon element with the fixed length and its digitised direction serves as the next starting point.

The previous construction is done with direction independent step size. For the general direction dependent step size replace the circle in the description above by the step size dependency defined in Clause 6.2.4.

A1 In order to minimize integration of digitalisation error, each starting point must be computed with relatively high accuracy, i.e. its resolution shall be at least 100 times finer than the spatial resolution of the minutiae. **A1**

If the skeleton line ends during a step it is linearly extended to fill the polygon element length. The line encoding is completed with the minutiae type. For a true minutiae ending, its direction and the endpoint coordinates are stored. For a virtual ending, the relative minutia position on the current step is stored.

If the direction change of the skeleton line cannot be described by a direction element, the line encoding shall be interrupted by a “virtual continuation” and a new line encoding shall begin with the same point without repeating the minutia data.

A bifurcation (trifurcation, etc.) (Figure 4 and Figure C.2) is represented by two (or more) skeleton line encodings. One skeleton line passes the bifurcation without a real minutia at its position (Figure 4). All other

lines end or start here and are assigned the type “bifurcation”. It is recommended to use the straightest ridge line passing the bifurcation without encoding a real minutia.

NOTE The most straight line is probably the dominant line, for which repetitive encodings with this part of ISO/IEC 19794 will not result in different line encodings - while the branching off line may swap from bifurcation to a ridge ending. i.e. depending from the sensor conditions in some images a bifurcation seems to be a ending with the dominant line passing through.

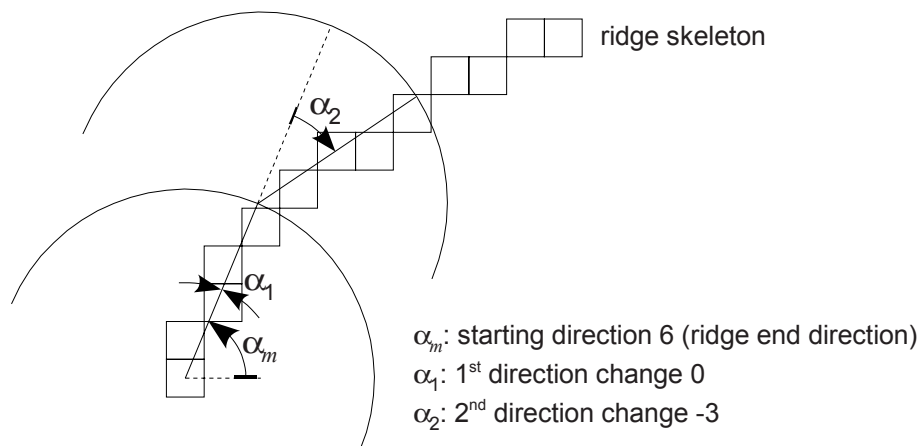


Figure 3 — The direction encoding starting from a skeleton end point. A bit-depth of 4 is used for direction change

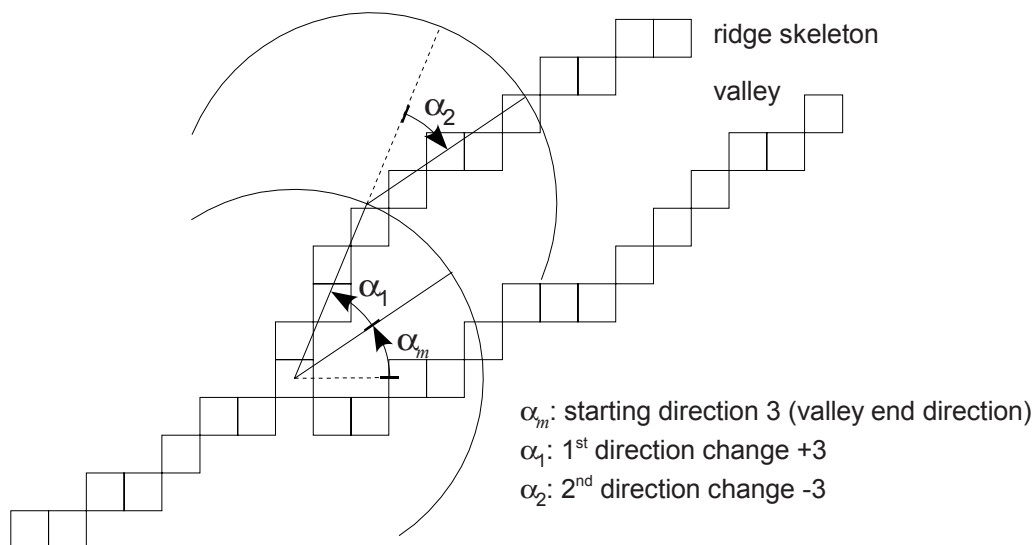


Figure 4 — The direction encoding starting from a skeleton bifurcation point. A bit-depth of 4 is used for direction change

6.2.4 Direction element length

At most steps the direction change will be straight or nearly straight. With an increase step length on small direction changes and reduced angular range the number of direction elements are reduced.

The direction change dependant step size (Figure 5) and resolution is characterised by 4 parameters:

- The number of directions, N_π , on π or 180° . This gives the angular resolution, e. g. with $N_\pi = 32$ the resolution is $5,625^\circ$.

- With the bit-depth for one direction code element one gets the number of possible directions at each step. Since the change is symmetric to 0, the angular range is

$$\alpha_{\max} = \pm(180^\circ / N_\pi) (2^{\text{bit-depth}-1} - 1) \quad (1)$$

NOTE 1 With a resolution of $5,625^\circ$ and at a bit-depth of 4, this gives a maximal bending of $\alpha_{\max} = \pm 39,375^\circ$

- The step length for going straight, S_s .
- The maximal displacement perpendicular to the current direction, S_p . In the representation header this value is stored relative to the straight step size, S_s , as $256 \times S_p/S_s$. If $256 \times S_p/S_s$ is set to 0 in the representation header a constant step length of S_s for all direction elements is used.

The design characteristics for the direction dependant step size are

- constant angular resolution, i. e. the distance between subsequent bending angles, α_n , is constant:
 $|\alpha_i - \alpha_{i\pm 1}| = \text{constant for all } i \in \{.., -2, -1, 0, 1, 2, ..\}.$
- constant spatial accuracy for all direction changes, i. e. the distance between subsequent steps, $\vec{r}_i$, is constant:
 $|\vec{r}_i - \vec{r}_{i\pm 1}| = \text{constant for all } i \in \{.., -2, -1, 0, 1, 2, ..\}.$

With these conditions the endings of all of possible directions, $\vec{r}_i$, for one step are located on two circular arches as shown in Figure 5. Thus the direction dependant step size, $|\vec{r}_i|$, is defined by:

$$|\vec{r}_i| = \begin{cases} \frac{(S_s^2 + 4S_p^2)}{4S_p} \sin(2\varphi - |\alpha_i|) & \text{for } S_p > 0 \\ S_s & \text{for } S_p = 0 \end{cases} \quad (2)$$

with the angle α_i between current direction and step $\vec{r}_i$ defined as:

$$\alpha_i = 180^\circ i / N_\pi \quad (3)$$

and where:

- $\varphi = \arctan(2S_p / S_s)$,
- $i \in \{.., -2, -1, 0, 1, 2, ..\}$ is the number of the direction change,
- S_s is the step length for going straight,
- S_p is the maximal displacement perpendicular to the current direction, and
- N_π is the number of directions on π or 180° .

An example for the angle dependant step size is given in Annex C.

NOTE 2 The maximal curvature of the polygon is achieved with the minimal step size $r_{\min} = r(\alpha_{\max})$ from (2) at the maximal bending angle $\alpha_{\max}$ from (1). A polygon with constant bending angle $\alpha_{\max}$ and constant element length $r_{\min}$ has a radius $R = 180^\circ r_{\min} / (\pi \alpha_{\max})$. With $S_s = 16$, $S_p = 3,75$, and $\alpha_{\max} = 39,375^\circ$, a minimal step length $r_{\min} = 3,9$ and a radius of 5,7 pixel at a resolution of 100 ppcm is attained. At high resolution level the step length is cut in half, $r_{\min} = 1,95$, thereby getting a radius of 2,85 pixels. With these settings a u-turn down to 0,6mm Sdiameter may be represented by a polygon without interruption by a virtual continuation minugia.

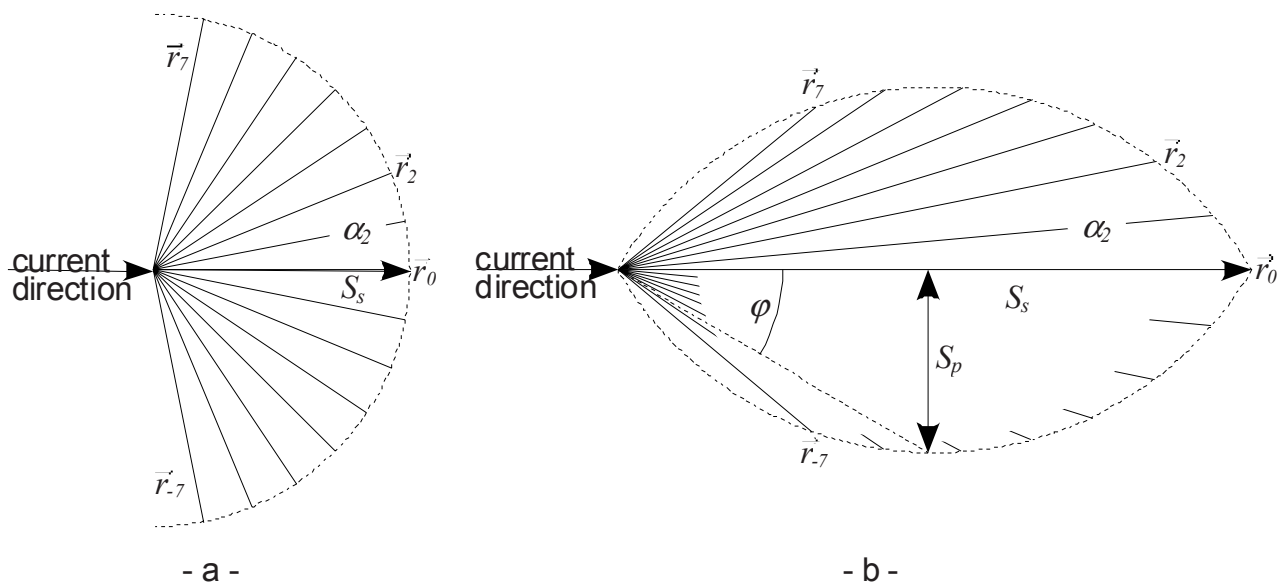


Figure 5 — Step length dependency of direction change

- (a) with $S_p = 0$ a constant step length is used, here at a angular resolution of $11,25^\circ$
(b) with $S_p > 0$ the steps at small bending angles are increased while steps at large bending angles are short. Here again 15 directions are encoded at higher angular example resolution of $5,625^\circ$

6.3 Skeleton line neighbourhood index

The skeleton line gives the spatial connectivity in one dimension along the line. The direction perpendicular to the line is given by the neighbouring lines. Thus to help any comparison algorithm to analyse and compare a local two dimensional image area a link to the adjacent lines is very usefull. This link is given by list of neighbours for each encoded line. (see C.5)

6.3.1 Adjacent lines

Two encoded ridge lines are neighbours to each other

- a) if they are surrounding the same part of a valley
 - 1) for a not interrupted distance of least the width of the valley
 - 2) or for the whole line length of one of the lines (i.e. one of the lines is too short to comply with the condition 1)
- b) and if the image has sufficient not interrupted quality to support this ridge-valley-ridge-structure over the whole area needed to comply the condition a).

6.3.2 Recording the neighbour indices

The line index is the sequential number of the encoded lines. A new line is starting with a starting minutia of any type (including continuation minutiae).

For each line with index number L one gets a list of neighbouring lines with indices A_i . If line 1 is a neighbour of line 2 also line 2 is a neighbour of line 1. So to get each neighbour relation only once, only lines with an index number $A_i \leq L$ are listed as neighbour of line L . This neighbourhood index list, including the line index L , is sorted by decreasing line index:

$$L, A_1, \dots, A_n \quad \text{where} \quad L \geq A_1, A_1 > A_2, \dots, A_{n-1} > A_n,$$

where n is the number of neighbourhood entries for Line L . Since a line may be a neighbour to itself (e.g. at a u-turn), the first number in this list A_1 may be equal L . But since it is not useful to list a neighbourhood relation twice, any of the other indices shall be different i.e. $A_{i-1} > A_i$.

Then the subsequent differences between the line index L and the neighbour indices A_i are calculated:

$$L-A_1, A_1-A_2, \dots, A_{n-1}-A_n, \quad (4)$$

The following data is recorded for one line:

- The number of neighbourhood entries for this line
- followed by the list of index differences.

Concatenating the neighbour index data for all encoded lines in the same order as the line encodings in the record gives the skeleton line neighbouring index list.

The skeleton line neighbourhood index data starts with the bit-depth necessary to store the elements in the index list. The bit-depth is recorded in one byte followed by the neighbourhood index list, packed to bytes with a bit-depth given.

7 Finger pattern skeletal data record format

7.1 Introduction

The record format contains fields for both public and extended (proprietary) finger pattern skeletal interchange data. With the exception of the format identifier and the version number for this part of ISO/IEC 19794, which are null-terminated ASCII character strings, all data is represented in binary format. There are no record separators or field tags; fields are parsed by byte count.

7.1.1 Pattern record format summary

Table 1 is a reference for the fields present in the finger pattern skeletal data record format. Optional extended data formats for ridge counts, core and delta data, zonal quality information and sweat pore position data are not represented here.

Table 1 — Finger pattern skeletal data record format summary

	Field	Size	Values	Notes
General Header	Format Identifier	4 bytes	46534b00 _{HEX} (‘FSK’ 0 _{HEX})	“FSK ” – finger pattern skeletal record
	Version of this part of ISO/IEC 19794	4 bytes	30323000 _{HEX} (‘0”2”0’00 _{HEX})	This number indicates the second version of this part of ISO/IEC 19794 used for constructing the iris image data record and shall be placed in four bytes. This version number shall consist of three ASCII numerals followed by a zero byte as a NULL string terminator.
	Length of total record in bytes	4 bytes		
	Number of finger representations in record	2 bytes	1 to 255	
	Certification flag	1 bytes		00 _{HEX} no representation contains a certification record 01 _{HEX} all representations contain a certification record
Representation Body (one per representation)	Representation length		4 bytes	The representation-length field denotes the length in bytes of the representation including the representation header fields.
	Capture date and time		9 bytes	The capture date and time in Coordinated Universal Time (UTC). Its value shall be encoded in the form given in ISO/IEC 19794-1.
	Capture device technology identifier		1 byte	0 to 20
	Capture device vendor identifier		2 bytes	0000 _{HEX} to FFFF _{HEX}
	Capture device type identifier		2 bytes	0000 _{HEX} to FFFF _{HEX}
	Number of quality blocks		1 byte	0 to 255 This field is followed by the number of 5-byte Quality Blocks reflected by its value. A value of zero (0) means that no attempt was made to assign a quality score. In this case, no Quality Blocks are present.
	Quality block	Quality score	1 byte	0 to 100, 255 0: lowest 100: highest 255: failed attempt to assign a quality score
		Quality algorithm vendor identifier	2 bytes	0000 _{HEX} to FFFF _{HEX}
		Quality algorithm identifier	2 bytes	0000 _{HEX} to FFFF _{HEX}
	Number of certifications		1 byte	00 _{HEX} to FF _{HEX} 00 _{HEX} no certification information

		Field	Size	Values	Notes
	Certification record	Certification authority identifier	2 bytes	0000 _{HEX} to FFFF _{HEX}	
		Certification scheme identifier	1 byte	00 _{HEX} to FF _{HEX}	Table 3
		Finger position	1 byte	0 to 10	Table 4
		Representation number	1 byte	0 to 15	
		Resolution of finger pattern [ppcm]	1 byte	1 to 255	Recommended 100ppcm
		Impression type	1 byte	0 to 3, 8 to 23 to 29	Table 5
		Skeleton image size in x	2 bytes		in pixels
		Skeleton image size in y	2 bytes		in pixels
		Bit-depth of direction code start and stop point coordinates	1 byte	8 to 16	Recommended 8
		Bit-depth of direction code start and stop direction	1 byte	4 to 8	Recommended 6
		Bit-depth of direction in direction code	1 byte	3 to 8	Recommended 4
		Step size of direction code S_s	1 byte	1 to 255	Recommended 16
		Relative perpendicular step size $256 \times S_p/S_s$	1 byte	0 to 255	Recommended 60
		Relative perpendicular step size $256 \times S_p/S$	1 byte	0 to 255	Recommended 60
		s Number N_π of directions on 180°	1 byte	1 to 255	Recommended 32
		Length of finger pattern skeletal data block	2 bytes		
		Length of finger pattern skeletal data	2 bytes		
		Finger pattern skeletal data	In prev. field		
		Length of skeleton line neighbourhood index data	2 bytes		
		Skeleton line neighbourhood index data	In prev. field		
		Extended data block length	2 bytes		0000 _{HEX} = no extended area
		Extended data area type code	2 bytes	00 _{HEX} to FF _{HEX}	only present if extended data block length $\neq 0$ Each extended data area may contain vendor-specific data, or one or more of the following (in any order): — Ridge count data, — Core and delta data — Zone quality data — Sweat pore position data — Skeleton structural data
		Extended data area length	2 bytes		
		Extended data	In prev. field		

7.2 Record organization

The organization of the record is as follows:

- A fixed-length (15-byte) general header containing information about the overall record, including the number of finger representations represented and the overall record length in bytes;
- A single finger record for each finger, consisting of:
 - A variable length representation header containing information about the data for a single finger;
 - The variable length fingerprint pattern skeletal description;
 - An extended data block containing the extended data block length and zero or more extended data areas for each finger.

All multi-byte quantities are represented in Big-Endian format; that is, the more significant bytes of any multi-byte quantity are stored at lower addresses in memory than (and are transmitted before) less significant bytes. Bit order follows the same endianness as the byte order. That is, the most significant bit is stored at the lowest bit address. All numeric values are fixed-length integer quantities.

7.3 General header

There shall be one and only one general header for the finger pattern skeletal data record. The general header will contain information describing the identity and characteristics of the device that generated the data.

7.3.1 Format identifier

The finger pattern skeletal data record shall begin with a format identifier to be recorded in four bytes. For this part of ISO/IEC 19794, it shall consist of the three ASCII characters “FSK”, followed by a zero byte as a NULL string terminator.

7.3.2 Version number

The version number for the version of this part of ISO/IEC 19794 used in constructing the record shall be placed in four bytes. This version number shall consist of three ASCII numerals followed by a zero byte as a NULL string terminator. The first and second character will represent the major revision number and the third character will represent the minor revision number. Upon approval of this specification, the version number shall be “020” (an ASCII ‘0’ followed by an ASCII ‘2’ and an ASCII ‘0’).

7.3.3 Length of total record

The length of the entire BDIR shall be recorded in four bytes. This count shall be the total length of the BDIR including the general record header and one or more representation records.

7.3.4 Number of finger representations

The total number of representation records contained in the BDIR shall be recorded in two bytes. A minimum of one representation is required.

7.3.5 Certification flag

The one-byte certification flag shall indicate whether each Representation Header includes a certification record. A value of 00_{Hex} shall indicate that no representation contains a certification record. A value of 01_{Hex} shall indicate that all representations contain a certification record.

NOTE A certification record that is present may contain 0 certifications (in that case the number-of-certifications field in the certification record has the value 0).

7.4 Single finger record format

7.4.1 Finger Pattern Skeletal Representation Header

A finger pattern skeletal representation header shall start each area of finger data providing information for that finger. There shall be one finger pattern skeletal representation header for each finger contained in the finger pattern skeletal data record. The finger pattern skeletal representation header will occupy at least 37 bytes as described below. Note that it is permissible for more than one single finger record to represent the same finger, with (presumably) different data.

7.4.1.1 Representation length

The representation-length field denotes the length in bytes of the representation including the representation header fields.

7.4.1.2 Capture date and time

The capture date and time field shall indicate when the capture of this representation started in Coordinated Universal Time (UTC). The capture date and time field shall consist of 9 bytes. Its value shall be encoded in the form given in ISO/IEC 19794-1. This field shall indicate the date and time the representation was captured. This field is not intended encode the time the record was instantiated.

7.4.1.3 Capture device technology identifier

The capture device technology ID shall be encoded in one byte. This field shall indicate the class of capture device technology used to acquire the captured biometric sample. A value of 00_{Hex} indicates unknown or unspecified technology. See Table 2 for the list of possible values.

Table 2 — Capture device technology identifiers

Capture device technology identifier	Class of device technology
0	Unknown or unspecified
1	White light optical TIR
2	White light optical direct view on platen Note: Card scanner should encode their technology type as "white light optical direct view on platen".
3	White light optical touchless
4	Monochromatic visible optical TIR
5	Monochromatic visible optical direct view on platen
6	Monochromatic visible optical touchless
7	Monochromatic IR optical TIR
8	Monochromatic IR optical direct view on platen
9	Monochromatic IR optical touchless
10	Multispectral optical TIR
11	Multispectral optical direct view on platen
12	Multispectral optical touchless

13	Electro luminescent
14	Semiconductor capacitive
15	Semiconductor RF
16	Semiconductor thermal
17	Pressure sensitive
18	Ultrasound
19	Mechanical
20	Glass fiber

7.4.1.4 Capture device vendor identifier

The capture device vendor identifier shall be recorded in two bytes. It shall identify the biometric organisation that owns the product that created the BDIR and shall be registered with the IBIA or other approved registration authority. A value of all zeros shall indicate that the capture device vendor is unreported.

7.4.1.5 Capture device type identifier

This capture device type identifier shall be recorded in two bytes. It shall identify the product type that created the BDIR and shall be assigned by the registered BDIR product owner or other approved registration authority. A value of all zeros shall indicate that the capture device type is unreported.

7.4.1.6 Finger quality

7.4.1.6.1 General

A quality record shall consist of a length field followed by zero or more quality blocks.

7.4.1.6.2 Number of quality blocks

The first byte is mandatory and shall contain the number of blocks of quality information of the overall finger pattern skeletal data. Subsequent 5-byte blocks shall contain the specific quality/vendor/algorithm information for each quality/vendor/algorithm evaluation. A value of zero (0) means that no attempt was made to assign a quality score. In this case, no Quality Blocks are present.

7.4.1.6.3 Quality score

Quality score, as defined in ISO/IEC 29794-1, shall be a quantitative expression of the predicted verification performance of the biometric sample. Valid values for Quality Score are integers between 0 and 100, where higher values indicate better quality. A value of 255 is to handle a special case. An entry of 255 shall indicate a failed attempt to calculate a quality score. Multiple quality scores calculated by the same algorithm (same vendor identifier and Quality Algorithm identifier) shall not be present in a single representation.

7.4.1.6.4 Quality algorithm vendor identifier

To enable the recipient of the quality score to differentiate between quality scores generated by different algorithms, the provider of quality scores shall be uniquely identified by the next two bytes. This Vendor identifier shall be registered with the International Biometrics Industry Association (IBIA).

7.4.1.6.5 Quality algorithm identifier

The remaining two bytes shall specify an integer product code assigned by the vendor of the Quality Algorithm ID. It indicates which of the vendor's algorithms (and version) was used in the calculation of the quality score and must be within the range of 1 to 65535.

7.4.1.7 Capture device certifications

7.4.1.7.1 General

The multi-byte certification record contains information to indicate the compliant certification procedures that were used to test the biometric capture equipment used. If the certification flag in the general header has a value of 00_{HEX}, no capture device certification information shall be present in any of the representation header records for that finger pattern skeletal record.

7.4.1.7.2 Number of certifications

The first byte is mandatory and shall contain the number of successful certifications for the capture device. This byte is followed by 3-byte blocks containing certification information. A value of 00_{HEX} in this first byte shall indicate that this capture device has not been certified and no certification blocks follow.

7.4.1.7.3 Certification authority identifier

Certification authority identifier shall be encoded in two bytes. Certification Authority is the agency that certifies a device according to a particular capture device quality specification. Certification authority identifier shall be registered by the IBIA or other approved registration authority.

7.4.1.7.4 Certification scheme identifier

This last byte of the certification block shall identify a certification scheme used to certify the capture device. A list of current certification scheme identifiers is contained in Table 3.

Table 3 — Identifiers for certification schemes specified in Annexes to this part of ISO/IEC 19794

Certification scheme identifier	Normative reference (Title of Annex or of standard)
01 _{HEX}	Annex B.1 Image quality specification for AFIS systems
02 _{HEX}	Annex B.2 Image quality specification for personal verification
03 _{HEX}	Annex B.3 Requirements and test procedures for optical fingerprint scanners

7.4.1.8 Finger position

The finger position code shown on Table 4 shall be recorded in one byte. The codes for this byte shall be as defined in Table 5 of ANSI/NIST-ITL 1-2007, "Data format for the interchange of fingerprint, facial, & other biometric information". This table is reproduced here in Table 2 for convenience. Only codes 0 through 10 shall be used, the "plain" codes included in Table 5 of ANSI/NIST ITL 1-2007 are not relevant for this part of ISO/IEC 19794.

Table 4 — Finger position codes

Finger position	Code
Unknown finger	0
Right thumb	1
Right index finger	2
Right middle finger	3
Right ring finger	4
Right little finger	5
Left thumb	6
Left index finger	7
Left middle finger	8
Left ring finger	9
Left little finger	10

7.4.1.9 Representation number

If more than one finger pattern record in a general record is from the same finger, each pattern record shall have a unique representation number. The combination of finger location and representation number shall uniquely identify a particular pattern record within a general record. Multiple finger pattern records from the same finger shall be numbered with increasing representation numbers, beginning with zero. Where only one finger pattern record is taken from each finger, this field shall be set to 0. The representation number shall be recorded in one byte.

7.4.1.10 Resolution of scaled image

The resolution (in ppcm) of the scaled finger image(s) shall be uniform in the x and y-directions and shall be stored in 1 byte.

7.4.1.11 Impression type

The impression type of the finger images that the finger pattern skeletal data was derived from shall be recorded in one byte. The codes for this byte are shown in Table 5. These codes are derived from Table 11 of ANSI/NIST-ITL 1-2007, "Data format for the interchange of fingerprint, facial, & other biometric information". The "swipe" type identifies data records derived from image streams generated by sliding the finger across a small sensor. Only codes 0 through 3, 8, 24 and 28 through 29 shall be used; the "latent" and "palm" codes are not relevant for this part of ISO/IEC 19794.

Table 5 — Impression type codes

Description	Code
Live-scan plain	0
Live-scan rolled	1
Nonlive-scan plain	2
Nonlive-scan rolled	3
<i>Latent impression</i>	4
<i>Latent tracing</i>	5
<i>Latent photo</i>	6
<i>Latent lift</i>	7
Live-scan swipe	8
Vertical roll	9

Reserved by SC37	10 to 23
Live-scan optical contactless plain	24
Reserved by SC37	25 to 27
Other	28
Unknown	29

7.4.1.12 Size of skeleton image in x direction

The size of the skeleton image in pixels in the x direction shall be contained in 2 bytes.

7.4.1.13 Size of skeleton image in y direction

The size of the skeleton image in pixels in the y direction shall be contained in 2 bytes.

7.4.1.14 Bit-depth of direction code start and stop point coordinates

The bit-depth used to represent the x and y-coordinate of the starting and ending point in the direction code description of the skeleton shall be recorded in 1 byte.

7.4.1.15 Bit-depth of direction code start and stop direction

The bit-depth used to represent the direction of the starting and ending point in the direction code description of the skeleton shall be recorded in 1 byte.

7.4.1.16 Bit-depth of direction in direction code

The bit-depth used to represent the direction in the direction code shall be recorded in 1 byte.

7.4.1.17 Step size of direction code

The maximal step size S_s in the current direction of each direction code step shall be recorded in 1 byte.

7.4.1.18 Relative perpendicular step size of direction code

The relative perpendicular step size $\text{floor}(256 \times S_p/S_s)$ of the direction code shall be recorded in 1 byte.

7.4.1.19 Number of directions on 180°

The angular resolution of the direction code is stored as the number N_π of directions on 180° and shall be recorded in 1 byte.

7.4.1.20 Length of finger pattern skeletal data block

The length (in bytes) of the finger pattern skeletal data block recorded for the finger shall be recorded in two bytes. The length provided includes any padding bits necessary to complete the last byte of finger pattern skeletal data.

7.4.2 Finger pattern skeletal data block

The finger pattern skeletal data block for a single finger has two parts: the finger pattern skeletal data and the skeleton line neighbourhood index data. Each part is recorded together with a length descriptor as follows.

7.4.2.1 Length of finger pattern skeletal data

The length (in bytes) of the finger pattern skeletal data shall be recorded in two bytes. The length provided includes any padding bits necessary to complete the last byte of finger pattern skeletal data.

7.4.2.2 Finger pattern skeletal data

The finger pattern skeletal data for a single finger shall be recorded as defined in Clauses 6.1 and 6.2.

7.4.2.3 Length of skeleton line neighbourhood index data

The length (in bytes) of the skeleton line neighbourhood index data shall be recorded in two bytes. The length provided includes any padding bits necessary to complete the last byte of finger pattern skeletal data.

7.4.2.4 Skeleton line neighbourhood index data

The skeleton line neighbourhood index data for a single finger shall be recorded as defined in Clause 6.3.

7.5 Extended data

The extended data area of the finger pattern skeletal data record is open to placing additional data that may be used by the comparison equipment. The size of this area shall be kept as small as possible, augmenting the data stored in this part of ISO/IEC 19794 pattern skeletal data area. The extended data for each finger representation shall immediately follow this part of ISO/IEC 19794 pattern skeletal data for that finger representation and shall begin with the extended data block length. More than one extended data area may be present for each finger and the extended data block length will be the summation of the lengths of each extended data area. The data block length is used as a signal for the existence of the extended data while the individual extended data length fields are used as indices to parse the extended data. Note that the extended data area cannot be used alone, without this part of ISO/IEC 19794 portion of the pattern skeletal data record.

While the extended data area allows for inclusion of proprietary data within the pattern skeletal format, this is not intended to allow for alternate representations of data that can be represented in open manner as defined in this part of ISO/IEC 19794. In particular, ridge count data, core and delta data, zonal quality information or sweat pore positions shall not be represented in proprietary manner to the exclusion of the publicly defined formats in this part of ISO/IEC 19794. Additional ridge count, core and delta, zonal quality information or sweat pore positions may be placed in a proprietary extended data area if this part of ISO/IEC 19794 fields defined below are also populated. The intention of this part of ISO/IEC 19794 is to provide interoperability.

7.5.1 Common extended data fields

7.5.1.1 Extended data block length

All pattern skeletal data records shall contain the extended data block length. This field will signify the existence of extended data, and shall be recorded in 2 bytes. A value of all zeros (0000_{HEX} hexadecimal) will indicate that there is no extended data and that the file will end or continue with the next finger representation. A nonzero value will indicate the length of all extended data starting with the next byte.

7.5.1.2 Extended data area type code

The extended data area type code shall be recorded in two bytes, and shall distinguish the format of the extended data area as defined by the Vendor specified by the CBEFF_BDB_product_owner and CBEFF_BDB_product_type in the CBEFF header. A value of zero in both bytes is a reserved value and shall not be used. A value of zero in the first byte, followed by a non-zero value in the second byte, shall indicate that the extended data area has a format defined in this part of ISO/IEC 19794. A non-zero value in the first byte shall indicate a vendor specified format, with a code maintained by the vendor. Refer to Table 6 for a summary of the extended data area type codes. If the extended data block length (7.5.1.1) for the finger representation is zero, indicating no extended data, this field shall not be present.

NOTE If vendor defined extended data is present and the Standard Biometric Header (SBH) does not support CBEFF_BDB_product_owner and CBEFF_BDB_product_type, then the link between the extended data and the vendor will be lost.

Table 6 — Extended data area type codes

First byte	Second byte	Identification
00 _{HEX}	00 _{HEX}	Reserved by ISO/IEC JTC1 SC37
00 _{HEX}	01 _{HEX}	ridge count data (Clause 7.5.2)
00 _{HEX}	02 _{HEX}	core and delta data (Clause 7.5.3)
00 _{HEX}	03 _{HEX}	zonal quality data (Clause 7.5.4)
00 _{HEX}	04 _{HEX}	sweat pore position data (Clause 7.5.5)
00 _{HEX}	05 _{HEX}	skeleton structural data (Clause 7.5.6)
00 _{HEX}	06 _{HEX} -FF _{HEX}	Reserved by ISO/IEC JTC1 SC37
01 _{HEX} -FF _{HEX}	00 _{HEX}	Reserved by ISO/IEC JTC1 SC37
01 _{HEX} -FF _{HEX}	01 _{HEX} -FF _{HEX}	vendor-defined extended data

7.5.1.3 Extended data area length

The length of the extended data area, including the extended data area type code and length of data fields, shall be recorded in two bytes. This value is used to skip to the next extended data if the comparison algorithm cannot decode and use this data. If the extended data block length (7.5.1.1) for the finger representation is zero, indicating no extended data, this field shall not be present.

7.5.1.4 Extended data area

The extended data area field of the extended data block is defined by the equipment that is generating the finger pattern skeletal data record, or by common extended data formats contained in this part of ISO/IEC 19794; see Clauses 7.5.2, 7.5.3, 7.5.4, 7.5.5 and 7.5.6. If the extended data block length (7.5.1.1) for the finger representation is zero, indicating no extended data, this field shall not be present.

7.5.2 Ridge count data format

If the extended data area type code is 0001_{HEX}, the extended data area contains ridge count information. This format is provided to contain optional information about the number of fingerprint ridges between pairs of minutiae points. Each ridge count is associated with a pair of minutiae points contained in the finger pattern skeletal data area defined in Clause 7.4.2; no ridge information may be contained that is associated with minutiae not included in the corresponding skeletal data area. Ridge counts shall not include the ridges represented by either of the associated minutiae points. Refer to Figure 6 for clarification; the ridge count between minutiae A and B is 1, while the ridge count between minutiae B and C is 2.

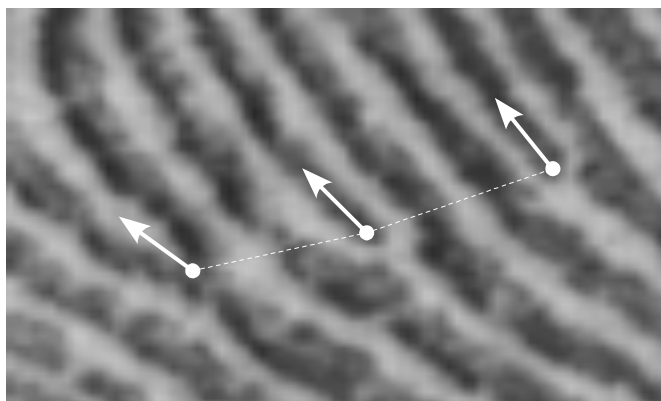


Figure 6 — Example ridge count data. Note the difference of the minutiae positions to ISO/IEC 19794-2 as mentioned in 6.1.4

7.5.2.1 Ridge count extraction method

The ridge count data area shall begin with a single byte indicating the ridge count extraction method. Ridge counts associated with a particular centre minutiae point are frequently extracted in one of two ways: by extracting the ridge count to the nearest neighbouring minutiae in each of four angular regions (or quadrants), or by extracting the ridge count to the nearest neighbouring minutiae in each of eight angular regions (or octants). The ridge count extraction method field shall indicate the extraction method used, as shown in Table 7.

Table 7 — Ridge count extraction method codes

RCE method field value	Extraction method	Comments
00 _{HEX}	Non-specific	No assumption shall be made about the method used to extract ridge counts, nor their order in the record; in particular, the counts may not be between nearest-neighbour minutiae
01 _{HEX}	Four-neighbour (quadrants)	For each centre minutiae used, ridge count data was extracted to the nearest neighbouring minutiae in four quadrants, and ridge counts for each centre minutiae are listed together
02 _{HEX}	Eight-neighbour (octants)	For each centre minutiae used, ridge count data was extracted to the nearest neighbouring minutiae in eight octants, and ridge counts for each centre minutiae are listed together

If either of these specific extraction methods are used, the ridge counts shall be listed in the following way:

- all ridge counts for a particular centre minutiae point shall be listed together;
- the centre minutiae point shall be the first minutiae point references in the three-byte ridge count data;
- if a given quadrant or octant has no neighbouring minutiae in it, a ridge count field shall be recorded with both the minutiae index and the ridge count fields set to zero (so that, for each centre minutiae, there shall always be four ridge counts recorded for the quadrant method and eight ridge counts recorded for the octant method);
- no assumption shall be made regarding the order of the neighbouring minutiae.

7.5.2.2 Ridge count data

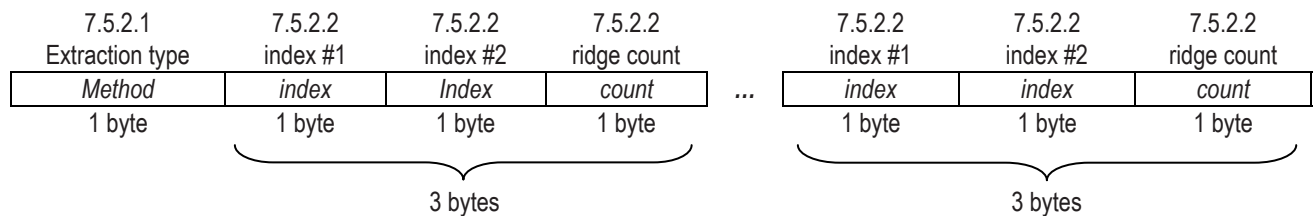
The ridge count data shall be represented by a list of three-byte elements. The first and second bytes are an index number, indicating which minutiae in the corresponding finger pattern skeletal data are being considered. The third byte is a count of the ridges intersected by a direct line between these two minutiae.

If a given quadrant or octant has no neighboring minutiae in it, a ridge count data three-byte element shall be recorded with the first minutia index field set to the central minutia index number, the second minutia index field set to 255 and the ridge count field set to 255. For each central minutia, there shall always be four ridge counts recorded for the quadrant method and eight ridge counts recorded for the octant method.

The ridge count data shall be listed in increasing order of the index numbers. There is no requirement that the ridge counts be listed with the lowest index number first. Since the minutiae are not listed in any specified geometric order, no assumption shall be made about the geometric relationships of the various ridge count items.

7.5.2.3 Ridge count format summary

The ridge count data format shall be as follows:



7.5.3 Core and delta data format

If the extended data area type code is 0002_{HEX}, the extended data area contains core and delta information. This format is provided to contain optional information about the placement and characteristics of the cores and deltas on the original fingerprint image. Core and delta points are determined by the overall pattern of ridges in the fingerprint. There may be zero or more core points and zero or more delta points for any fingerprint. Core and delta points may or may not include angular information.

The core and delta information shall be represented as follows. The first byte shall contain the number of core points included; valid values are 0 to 15.

7.5.3.1 Number of cores

The number of core points represented shall be recorded in the least significant four bits of this byte. Valid values are from 0 to 15. The most significant four bits of this byte shall be reserved by ISO/IEC JTC1 SC37 for future revision of this specification. For version 2.0 of this part of ISO/IEC 19794, these bit values shall be set to 0.

7.5.3.2 Core information type

The core information type shall be recorded in the two most significant bits of the two bytes of the x coordinate of the core position. The bits "01" will indicate that the core has angular information while "00" will indicate that no angular information is relevant for the core type. If this field is "00", then the angle field shall not be present for this core.

7.5.3.3 Core position

If there are ridge endings enclosed by the innermost recurving ridgeline, the ending nearest to the maximal curvature of the recurving ridgeline defines the core position. If the core is a u-turn of a ridgeline not enclosing ridge endings, the valley end defines the core position.

The x coordinate of the core shall be recorded in the least significant fourteen bits of the first two bytes (fourteen bits). The y coordinate shall be placed in the least significant fourteen bits of the following two bytes. The most significant two bits of these two bytes shall be reserved by ISO/IEC JTC1 SC37 for future revision of this specification. For version 1.0 of this part of ISO/IEC 19794, these bit values shall be set to 0. The coordinates shall be expressed in pixels at the resolution indicated in the general header.

7.5.3.4 Core angle

If the core has a discernible angle of direction it shall be recorded in the core information, since this characterises the type of core. The core has a direction if there is a ridge or a group of ridges pointing towards it. The angle of a core is defined by the angle of the tangent to these ridge lines as close as possible to the core position. The tangent is pointing to the open side of the U-structured ridge.

The angle of the core shall be recorded in one byte in units of 1,40625 (360/256) degrees. The core angle is measured increasing counter-clockwise starting from the horizontal axis to the right. The value shall be a non-negative value between 0 and 255, inclusive. For example, an angle value of 16 represents 22,5 degrees. If the core information type is zero (see Clause 7.5.3.2), then this field shall not be present for this core.

7.5.3.5 Number of deltas

The number of delta points represented shall be recorded in the least significant four bits of this byte. Valid values are from 0 to 15. The most significant four bits of this byte shall be reserved by ISO/IEC JTC1 SC37 for future revision of this specification. For version 1.0 of this part of ISO/IEC 19794, these bit values shall be set to 0.

7.5.3.6 Delta information type

The delta information type shall be recorded in the two most significant bits of the two bytes of the x coordinate of the delta position. The bits "01" will indicate that the delta has angular information while "00" will indicate that no angular information is relevant for the delta type. If this field is "00", then the angle fields shall not be present for this delta.

7.5.3.7 Delta position

For a delta there are three points of divergences each placed between the two ridges at the location where the ridges begin to diverge; that is, where the ridges that have been parallel or nearly parallel begin to spread apart as they approach the delta. The position of the delta is defined by the spatial mean of these three points.

The x coordinate of the delta shall be recorded in the least significant fourteen bits of the first two bytes (fourteen bits). The y coordinate shall be placed in the least significant fourteen bits of the following two bytes. The most significant two bits of these two bytes shall be reserved by ISO/IEC JTC1 SC37 for future revision of this specification. For version 1.0 of this part of ISO/IEC 19794, these bit values shall be set to 0. The coordinates shall be expressed in pixels at the resolution indicated in the general header.

7.5.3.8 Delta angles

For all observable divergences the angle is defined by the direction of the tangent before the pair of ridges begins to diverge. The angle shall point from divergent towards parallel lines; that is, the angles shall point outwards from the delta.

The three angle attributes of the delta shall each be recorded in one byte in units of 1,40625 (360/256) degrees. The delta angle is measured increasing counter-clockwise starting from the horizontal axis to the