INTERNATIONAL STANDARD

# ISO/IEC 19794-8

Second edition
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# 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
ISO/IEC 19794-8:2011(E)

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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.



 

# Information technology — Biometric data interchange formats —

# Part 8: Finger pattern skeletal data



## 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 asssertions 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.

## 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.

## 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-bitvalue 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).

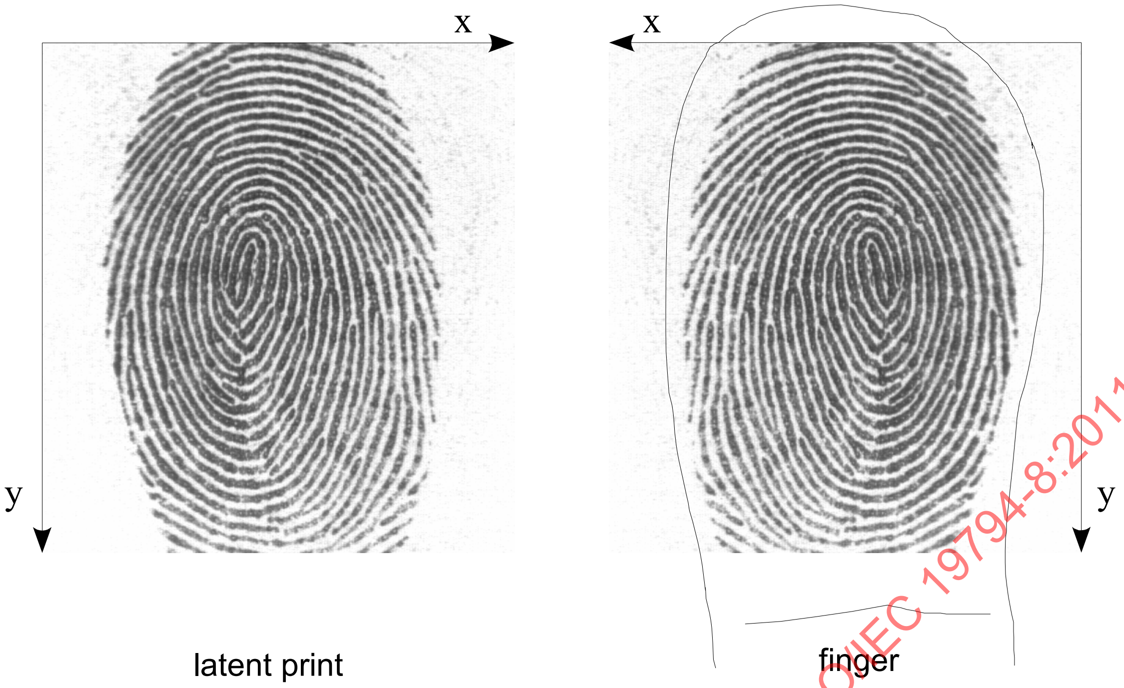


**Figure 1 — Coordinate system**

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° per least significant bit. A resolution below the recommended 64 directions (5,625°)(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…0 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° to +39,375°;

— 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;

— minutia 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 minutia on the line element follows:

— the relative minutia position $l/S_n$ is scaled to the range 0-3 via min(3, 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 minutia, and $S_n$ the step length of the last line element (Figure 2).

— If the skeleton line ends at a true minutia (type number 01 or 10) or is interrupted by a virtual continuation (type number 11) a byte-aligned minutia description follows. In order to keep the alignment overhead small it is done in the following manner: If the previously stored minutia type of the line end is already starting byte aligned, the minutia 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 minutia 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.

— 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).

If the ending minutia 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.



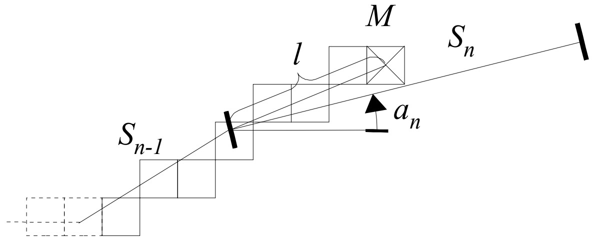


**Figure 2 — The relative minutia position on a polygon line element is the ratio $l/S_n$, where $S_n$ is the length of the line element passing the minutia $M$ and $l$ is the distance between the start of $S_n$ and minutia $M$. $\alpha_n$ is the angle of $S_n$.**

### 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 $\alpha_i$ 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.

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 finger than the spatial resolution of the minutiae.

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.

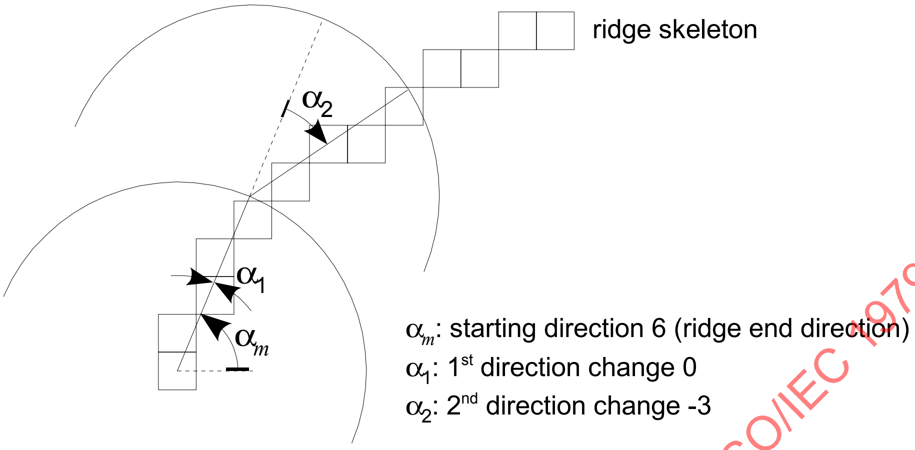


**Figure 3 — The direction encoding starting from a skeleton end point. A bit-depth of 4 is used for direction change**

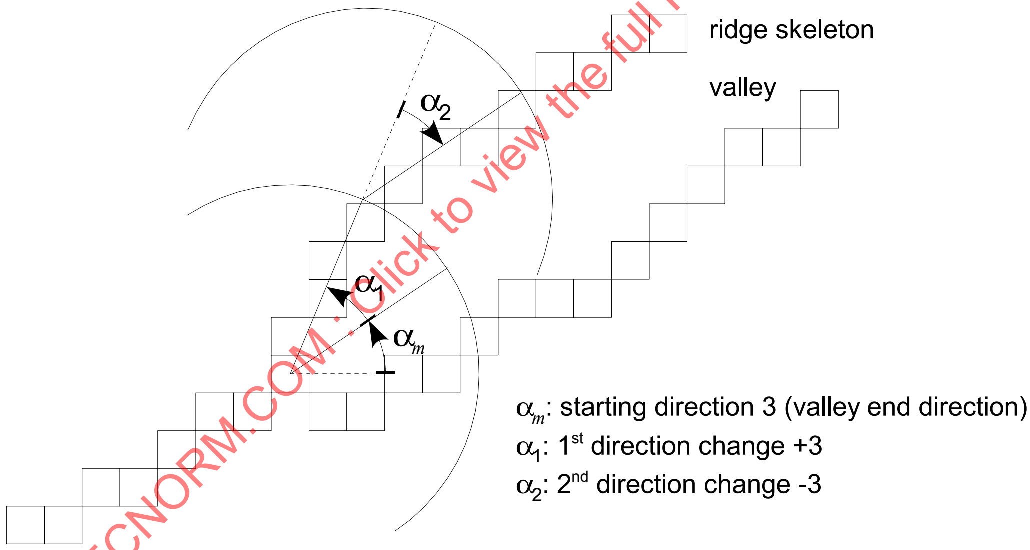


**Figure 4 — The direction encoding starting from a skeleton bifurcation point. A bit-depth of 4 is used for direction change**

### 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, $N_\pi$, on $\pi$ or 180°. This gives the angular resolution, e. g. with $N_\pi$ = 32 the resolution is 5,625°.



 

— 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

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

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

— 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, $\alpha_n$, is constant: $|\alpha_i - \alpha_{i\pm1}|$ = 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: $|\vec{r}_i - \vec{r}_{i\pm1}|$ = 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:

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

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

$$\alpha_i = 180°\, i / N_\pi \qquad (3)$$

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

— $N_\pi$ is the number of directions on $\pi$ 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 $R = 180°\, r_{min} / (\pi\, \alpha_{max})$. With $S_s = 16$, $S_p = 3{,}75$, and $\alpha_{max} = 39{,}375°$, 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 minutia.

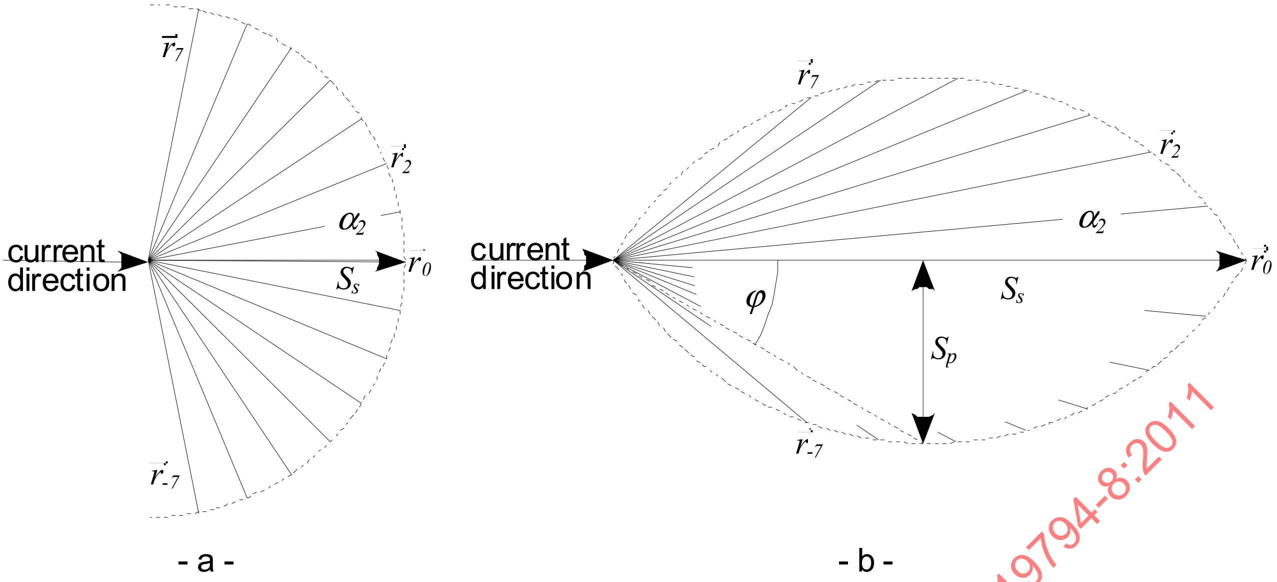


**Figure 5 — Step length dependency of direction change**
**(a) with $S_p$ = 0 a constant step length is used, here at a angular resolution of 11,25°**
**(b) with $S_p$ > 0 the steps at small bending angles are increased while steps at large bending angles are short. Here again 15 directions are encoded at higher angular example resolution of 5,625°**



## 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 interupted 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 interupted 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 sequencial 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:

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

 

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 usefull to list a neighourhood 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:

$$L\text{-}A_1,\ A_1\text{-}A_2,\ \ldots,\ A_{n-1}\text{-}A_n, \qquad (4)$$

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 |
| General Header | 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. |
| General Header | Length of total record in bytes | 4 bytes | | |
| General Header | Number of finger representations in record | 2 bytes | 1 to 255 | |
| General Header | Certification flag | 1 bytes | | 00 HEX no representation contains a certification record<br>01 HEX all representations contain a certification record |
| | | | | |
| Representation Body (one per representation) / Representation Header (one per representation) | Representation length | 4 bytes | | The representation-length field denotes the length in bytes of the representation including the representation header fields. |
| Representation Body / Representation Header | 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. |
| Representation Body / Representation Header | Capture device technology identifier | 1 byte | 0 to 20 | Table 2 |
| Representation Body / Representation Header | Capture device vendor identifier | 2 bytes | 0000 HEX to FFFF HEX | Identifier registered with IBIA |
| Representation Body / Representation Header | Capture device type identifier | 2 bytes | 0000 HEX to FFFF HEX | Vendor specified |
| Representation Body / Representation Header | 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.<br>A value of zero (0) means that no attempt was made to assign a quality score. In this case, no Quality Blocks are present. |
| Representation Body / Representation Header / Quality block | Quality score | 1 byte | 0 to 100, 255 | 0: lowest<br>100: highest<br>255: failed attempt to assign a quality score |
| Representation Body / Representation Header / Quality block | Quality algorithm vendor identifier | 2 bytes | 0000 HEX to FFFF HEX | |
| Representation Body / Representation Header / Quality block | Quality algorithm identifier | 2 bytes | 0000 HEX to FFFF HEX | |
| Representation Body / Representation Header | 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<br>to FFFF HEX | |
| | Certification record | Certification scheme identifier | 1 byte | 00 HEX<br>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 × $S_p/S_s$ | 1 byte | 0 to 255 | Recommended 60 |
| | | Relative perpendicular step size 256 × $S_p/S$ | 1 byte | 0 to 255 | Recommended 60 |
| | | $_s$Number $N_\pi$ 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<br>to FF HEX | only present if extended data block length ≠ 0<br>*Each extended data area may contain vendor-specific data, or one or more of the following (in any order):*<br>— *Ridge count data,*<br>— *Core and delta data*<br>— *Zone quality data*<br>— *Sweat pore position data*<br>— *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<br>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 |
| *Latent impression* | *4* |
| *Latent tracing* | *5* |
| *Latent photo* | *6* |
| *Latent lift* | *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 floor(256 × $S_p/S_s$) 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 $N_\pi$ 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.

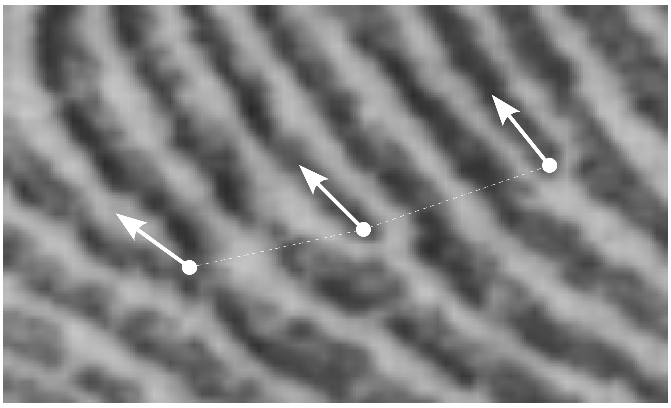

**Figure 6 — Example ridge count data. Note the difference of the minutiae positions to ISO/IEC 19794-2 as mentioned in 6.1.4**

#### 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:

| 7.5.2.1 Extraction type | 7.5.2.2 index #1 | 7.5.2.2 index #2 | 7.5.2.2 ridge count | | 7.5.2.2 index #1 | 7.5.2.2 index #2 | 7.5.2.2 ridge count |
|---|---|---|---|---|---|---|---|
| *Method* | *index* | *Index* | *count* | … | *index* | *index* | *count* |
| 1 byte | 1 byte | 1 byte | 1 byte | | 1 byte | 1 byte | 1 byte |
| | 3 bytes | | | | 3 bytes | | |

### 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 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 delta information type is zero (see Clause 7.5.3.6), then this field shall not be present. If not all three angles can be extracted from the image because of noise or image cropping, the angle fields affected shall be filled by repeating any of the other angle(s) for the same delta.

#### 7.5.3.9 Core and delta format summary

The core format shall be as follows:

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| | 7.5.3.1 | 7.5.3.2 | 7.5.3.3 | | 7.5.3.3 | 7.5.3.4 | 7.5.3.2, 7.5.3.3 & 7.5.3.4 |
| Reserved | # of cores | Core info type | X location | Reserved | Y location | Core Angle | … |
| Reserved | *# cores* | *Type* | *x coordinate* | *reserved* | *y coordinate* | *angle* | … |
| 4 bits | 4 bits | 2 bits | 14 bits | 2 bits | 14 bits | 1 byte | 5 bytes |
| 1 byte | | 2 bytes | | 2 bytes | | only present if core info type not zero | zero or more additional cores |

The delta format shall be as follows:

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | 7.5.3.5 | 7.5.3.6 | 7.5.3.7 | | 7.5.3.7 | 7.5.3.8 | | | 7.5.3.6, 7.5.3.7 & 7.5.3.8 | | |
| Reserved | # of deltas | Delta info type | X location | Reserved | Y location | Delta Angles | | | … | … | … |
| Reserved | *# deltas* | *Type* | *x coordinate* | *reserved* | *y coordinate* | *ang1* | *ang2* | *ang3* | … | … | … |
| 4 bits | 4 bits | 2 bits | 14 bits | 2 bits | 14 bits | 3 bytes | | | 7 bytes | | |
| 1 byte | | 2 bytes | | 2 bytes | | only present if delta info type not zero | | | zero or more additional deltas | | |

### 7.5.4 Zonal quality data

If the extended data area type code is 0003 HEX, the extended data area contains zonal quality data. This format is provided to contain optional information about the quality of the fingerprint image within each cell in a grid defined on the original fingerprint image. Within each cell, the quality may depend on the presence and clarity of ridges, spatial distortions and other characteristics.

The zonal quality data shall be represented as follows. The first three bytes shall contain the horizontal, the vertical cell sizes in pixels and the bit-depth of the cell quality information. These size bytes shall be followed by the quality indications for each cell. All cells are the same size, with the exception of the final cells in each row and in each column. The final cell in each row and in each column may be less than the stated cell size, if the cell width and height are not factors of the image width and height, respectively.

#### 7.5.4.1 Cell width and height

The number of pixels in cells in the x-direction (horizontal) shall be stored in one byte. Permissible values are 1 to 255. The number of pixels in cells in the y-direction (vertical) shall be stored in one byte. Permissible values are 1 to 255.

#### 7.5.4.2 Cell quality information depth

The bit-depth of the cell quality information shall be contained in one byte. This value will indicate the number of bits per cell used to indicate the quality.



 

#### 7.5.4.3 Cell quality data

The quality of the fingerprint image in each cell shall be represented by one or more bits, as indicated in 7.5.4.2. Quality data for cells shall be stored in usual “raster” order – left to right, then top to bottom. If the finger image within this cell is of good clarity and significant ridge data is present, the cell quality shall be represented by higher values (by the bit value ‘1’ if the information depth is 1). If the cell does not contain significant ridge data, or the ridge pattern within the cell is blurred, broken or otherwise of poor quality, the cell quality shall be represented by lower values (the bit value ‘0’ if the information depth is 1).

The cell quality shall be packed into bytes. The final byte in the cell quality data may be packed with bit values of zero (‘0’) for the least significant bits as required to complete the last byte.

#### 7.5.4.4 Zonal quality data format summary

The zonal quality data format shall be as follows:

| 7.5.4.1<br>Cell Width | 7.5.4.1<br>Cell Height | 7.5.4.2<br>Information Depth | 7.5.4.3<br>Cell Quality Data | |
|---|---|---|---|---|
| *x cell size* | *y cell size* | *depth* | *Cell quality bits* | *00…0* |
| 1 byte | 1 byte | 1 byte | data bits | padding bits |

### 7.5.5 Sweat pore position data

The position, size and shape of sweat pores are unique characteristic features that can enhance pattern and minutiae based verification. A fingerprint image with clearly visible pores is depicted in Figure 7. A fingerprint image may contain as many as 2700 sweat pores. Their size shape and location can be used as features for fingerprint comparison. In this part of ISO/IEC 19794 only the sweat pore position along the skeleton line is encoded. [7]



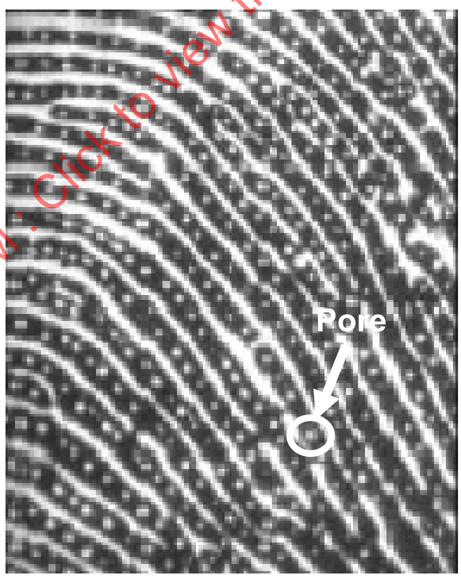


**Figure 7 — Fingerprint fragment with sweat pores (image from [6])**

The encoding of the sweat pore positions starts with a 3 byte header containing the resolution (2 bytes) and the bit-depth of each description element. Then for each skeleton line in 7.4.2 a series of sweat pore distance description elements follows.

#### 7.5.5.1 Sweat pore position resolution

The resolution of the sweat pore position description is stored in 2 bytes. The minimum recommended value is 200 ppcm.

#### 7.5.5.2 Sweat pore distance information depth

The bit-depth of the sweat pore distance elements is stored in one byte. The valid range is 2 to 8 bits, minimum recommended is 4.

#### 7.5.5.3 Sweat pore position description

For each skeleton line in 7.4.2 the sweat pore distance description starts with the value 00…0. A series of sweat pore distance elements describe the position of the sweat pores along the skeleton line. Values 00…1 to 11…0 give the successive distance between sweat pores. The value 11…1 indicates that there is no sweat pore up to the distance 11…0. Thus each element of bit-depth in 7.5.5.2 has a valid distance range from 1 to ($2^{bitdepth}$–2) at the resolution in 7.5.5.1. The final byte in the sweat pore position data shall be packed with bit values of zero (‘0’) for the least significant bits as required to complete the last byte.

#### 7.5.5.4 Sweat pore position format summary

The sweat pore position data format shall be as follows:

| 7.5.5.1<br>Position resolution | 7.5.5.2<br>Information depth | 7.5.5.3<br>Sweat pore position description | |
|---|---|---|---|
| *Resolution [ppcm]* | *Depth* | *Distance elements* | *00…0* |
| 2 bytes | 1 byte | data bits | padding bits |

### 7.5.6 Finger pattern skeleton structural data

For some comparison algorithms it may be useful to follow all ridge lines ending at a real minutia. With the skeleton description to get the ridge near the ending minutiae the whole line has to be reconstructed. To find all ridges starting from a bifurcation the situation is even worse, an extensive search has to be done to find the line passing the bifurcation.

To reconstruct a ridge line in reversed order one needs the direction of the last direction element, the step length of the last step and the resolution level (6.2.1).

To know the line passing a bifurcation, the line number is needed. To reconstruct this line starting at the bifurcation the exact position of the minutia on this line, the direction of the corresponding element and the resolution level (6.2.1) have to be provided.

The skeleton structural data starts with the bit-depth necessary to store the line index. This bit-depth is stored in one byte and has the range from 4 to 16. The structural information following has the same order as the real minutiae in the skeleton data and it is stored in a data packed compacted bit form with no record separators or field tags.

For real minutiae at the end of a skeleton line the following data is stored:

— Type of the structural data element, here 0 for line end information. This value is stored with a bit-depth of 1.

— Direction of the last polygon line element ($\alpha_n$ in Figure 2) with the same angular resolution as the direction elements in direction code ($N_\pi/\pi$) and a bit-depth necessary to store $2N_\pi$–1.

— Relative position of the minutia on line element min($S_s$–1, floor($S_s l/S_n$)), where $l$ is the distance between the start of the last line element and the minutia and $S_n$ the step length of the last line element, see Figure 2. This value is stored with a bit-depth necessary to store $S_s$–1.

— Resolution level with the values 0 for normal 1 for high resolution. This value isstored with a bit-depth of 1.

For each bifurcation store:

— Type of the structural data element, here 1 for information about a bifurcation. This value is stored with a bit-depth of 1.

— Line number, starting with index origin 0. This value is stored with a bit of 8.

— Line element number, starting with index origin 0. The bit-depth for this value is defined in the first byte of the skeleton structural data.

— Direction of the polygon line element passing the bifurcation ($\alpha_n$ in Figure 2) with the same angular resolution as the direction elements in direction code ($N_\pi/\pi$) and a bit-depth necessary to store $2N_\pi$–1.

— Relative position of the bifurcation on line element min($S_s$–1, floor($S_s l/S_n$)), where $l$ is the distance between the start of the last line element passing the bifurcation and the minutia and $S_n$ the step length of the last line element, see Figure 2. This value is stored with a bit-depth necessary to store $S_s$–1.

— Resolution level with the values 0 for normal 1 for high resolution. This value is stored with a bit-depth of 1.

Where $S_s$ is the step length for going straight and $N_\pi$ is the number of directions on π or 180° (6.2.4), both defined in the general header.

A minutia of type 'ridge ending' encoded at the beginning of a skeleton line has no entry in the skeleton structural data. For a minutia of type 'ridge ending' encoded at the end of the skeleton line the line end information is stored (type 0). For a minutia of type 'ridge bifurcation' encoded at the beginning of a skeleton line the bifurcation information (type 1) is stored. For a minutia of type 'ridge bifurcation' encoded at the end of a skeleton line, first store the line end information (type 0) followed by the bifurcation information (type 1).

#### 7.5.6.1 Finger pattern skeleton structural data format summary

The finger pattern skeleton structural data format shall be as follows:

| Index depth | | Type line end | Direction | Realtive position | Resolution level | … |
|---|---|---|---|---|---|---|
| *depth $N_{idx}$* | … | *0* | *direction* | *position* | *level* | … |
| 1 byte | … | 1 bit | $N_d$ bits | $N_p$ bits | 1 bit | … |
| | … | For each real minutiae at the end of a skeleton line | | | | … |

| … | Type bifurcation | Line number | Element number | Direction | Relative position | Resolution level | … |
|---|---|---|---|---|---|---|---|
| … | *1* | *number* | *Number* | *direction* | *position* | *level* | … |
| … | 1 bit | 8 bits | $N_{idx}$ bits | $N_d$ bits | $N_p$ bits | 1 bit | … |
| … | For each bifurcation | | | | | | … |

| … | |
|---|---|
| … | *00…0* |
| … | padding bits |
| … | |

Where

— $N_d$ is the bit-depth necessary to store $2N_\pi$–1, e.g. with $N_\pi$=32 gives $N_d$ = 6 bit.

— $N_p$ is the bit-depth necessary to store $S_s$–1, e.g. with $S_s$ = 16 gives $N_p$ = 4 bit.

— $N_{idx}$ is the bit-depth necessary to store the line index. This number is given with the first byte of the structural data.

## 8 Finger pattern skeletal data card format

This part of ISO/IEC 19794 defines two card related encoding formats for finger pattern skeletal data, the normal size format and the compact size format. Such a format may be used e.g. as part of a Biometric Information Template as specified in ISO/IEC 7816-11 with incorporated CBEFF data objects, if off-card comparison is applied, or in the command data field of a VERIFY command, if comparison-on-card (CoC) is applied (see ISO/IEC 7816-4 and -11).

The two card formats represent two sets of fixed parameters (see 8.1 and 8.2). These fixed values are not included in the card format.

NOTE 1 For the record format these parameters are set in the representation header (7.3).

The finger pattern skeletal data card format consists of the finger pattern skeletal data block as defined in Clause 8.3 and optionally additional features (see Clause 8.5).

NOTE 2 The term “card” is used for smartcards as well as for other kind of tokens.

### 8.1 Normal size finger pattern skeletal format

For the normal size format most of the header entries for the record format get fixed to the following values:

| | |
|---|---|
| — Resolution of direction code start and stop point | 200 ppcm |
| — Bit-depth of direction code start and stop point in x | 11 |
| — Bit-depth of direction code start and stop point in y | 11 |
| — Bit-depth of direction code start and stop direction | 8 |
| — Bit-depth of direction in direction code | 4 |
| — Step size $S_s$ of direction code | 24 |
| — Relative perpendicular step size 256 × $S_p/S_s$ | 60 |
| — Number $N_\pi$ of directions on 180° | 32 |

### 8.2 Compact size finger pattern skeletal format

For the compact size format most of the header entries for the record format get fixed to the following values:

| | |
|---|---|
| — Resolution of direction code start and stop point | 100 ppcm |
| — Bit-depth of direction code start and stop point in x | 8 |
| — Bit-depth of direction code start and stop point in y | 8 |
| — Bit-depth of direction code start and stop direction | 6 |
| — Bit-depth of direction in direction code | 4 |
| — Step size $S_s$ of direction code | 16 |

— Relative perpendicular step size 256 × $S_p/S_s$ 60

— Number $N_\pi$ of directions on 180° 32

## 8.3 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.

### 8.3.1 Skeleton image size in x and y

The skeleton image size in pixels in x is stored in 2 bytes at a resolution of 100 ppcm for the compact and 200 ppcm for the normal format.

The skeleton image size in pixels in y is stored in 2 bytes at a resolution of 100 ppcm for the compact and 200 ppcm for the normal format.

### 8.3.2 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.

### 8.3.3 Finger pattern skeletal data

The finger pattern skeletal data for a single finger shall be encoded as defined in Clauses 6.1 and 6.2 with the definitions of 8.1 respectively. 8.2. If no sorting of the skeleton lines is necessary according to 8.4 their sequence is arbitrary.

### 8.3.4 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.

### 8.3.5 Skeleton line neighbourhood index data

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

## 8.4 The x or y coordinate extension for compact card format

If the x value of the skeleton image size (8.3.1) is greater than 255, the direction code must be sorted. The sorting will be performed according to the ascending x-coordinate of the starting position of the direction code.

If the y value of the skeleton image size (8.3.1) is greater than 255, the direction code must be sorted. The sorting will be performed according to the ascending y-coordinate of the starting position of the direction code.

Only the x or the y-image size, not both, shall exceed the range of 255.

With a bit-depth of 8 bit and resolution of 100 ppcm images of size 2,55 cm × 2,55 cm can be described; covering all available sensors capturing plane impression fingerprint images. For rolled impressions the requirements will be approximately 2,5 cm × 5 cm.

The direction code is sorted by the x-position of its starting point but only the least significant byte of the x coordinate is stored (equal to a mod(256) computation). The card can reconstruct the original sequence of coordinate values by adding 256 to all following entries when a violation of the ascending order occurs. So coordinates with a range of 2,55 cm × infinity can be stored in one byte.



 

Example

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Original sequence: | 60 | 76 | 277 | 333 | 581 | 797 | 860 | 986 | 1000 |
| Stored sequence: | 60 | 76 | 21 | 77 | 69 | 29 | 92 | 219 | 231 |

For each violation of the ascending order add 256 on all following entries:

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| + | 0 | 0 | 256 | 256 | 512 | 768 | 768 | 768 | 768 |
| Reconstructed sequence: | 60 | 76 | 277 | 333 | 581 | 797 | 860 | 986 | 1000 |

The most significant byte of x coordinate of the stop position is reconstructed by following the direction code and adding the displacements of each step.

The same construction principle may be applied also for the y coordinate.

## 8.5 Usage of additional features for the card format

In the card format other features beyond the finger skeletal data may be present. In this case the usage of the biometric data template (tag '7F2E' ) as described in ISO/IEC 7816-11 and defined in ISO/IEC 7816-6 is mandatory. Table 8 shows the biometric data template with its embedded data objects. If proprietary data are appended, then the biometric data in standardized format (DOs with tag '90' – '93') shall be encapsulated in the DO with tag 'A1'.

**Table 8 — Biometric data template**

| **Tag** | **Length** | **Value** | | | **Presence** |
|---|---|---|---|---|---|
| '7F2E' | Variable | Biometric data template | | | |
| | | **Tag** | **Length** | **Value** | |
| | | '90' | variable | Finger skeletal data according to 8.1 or 8.2, dependent on the indicated format owner/format type | mandatory |
| | | '91' | variable | Ridge cont data according to 7.5.2 | optional |
| | | '92' | variable | Core point data according to 7.5.3 | optional |
| | | '93' | variable | Delta point data according to 7.5.3 | optional |
| | | '94' | variable | Cell quality data according to 7.5.4 | optional |
| | | '95' | variable | Sweat pore position data according 7.5.5 | optional |
| | | '96' | variable | Skeleton structural data to 7.5.6 | optional |
| | | '81'/'A1' | variable | Biometric data with standardized format, see note | optional |
| | | '82'/'A2' | variable | Biometric data with proprietary format | optional |
| NOTE | If the DO with tag '81' is used, then the data according to 8.1 or 8.2 follow without encapsulation. | | | | |

## 8.6 Comparison parameters and card capabilities

Biometric comparison algorithm parameters are used to indicate implementation specific values to be observed by the outside world when computing and structuring the biometric verification data. They can be encoded as DOs embedded in a biometric comparison parameter template as defined in ISO/IEC 19785-1 (see Annex related to smartcards, Table 1).

The comparison parameters and card capabilities for the pattern skeletal format are the maximal data size and the feature handling indicator encoded in the DO 'Biometric algorithm parameters' (tag 'B1' within the BIT, see ISO/IEC 7816-11) (see Table 9).

**Table 9 — DO ‘Biometric algorithm parameters’**

| Tag | Length | Value | | |
|---|---|---|---|---|
| ‘B1’ | variable | Biometric algorithm parameters template | | |
| | | **Tag** | **Length** | **Value** |
| | | ‘81’ | 2 | Maximal data size |
| | | ‘83’ | 1 | Feature handling indicator, see Table 10 |

### 8.6.1 Maximal data size

The maximal data size for the skeleton finger description accepted by a specific card is limited e.g. due to buffer restrictions and computing capabilities.

The maximal data size accepted is therefore an implementation dependent value and shall be indicated using the DO ‘Maximal data size’ (tag ‘81’, value field 2 bytes). The nesting of this DO in the DO ‘Biometric algorithm parameters’ is shown in Table 9.

If the length of the finger pattern skeletal data record exceeds the maximum number processible by a card, truncation is necessary. The truncation is a 2 step process. At first, finger skeleton lines of poor quality are eliminated. If still the data length is too large, then truncation shall be made by peeling off skeleton segments from the convex hull of the described area.

For the indication of the maximal data size expected by the card the DO Maximal data size as shown in Table 10 shall be used.

If this DO is not present in the BIT, the maximal data size is unlimited.

### 8.6.2 Indication of card capabilities

If a card with on-card comparison supports one or more of the additional features, then the capabilities shall be indicated using the DO ‘Feature handling indicator’ (tag ‘83’, value field 1 byte). The nesting of this DO ‘ in the DO ‘Biometric algorithm parameters’ is shown in Table 9, the coding is denoted in Table 10.

**Table 10 — Coding of the feature handling indicator**

| b8 | b7 | b6 | b5 | b4 | b3 | b2 | b1 | Meaning |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | 1 | Ridge count supported |
| | | | | | | 1 | | Core points supported |
| | | | | | 1 | | | Delta points supported |
| | | | | 1 | | | | Cell quality supported |
| | | | 1 | | | | | Sweat pore positions supported |
| | | 1 | | | | | | Skeleton structural data supported |
| x | x | | | | | | | RFU (Default: 0) |

## 8.7 Pattern card format summary

Table 11 is a reference for the fields present in the finger pattern skeletal data card 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 11 — Pattern card format summary**

| Field | Size | Values | Notes |
|---|---|---|---|
| Tag | Variable | | Encoded in ASN.1 according Table 8 |
| Length | Variable | | Encoded in ASN.1 |
| | | | |
| Skeleton image size in x | 2 bytes | | in pixels |
| Skeleton image size in y | 2 bytes | | in pixels |
| Length of finger pattern skeletal data | 2 bytes | | in bytes |
| Finger pattern skeletal data | In prev. field | | |
| Length of skeleton line neighbourhood index data | 2 bytes | | In bytes |
| Skeleton line neighbourhood index data | In prev. field | | |

## 9 CBEFF format owner and format types

Format owner and format type are encoded according to CBEFF. The format owner is ISO/IEC JTC 1/SC 37. The IBIA registered format owner id is '0101' Hex ('257' Decimal).

The format type denotes one of the finger pattern skeletal formats according to this part of ISO/IEC 19794, see Table 12.

**Table 12 — Format types**

| CBEFF BDB format type identifier | Short name | Full object identifier |
|---|---|---|
| 17 ($0011_{Hex}$) | finger-pattern-skeletal-data-record | {iso registration-authority cbeff(19785) organization(0) jtc1-sc37(257) bdbs(0) finger-pattern-skeletal-data-record(17)} |
| 18 ($0012_{Hex}$) | finger-pattern-skeletal-data-card-normal | {iso registration-authority cbeff(19785) organization(0) jtc1-sc37(257) bdbs(0) finger-pattern-skeletal-data-card-normal(18)} |
| 19 ($0013_{Hex}$) | finger-pattern-skeletal-data-card-compact | {iso registration-authority cbeff(19785) organization(0) jtc1-sc37(257) bdbs(0) finger-pattern-skeletal-data-card-compact(19)} |

# Annex A
(normative)

# Conformance test methodology

## A.1 Overview

This part of ISO/IEC 19794 specifies a biometric data interchange format for storing, recording, and transmitting one or more Finger pattern skeletal representations. Each representation is accompanied by modality-specific metadata contained in a header record. This annex establishes tests for checking the correctness of the record.

The objective of this part of ISO/IEC 19794 cannot be completely achieved until biometric products can be tested to determine whether they conform to those specifications. Conforming implementations are a necessary prerequisite for achieving interoperability among implementations; therefore there is a need for a standardised conformance testing methodology, test assertions, and test procedures as applicable to specific modalities addressed by each part of ISO/IEC 19794. The test assertions will cover as much as practical of the ISO/IEC 19794 requirements (covering the most critical features), so that the conformity results produced by the test suites will reflect the real degree of conformity of the implementations to ISO/IEC 19794 data interchange format records. This is the motivation for the development of this conformance testing methodology.

This normative annex is intended to specify elements of conformance testing methodology, test assertions, and test procedures as applicable to this part of ISO/IEC 19794. For this edition of this part of ISO/IEC 19794, the content of this annex will be available as a separate document (Amendment), to supplement this part of ISO/IEC 19794.



 

# Annex B
(normative)

# Capture device certifications

## B.1 Image quality specification for AFIS systems

### B.1.1 General

These specifications apply to: (1) systems that scan and capture fingerprints[1] in digital, softcopy form, including hardcopy scanners such as card scanners, and live scan devices, altogether called “fingerprint scanners”; and (2) systems utilizing a printer to print digital fingerprint images to hardcopy called “fingerprint printers.” These specifications provide criteria for ensuring the image quality of fingerprint scanners and printers that input fingerprint images to, or generate fingerprint images from within, an Automated Fingerprint Identification System (AFIS).

Digital softcopy images obtained from fingerprint scanners shall have sufficient quality to allow the following functions to be performed: (l) conclusive fingerprint comparisons (identification or non-identification decision), (2) fingerprint classification, (3) automatic feature detection, and (4) overall AFIS search reliability. The fingerprint comparison process requires a high-fidelity image. Finer detail, such as pores and incipient ridges, are needed because they can play an important role in the comparison.

The fingerprint examiners in AFIS environment will depend upon softcopy-displayed images of scanned fingerprints to make comparisons, but will also need to accept and utilize hardcopy images in certain instances. For example, some contributors may print cards from live scan or card scan systems for submission to an AFIS. These hardcopy prints will be obtained from printers that include printing algorithms optimized for fingerprints. The printer’s principal function is to produce life-size prints of digital fingerprints that provide sufficient print quality to support fingerprint comparisons, *i.e.*, support identification or non-identification decisions.

The image quality requirements for fingerprint scanners are covered in Clauses B.1.2 and B.1.3. The compliance test procedures for these requirements are out of scope of this Annex. An example for a test specification that allows testing of conformance with this image quality specification is available [8].

### B.1.2 Fingerprint scanner

The fingerprint scanner shall be capable of producing images that exhibit good geometric fidelity, sharpness, detail rendition, gray-level uniformity, and gray-scale dynamic range, with low noise characteristics. The images shall be true representations of the input fingerprints without creating any significant artifacts, anomalies, false detail, or cosmetic image restoration effects.

The scanner’s final output spatial sampling rate in both sensor detector row and column directions shall be in the range: (R–0,01R) to (R+0,01R) and shall be gray-level quantized to eight bits per pixel (256 gray-levels). The magnitude of “R” is either 500 pixels per inch (ppi) or 1000 ppi; a scanner may be certified at either one or both of these spatial sampling rate levels. The scanner’s true optical spatial sampling rate shall be greater than or equal to R.

A scanner intended to scan standard 8,0 by 8,0 inch tenprint cards, shall be capable of capturing an area of at least 5,0 by 8,0 inches, which captures all 14 print blocks, either each print block as a separate image or all print blocks together as a single image. In terms of individual print blocks, Table B.1 gives the preferred capture sizes applicable to both card scan and live scan systems, with the exception that, when scanning fingerprint cards, the card form dimensions take precedence.

1 The term “fingerprint” in this appendix may also include palmprint, whole hand print, or a print from other parts of the human body.

**Table B.1 — Preferred capture sizes**

| | Preferred Width (in) | (mm) | Preferred Height (in) | (mm) |
|---|---|---|---|---|
| roll finger | 1,6* | 40,6 | 1,5 | 38,1 |
| plain thumb | 1,0 | 25,4 | 2,0 | 50,8 |
| plain 4-fingers (sequence check) | 3,2 | 81,3 | 2,0 | 50,8 |
| plain 4-fingers (identification flat) | 3,2 | 81,3 | 3,0 | 76,2 |
| full palm | 5,5 | 139,7 | 8,0 | 203,2 |
| half palm | 5,5 | 139,7 | 5,5 | 139,7 |
| writer's palm | 1,75 | 44,5 | 5,0 | 127,0 |

* Live scanner shall be capable of capturing at least 80% of full roll arc length, where full roll arc length is defined as arc length from nail edge to nail edge.



#### B.1.2.1 Linearity

##### B.1.2.1.1 Requirement

When measuring a stepped series of uniform target reflectance patches (*e.g.*, step tablet) that substantially cover the scanner's gray range, the average value of each patch shall be within 7,65 gray-levels of a linear, least squares regression line fitted between target reflectance patch values (independent variable) and scanner output gray-levels (dependent variable).

##### B.1.2.1.2 Background

All targets used in this image quality specification compliance verification are expected to be scanned with the scanner operating in a linear input/output mode. Linearity enables valid comparisons of test measurements with requirements, *e.g.*, a system's spatial frequency response in terms of Modulation Transfer Function is, strictly speaking, a linear systems concept. Linearity also facilitates comparisons between different scanners through the "common ground" concept. In atypical cases, a small amount of smooth, monotonic nonlinearity may be acceptable for the test target scans, *i.e.*, when it is substantially impractical and unrepresentative of operational use, to force linearity on the scanner under test (*e.g.*, some live scan devices). Linearity is not a requirement for the operational or test fingerprint scans, which allows for processing flexibility to overcome inadequate tonal characteristics of fingerprint samples.

#### B.1.2.2 Geometric accuracy

##### B.1.2.2.1 Requirement (across-bar)

When scanning a multiple, parallel bar target, in both vertical bar and horizontal bar orientations, the absolute value of the difference between the actual distance across parallel target bars and the corresponding distance measured in the image shall not exceed the following values for at least 99,0 percent of the tested cases in each print block measurement area and in each of the two orthogonal directions.

For 500-ppi scanner:

$D \leq 0{,}0007$, for $0{,}00 < X \leq 0{,}07$

$D \leq 0{,}01X$, for $0{,}07 \leq X \leq 1{,}50$

for 1000-ppi scanner:

$D \leq 0{,}0005$, for $0{,}00 < X \leq 0{,}07$

$D \leq 0{,}0071X$, for $0{,}07 \leq X \leq 1{,}5$

where:

D = |Y-X|

X = actual target distance

Y = measured image distance

D, X, Y are in inches.

##### B.1.2.2.2 Requirement (along-bar)

When scanning a multiple, parallel bar target, in both vertical bar and horizontal bar orientations, the maximum difference in the horizontal or vertical direction, respectively, between the locations of any two points within a 1,5-inch segment of a given bar image shall not exceed 0,016 inches for at least 99,0 percent of the tested cases in each print block measurement area and in each of the two orthogonal directions.

##### B.1.2.2.3 Background

The phrase: *multiple, parallel bar target* refers to a Ronchi target, which consists of an equal-width bar and space square wave pattern at 1,0 cy/mm, with high contrast ratio and fine edge definition. This target is also used to verify compliance with the scanner spatial sampling rate requirement given in clause B.1.2.

Across-bar geometric accuracy is measured across the imaged Ronchi target bars that substantially cover the total image capture area. The 500-ppi requirement corresponds to a positional accuracy of ± 1,0 percent for distances between 0,07 and 1,5 inches and a constant ± 0,0007 inches (1/3 pixel) for distances less than or equal to 0,07 inches. The 1000-ppi requirement corresponds to a positional accuracy of ± 0,71 percent for distances between 0,07 and 1,5 inches and a constant ± 0,0005 inches (1/2 pixel) for distances less than or equal to 0,07 inches.

This measurement procedure is also used to verify the ppi spatial sampling rate requirement given in clause B.1.2.3.

Along-bar geometric accuracy is measured along the length of an individual Ronchi target bar in the image. For a given horizontal bar, for example, the maximum difference between bar center locations (in vertical direction), determined from bar locations measured at multiple points along a 1,5" bar segment length, is compared to the maximum allowable difference requirement (analogously for vertical bar). This requirement is to ensure that pincushion or barrel distortion over the primary area of interest, *i.e.*, a single fingerprint, is not too large.

#### B.1.2.3 Spatial frequency response

##### B.1.2.3.1 Requirements

The spatial frequency response shall be measured using a continuous tone sine wave target denoted as Modulation Transfer Function (MTF) measurement unless the scanner cannot obtain adequate tonal response from this target, in which case a bi-tonal bar target shall be used to measure the spatial frequency response, denoted as Contrast Transfer Function (CTF) measurement. When measuring the sine wave MTF, it shall meet or exceed the minimum modulation values given in Table B.2 in both the detector row and detector column directions and over any region of the scanner's field of view. When measuring the bar CTF, it shall meet or exceed the minimum modulation values defined by equation 2-1 or equation 2-2 (whichever applies) in both the detector row and detector column directions and over any region of the scanner's field of view. CTF values computed from equations B.1 and B.2 for nominal test frequencies are given in Table B.3.

None of the MTF or CTF modulation values measured at specification spatial frequencies shall exceed 1,05.

The output sine wave image or bar target image shall not exhibit any significant amount of aliasing.

**Table B.2 — MTF Requirement using sine wave target**

| Frequency (cy/mm) | Minimum Modulation for 500 ppi Scanner | Minimum Modulationfor 1000 ppi Scanner | Maximum Modulation |
|---|---|---|---|
| 1 | 0,905 | 0,925 | 1,05 at all frequencies |
| 2 | 0,797 | 0,856 | |
| 3 | 0,694 | 0,791 | |
| 4 | 0,598 | 0,732 | |
| 5 | 0,513 | 0,677 | |
| 6 | 0,437 | 0,626 | |
| 7 | 0,371 | 0,579 | |
| 8 | 0,312 | 0,536 | |
| 9 | 0,255 | 0,495 | |
| 10 | 0,200 | 0,458 | |
| 12 | | 0,392 | |
| 14 | | 0,336 | |
| 16 | | 0,287 | |
| 18 | | 0,246 | |
| 20 | | 0,210 | |

Note: Testing at 7 and 9 cy/mm is not a requirement if these frequency patterns are absent from the sine wave target.

**Table B.3 — CTF Requirement using bar target (nominal test frequencies)**

| Frequency (cy/mm) | Minimum modulation for 500 ppi scanner | Minimum modulation for 1000 ppi scanner | Maximum modulation |
|---|---|---|---|
| 1,0 | 0,948 | 0,957 | 1,05 at all frequencies |
| 2,0 | 0,869 | 0,904 | |
| 3,0 | 0,791 | 0,854 | |
| 4,0 | 0,713 | 0,805 | |
| 5,0 | 0,636 | 0,760 | |
| 6,0 | 0,559 | 0,716 | |
| 7,0 | 0,483 | 0,675 | |
| 8,0 | 0,408 | 0,636 | |
| 9,0 | 0,333 | 0,598 | |
| 10,0 | 0,259 | 0,563 | |
| 12,0 | | 0,497 | |
| 14,0 | | 0,437 | |
| 16,0 | | 0,382 | |
| 18,0 | | 0,332 | |
| 20,0 | | 0,284 | |

Note: Testing at or near 7 and 9 cy/mm is a requirement when using a bar target.

It is not required that the bar target contain the exact frequencies listed in Table B.3; however, the target does need to cover the listed frequency range and contain bar patterns close to each of the listed frequencies. The following equations are used to obtain the specification CTF modulation values when using bar targets that contain frequencies not listed in Table B.3.

500-ppi scanner, for f = 1,0 to 10,0 cy/mm:

$$CTF = 3{,}04105E\text{-}04 * f^2 - 7{,}99095E\text{-}02 * f + 1{,}02774 \qquad \text{(eq.B.1)}$$

1000-ppi scanner, for f = 1,0 to 20,0 cy/mm:

$$CTF = -1{,}85487E\text{-}05 * f^3 + 1{,}41666E\text{-}03 * f^2 - 5{,}73701E\text{-}02 * f + 1{,}01341 \qquad \text{(eq.B.2)}$$

#### B.1.2.3.2 Background

For MTF assessment, the single, representative sine wave modulation in each imaged sine wave frequency pattern is determined from the sample modulation values collected from within that pattern. The sample modulation values are computed from the maximum and minimum levels corresponding to the “peak” and adjacent “valley” in each sine wave period. For a sine wave image, these maximum and minimum levels represent the image gray-levels that have been locally averaged in a direction perpendicular to the sinusoidal variation and then mapped through a calibration curve into target reflectance space. Sample image modulation in target reflectance space is then defined as:

modulation = (maximum - minimum) / (maximum + minimum)

The calibration curve is the curve of best fit between the image gray-levels of the density patches in the sine wave target and the corresponding target reflectance values. [It is assumed that sine wave target modulations and target density patch values are supplied by the target manufacturer.] The scanner MTF at each frequency is then defined as:

MTF = peak image modulation / target modulation

For CTF assessment, the modulations are determined directly in image space, normalized by the image modulation at zero frequency, instead of using a calibration curve. The scanner CTF at each frequency is then defined as:

CTF = peak image modulation / (zero frequency image modulation)

The bar target shall contain at least 10 parallel bars at each of the higher spatial frequencies (~50% Nyquist to Nyquist frequency), which helps to ensure capture of optimum scanner – target phasing and aids investigation of potential aliasing. The bar target shall also contain a very low frequency component, *i.e.*, a large square, bar, or series of bars whose effective frequency is less than 2,5 percent of the scanner’s final output spatial sampling rate. This low frequency component is used in normalizing the CTF; it shall have the same density (on the target) as the higher frequency target bars.

The upper limit of 1,05 modulation is to discourage image processing that produces excessive edge sharpening, which can add false detail to an image.

Aliasing on sine wave images or bar images may be investigated by quantitative analysis and from visual observation of the softcopy-displayed image.

### B.1.2.4 Signal-to-noise ratio

#### B.1.2.4.1 Requirement

The white signal-to-noise ratio and black signal-to-noise ratio shall each be greater than or equal to 125,0 in at least 97,0 percent of respective cases within each print block measurement area.



#### B.1.2.4.2 Background

The signal is defined as the difference between the average output gray-levels obtained from scans of a uniform low reflectance and a uniform high reflectance target, measuring the average values over independent 0,25 by 0,25 inch areas within each print block area. The noise is defined as the standard deviation of the gray-levels in each of these quarter-inch measurement areas. Therefore, for each high reflectance, low reflectance image pair there are two SNR values, one using the high reflectance standard deviation and one using the low reflectance standard deviation. To obtain a true measure of the standard deviation, the scanner is set up such that the white average gray-level is several gray-levels below the system’s highest obtainable gray-level and the black average gray-level is several gray-levels above the system’s lowest obtainable gray-level.

#### B.1.2.5 Gray-level uniformity

##### B.1.2.5.1 Requirement – adjacent row, column uniformity

At least 99,0 percent of the average gray-levels between every two adjacent quarter-inch-long rows and 99,0 percent between every two adjacent quarter-inch-long columns within each imaged print block area shall not differ by more than 1,0 gray-levels when scanning a uniform low-reflectance target and shall not differ by more than 2,0 gray-levels when scanning a uniform high-reflectance target.

##### B.1.2.5.2 Requirement – pixel-to-pixel uniformity

For at least 99,9 percent of all pixels within every independent 0,25 by 0,25 inch area located within each imaged print block area, no individual pixel's gray-level shall vary from the average by more than 22,0 gray-levels when scanning a uniform high-reflectance target and shall not vary from the average by more than 8,0 gray-levels when scanning a uniform low-reflectance target.

##### B.1.2.5.3 Requirement – small area uniformity

For every two independent 0,25 by 0,25 inch areas located within each imaged print block area, the average gray-levels of the two areas shall not differ by more than 12,0 gray-levels when scanning a uniform high-reflectance target and shall not differ by more than 3,0 gray-levels when scanning a uniform low-reflectance target.

##### B.1.2.5.4 Background

Measurements are made over multiple, independent test areas on a print block-by-print block basis. (For a live scanner, the entire capture area is normally considered a single print block area). To obtain a true measure of the standard deviation, the scanner is set up such that the white average gray-level is several gray-levels below the system's highest obtainable gray-level and the black average gray-level is several gray-levels above the system's lowest obtainable gray-level.

#### B.1.2.6 Fingerprint image quality

The scanner shall provide high quality fingerprint images; the quality will be assessed with respect to the following requirements.

##### B.1.2.6.1 Requirement – Fingerprint gray range

At least 80,0 percent of the captured individual fingerprint images shall have a gray-scale dynamic range of at least 200 gray-levels, and at least 99,0 percent shall have a dynamic range of at least 128 gray-levels.

##### B.1.2.6.2 Background

Card and live scan systems at a booking station have some control over dynamic range on a subject-by-subject or card-by-card basis, *e.g.*, by rolling an inked finger properly or by adjusting gain on a livescanner. However, with central site or file conversion systems where a variety of card types and image qualities are encountered in rapid succession, automated adaptive processing may be necessary. The eight-bits-per-pixel quantization of the gray-scale values for very low contrast fingerprints needs to more optimally represent the reduced gray-scale range of such fingerprints, but without significant saturation. The intent is to avoid excessively low contrast images without adding false detail.

Dynamic range is computed in terms of number of gray-levels present that have signal content, measuring within the fingerprint area and substantially excluding white background and card format lines, boxes, and text.

For card scanners, compliance with these dynamic range requirements shall be verified using a statistically stratified sample set of fingerprint cards. The test fingerprint card set may include cards with difficult-to-handle properties, *e.g.*, tears, holes, staples, glued-on photos, or lamination, for testing card scanners that have automatic document feeder mechanisms. For live scanners, compliance will be verified with sets of livescans produced by the vendor.



 

#### B.1.2.6.3 Requirement – Fingerprint artifacts and anomalies

Artifacts or anomalies detected on the fingerprint images that are due to the scanner or image processing shall not significantly adversely impact support to the functions of conclusive fingerprint comparisons (identification or non-identification decision), fingerprint classification, automatic feature detection, or overall AFIS search reliability.

#### B.1.2.6.4 Background

The fingerprint images will be examined to determine the presence of artifacts or anomalies that are due to the scanner or image processing; assessment may include measurements to quantify their degree of severity and significance. Image artifacts or anomalies such as the following non-inclusive list may be investigated.

- jitter noise effects
- sharp truncations in average gray-level between adjacent print blocks
- gaps in the gray-level histograms, *i.e.*, zero pixels in intermediate gray-levels, or clipping to less than 256 possible gray-levels
- imaging detector butt joints
- noise streaks
- card bleed-through
- gray-level saturation

#### B.1.2.6.5 Requirement – Fingerprint sharpness & detail rendition

The sharpness and detail rendition of the fingerprint images, due to the scanner or image processing, shall be high enough to support the fingerprint functions stated in Clause B.1.1, paragraph 2.

#### B.1.2.6.6 Background

Fingerprint sharpness and detail rendition that is due to the scanner or image processing may be investigated by employing suitable, objective image quality metrics, as well as by visual observation of the softcopy-displayed image.

### B.1.3 Identification flats

Traditional fingerprint sets contain both rolled and plain fingerprint images. The rolled impressions support the search processing and identification functions and the plain impressions are used primarily for sequence verification. Fingerprinting systems designed for “Identification Flats” civilian background checks capture a single set of plain impressions. This single set of plain impressions shall support finger sequence verification, search processing, and identification.

Image quality has historically been a challenge for civil background checks. Some programs require a large number of relatively low-volume capture sites, which makes training difficult. A key goal for identification flats scanners is to reduce the need for training so that inexperienced users consistently capture quality fingerprint images.

The identification flats scanner shall meet all of the requirements stated in Clause B.1.2 of this annex as well as the following requirements.

#### B.1.3.1 Requirement – Capture protocol

The system shall provide a simple capture protocol.

#### B.1.3.2 Background

A simple capture protocol supports the inexperienced user's ability to more consistently capture high quality fingerprints. Identification flats collection systems will be evaluated for their ability to produce a very small rate of failure to enroll in an operational setting. Systems with a minimum capture area of 3,2 inches (width) by 3,0 inches (height) that can capture four fingers simultaneously in an upright position will be considered in compliance with the simple capture protocol requirement. Other capture approaches will require specific testing and documentation.

#### B.1.3.3 Requirement – Verifiable finger sequence data

The method of capturing the fingers shall result in very low probability of error in the finger numbers.

#### B.1.3.4 Background

The fingerprinting system's capture protocol will be evaluated for its ability to capture verifiable finger sequence data. Systems with a minimum capture area of 3,2 inches (width) by 3,0 inches (height) that capture four fingers simultaneously in an upright position will be considered in compliance with the finger sequence requirements. Other capture approaches will require specific testing and documentation.



## B.2 Image quality specification for personal verification

### B.2.1 General

These specifications apply to fingerprint capture devices which scan and capture at least a single fingerprint in digital, softcopy form. These specifications provide criteria for insuring that the image quality of such devices is sufficient for the intended applications; a primary application is to support subject authentication via one-to-one fingerprint comparison.

The fingerprint capture device shall be capable of producing images which exhibit good geometric fidelity, sharpness, detail rendition, gray-level uniformity, and gray-level dynamic range, with low noise characteristics. The images shall be true representations of the input fingerprints, without creating any significant artifacts, anomalies, false detail, or cosmetic image restoration effects. The fingerprint capture device is expected to generate good quality finger images for a very high percentage of the user population, across the full range of environmental variations seen in the intended applications.

### B.2.2 Requirements

The compliance test procedures are out of scope of this Annex. An example for a test specification that allows testing of conformance with this image quality specification is available [8].

Verification of compliance of the fingerprint capture device with the requirements shall primarily be performed by the *Test Method*, i.e., verification through systematic exercising of the item with sufficient instrumentation to show compliance with the specified quantitative criteria.

The device shall be tested to meet the requirements in its normal-operating-mode, with the following possible exceptions:

1) If the device has a strong anti-spoofing feature, of a type whereby only live fingerprints will produce an image, then this feature needs to be switched-off or bypassed in the target test mode of operation.

2) If the device's normal output is not a monochrome gray scale image, e.g., it is a binary image, minutia feature set, color image, etc., then the monochrome gray scale image needs to be accessed and output in the test mode of operation.

3) Other normal-operating-mode features of the device similar/comparable/analogous to (1) and (2) may need to be disengaged.

 

Table B.4 gives some of the basic requirements for the single finger capture device.

**Table B.4 — Basic requirements**

| Parameter | Requirement |
|---|---|
| Capture Size | ≥ 12,8 mm wide by ≥ 16,5 mm high |
| True Optical or Native Spatial sampling rate (Nyquist frequency) | ≥ 500 ppi in sensor detector row and column directions |
| Spatial sampling rate Scale | 490 ppi to 510 ppi in sensor detector row and column directions |
| Image Type | Capability to output monochrome image at 8 bits per pixel, 256 gray-levels (prior to any compression) |

mm = millimeters
ppi = pixels per inch
≥ greater than or equal to

#### B.2.2.1 Geometric accuracy

##### B.2.2.1.1 Requirement #1 (across-bar)

A multiple, parallel bar target with a one cy/mm frequency is captured in vertical bar and horizontal bar orientations. The absolute value of the difference between the actual distance across parallel target bars, and the corresponding distance measured in the image, shall not exceed the following values, for at least 99% of the tested cases in each of the two orthogonal directions.

$D \leq 0{,}0013$, for $0{,}00 < X \leq 0{,}07$

$D \leq 0{,}018X$, for $0{,}07 \leq X \leq 1{,}50$

where:

D = |Y-X|
X = actual target distance
Y = measured image distance
D, X, Y are in inches

##### B.2.2.1.2 Requirement #2 (along-bar)

A multiple, parallel bar target with a one cy/mm frequency is captured in vertical bar and horizontal bar orientations. The maximum difference between the horizontal direction locations (for vertical bar) or vertical direction locations (for horizontal bar), of any two points separated by up to 1,5 inches along a single bar's length, shall be less than 0,027 inches for at least 99% of the tested cases in the given direction.

Requirements #1 and #2 may be verified by the *Inspection Method* instead of the *Test Method*, if the fingerprint capture device has all of the following characteristics, and adequate documentation for these characteristics is supplied:

— Construction of a suitable 1 cy/mm Ronchi target that will produce measurable images with the capture device requires extraordinary effort and resources.

— The sensor is a two-dimensional staring array (area array) on a plane (not curved) surface.

— There is no movement of device components, nor purposeful movement of the finger, during finger image capture.

— There is no device hardware component (e.g., a lens or prism) between the finger and the sensor, with the possible exception of a membrane on the sensor surface which, if present, does not alter the geometry of the imaged finger.

— Any signal processing applied to the captured finger image does not alter the geometry of the captured finger image.

#### B.2.2.1.3 Background

The phrase: *multiple, parallel bar target* refers to a Ronchi target, which consists of an equal width bar and space square wave pattern at 1,0 cy/mm, with high contrast ratio and fine edge definition.

Across-bar geometric accuracy is measured across the imaged Ronchi target bars, which cover the total image capture area. The requirement corresponds to a positional accuracy of ± 1,8% for distances between 0,07 and 1,5 inches, and a constant ± 0,0013 inches (2/3 pixel) for distances less than or equal to 0,07 inches. These across-bar measurements are also used to verify compliance with the device's spatial sampling rate scale tolerance requirement given in Table B.4.

Along-bar geometric accuracy is measured along the length of an individual Ronchi bar in the image. For a given horizontal bar, for example, the maximum difference between bar center locations (in vertical direction), determined from bar locations measured at multiple points along bar's length, is compared to the maximum allowable difference requirement (analogously for vertical bar). This requirement is to ensure that pincushion, barrel, or other types of distortion are not too large, over the area of a single fingerprint.



### B.2.2.2 Spatial frequency response (SFR)

#### B.2.2.2.1 Requirements

The spatial frequency response shall normally be measured by either using a bi-tonal, high contrast bar target, which results in the device's Contrast Transfer Function (CTF), or by using a continuous-tone sine wave target, which results in the device's Modulation Transfer Function (MTF). If the device cannot use a bar target or sine wave target, i.e., a useable/measurable image cannot be produced with one of these targets, then an edge target can be used to measure the MTF[2].

The CTF or MTF shall meet or exceed the minimum modulation values defined in equation 1 (for CTF) or equation 2 (for MTF), over the frequency range of 1,0 to 10,0 cy/mm, in both the detector row and detector column directions, and over any region of the total capture area. Table B.5 gives the minimum CTF and MTF modulation values at nominal test frequencies. None of the CTF or MTF modulation values in the 1,0 to 10,0 cy/mm range shall exceed 1,12, and the target image shall not exhibit any significant amount of aliasing in that range.

Equation 1:

$$CTF = -5{,}71711E-05 * f^4 + 1{,}43781E-03 * f^3 - 8{,}94631E-03 * f^2 - 8{,}05399E-02 * f + 1{,}00838$$

Equation 2:

$$MTF = -2{,}80874E-04 * f^3 + 1{,}06255E-02 * f^2 - 1{,}67473E-01 * f + 1{,}02829$$

(equations valid for f = 1,0 to f = 10,0 cy/mm)

[2] If it is conclusively shown that neither a sine wave target, nor bar target, nor edge target can be used in a particular device, other methods for SFR measurement may be considered.

**Table B.5 — CTF and MTF Requirements at nominal test frequencies**

| Frequency (f) in cy/mm at object plane | Minimum CTF Modulation when using Bar Target | Minimum MTF Modulation when using Sine Wave or Edge Target |
|---|---|---|
| 1,0 | 0,920 | 0,871 |
| 2,0 | 0,822 | 0,734 |
| 3.0 | 0,720 | 0,614 |
| 4,0 | 0,620 | 0,510 |
| 5,0 | 0,526 | 0,421 |
| 6,0 | 0,440 | 0,345 |
| 7,0 | 0,362 | 0,280 |
| 8,0 | 0,293 | 0,225 |
| 9,0 | 0,232 | 0,177 |
| 10,0 | 0,174 | 0,135 |



#### B.2.2.2.2 Background

The 1,12 upper limit for modulation is to discourage image processing that produces excessive edge sharpening, which can add false detail to an image and/or excessive noise.

Aliasing can be investigated quantitatively (e.g., Fourier analysis) and, for sine wave or bar images, from visual observation of the softcopy-displayed images. It is recognized and accepted that some amount of aliasing-due-to-decimation is often unavoidable at the higher frequencies, but aliasing-due-to-upscaling is not acceptable at any frequency within the required Nyquist limit.

The target can be fabricated of any material and on any substrate suitable for measurement with the given device, working in reflective, transmissive, or other signal transfer mode, and in either two-dimensions or three-dimensions.

If the relation between output gray-level and input signal level is nonlinear, i.e., the device's input/output response is nonlinear, then this needs to be appropriately accounted for in the computations for MTF or CTF. [MTF and CTF are strictly defined only for a linear or linearized system.]

It is not required that the CTF or MTF be obtained at the exact frequencies listed in Table B.5; however, the CTF or MTF does need to cover the listed frequency range, and contain frequencies close to each of the listed frequencies.

Sine Wave Target - Commercially manufactured sine wave targets commonly contain a calibrated step tablet for measurement of the device's input/output response, and the target sine wave modulation values are also supplied, which are used to normalize the device output modulation values to arrive at the device MTF.

Bar Target - The bar target shall contain an adequate number of parallel bars at each spatial frequency, i.e., enough bars to help ensure capture of optimum phasing between the target and the device's sensor, and to aid investigation of potential aliasing. The bar target shall also contain a very low frequency component (less than 0,3 cy/mm), such as a single large bar, with the same density as the other bars (used for normalization).

If the device has a nonlinear response then a procedure analogous to that used for sine wave processing will have to be used to establish the effective bar image modulation values in target space.

The spatial frequency response of the bar target itself may not be known. In such a case, the device output bar modulation values (in image space or, if nonlinear response, in target space) are normalized by the near-zero frequency bar output modulation value, resulting in an acceptable measure of the device CTF.

Edge Target - The computation of MTF from an imaged edge target follows the relevant ISO standard [9]. The target edge is oriented at an angle of 5,2 degrees, alternately with respect to the sensor row and column directions. If the device has a nonlinear response then the nonlinearity needs to be measured and taken into account in the computations. The computed output modulation values are normalized to 1,0 at zero frequency (by dividing by the area of the line spread function), resulting in an acceptable measure of the device MTF. If the spatial frequency response of the target edge is known, then a further division by that response function is performed to obtain a more exact measure of the device MTF. The edge target shall contain at least two fiducial marks from which the image scale in the across-the-edge direction can be measured, in pixels per inch.

#### B.2.2.3 Gray-level uniformity

##### B.2.2.3.1 Requirement #1 - adjacent row, column uniformity

At least 99% of the average gray-levels between every two adjacent quarter-inch long rows and 99% between every two adjacent quarter-inch long columns, within the capture area, shall not differ by more than 1,5 gray-levels when scanning a uniform dark gray target, and shall not differ by more than 3,0 gray-levels when scanning a uniform light gray target.

##### B.2.2.3.2 Requirement #2 - pixel to pixel uniformity

For at least 99,0% of all pixels within every independent 0,25 by 0,25 inch area located within the capture area, no individual pixel's gray-level shall vary from the average by more than 8,0 gray-levels when scanning a uniform dark gray target, and no individual pixel's gray-level shall vary from the average by more than 22,0 gray-levels when scanning a uniform light gray target.

##### B.2.2.3.3 Requirement #3- small area uniformity

For every two independent 0,25 by 0,25 inch areas located within the capture area, the average gray-levels of the two areas shall not differ by more than 3,0 gray-levels when scanning a uniform dark gray target, and shall not differ by more than 12,0 gray-levels when scanning a uniform light gray target.

##### B.2.2.3.4 Requirement #4 - Noise

The noise level, measured as the standard deviation of gray-levels, shall be less than 3,5 in every independent 0,25 by 0,25 inch area located within the capture area, when scanning a uniform dark gray target and a uniform light gray target.

##### B.2.2.3.5 Background

Any suitable uniform light gray target and dark gray target may be used for measuring requirements #1 to #4, including a pseudo-target. [The pseudo-target concept images the blank capture area with, for example, the exposure time turned up or down, producing a uniform light gray or dark gray image, respectively.] Each target needs to cover the entire capture area.

The device is set up such that the light average gray-level is at least 4 gray-levels below the device's highest obtainable gray-level when capturing fingerprints, and the dark average gray level is at least 4 gray-levels above the device's lowest obtainable gray-level when capturing fingerprints. This avoids possible saturation levels and levels that are outside the range obtained in actual fingerprint captures.

#### B.2.2.4 Fingerprint image quality

The fingerprint capture device shall provide fingerprint image quality which is high enough to support the intended applications; a primary application is to support subject authentication via one-to-one fingerprint comparison.

The image quality will be assessed with respect to the following requirements, by applying visual and quantitative measurements to test livescans captured on the given device. These test livescans shall consist of:

— a set of 20 fingers, nominally acquired from 10 different subjects and 2 fingers per subject (preferably left/right index finger) and,

— a set of 5 index finger repeat captures from the same hand of a single subject.

All of these test livescans shall be supplied for assessment in 8 bits per pixel, monochrome (grayscale), uncompressed format (and have never been lossy-compressed).

**B.2.2.4.1 Requirement #1 - Fingerprint Gray Range**

At least 80,0 % of the captured individual fingerprint images shall have a gray-scale dynamic range of at least 150 gray-levels.

**B.2.2.4.2 Background**

Dynamic range is computed in terms of number of gray-levels present that have signal content, measuring within the fingerprint area and substantially excluding non-uniform background areas.

**B.2.2.4.3 Requirement #2 - Fingerprint Artifacts and Anomalies**

Artifacts or anomalies detected on the fingerprint images, which are due to the device or image processing, shall not significantly adversely impact supporting the intended applications.

**B.2.2.4.4 Background**

The fingerprint images will be examined to determine the presence of artifacts or anomalies which are due to the device or image processing; assessment may include measurements to quantify their degree of severity and significance. Image artifacts or anomalies such as the following non-inclusive list may be investigated:

• jitter noise effects
• localized offsets of fingerprint segments
• sensor segmentation / butt joints
• noise streaks, erratic pixel response
• gray-level saturation
• poor reproduceability

**B.2.2.4.5 Requirement #3 - Fingerprint Sharpness & Detail Rendition**

The sharpness and detail rendition of the fingerprint images, due to the device or image processing, shall be high enough to support the intended applications.

**B.2.2.4.6 Background:**

Fingerprint sharpness and detail rendition, which is due to the device or image processing, may be investigated by employing suitable, objective image quality metrics, as well as by visual observation of the softcopy-displayed images.

## B.3 Requirements and test procedures for optical fingerprint scanners

### B.3.1 Introduction

This annex details requirements and testing procedures for high quality optical fingerprint scanners.

### B.3.2 Testing prerequisites

#### B.3.2.1 Requirements on the testing laboratory

All measurements have to be performed within a completely darkened optical laboratory without the influence of external light sources. The insensitivity of the scanner to external stray light is not subject of the tests to be performed. For some of the measurements it is necessary to extract light which is emitted by the scanner via prisms; this strongly enhances the sensitivity of the scanner with respect to false light. An exception here is the recording of fingerprints to test the gray scale range. For this test the normal room illumination has to be switched on, to ensure normal environment conditions similar to the typical usage of the device. While carrying out the measurements it has to be ensured that the optical surface of the fingerprint recording area has to be cleaned. For performing the tests on the scanner the test lab uses the following test tools:

- suitable software for data evaluation (Clause B.3.2.3)
- spreadsheet software
- suitable test targets (Clause B.3.2.4)

The personal of the test lab has to have fundamental knowledge on the test of optical systems/instruments, especially on the test of fingerprint scanners.

#### B.3.2.2 Requirements on the test object

For the test of the fingerprint scanner the manufacturer has to state the exact optical principle of the scanner, including necessary drawings (or pictures, tables). An image capture area of at least 16 mm x 20 mm is required.

The fingerprint scanner to be tested has to be fully functional. Adaptive or dynamic adjustment, calibration algorithms or spoof detection mechanisms inside the scanner or the scanner software (on the PC), which may include filters, compensation, optimization, dynamic contrast adjustment, have to be disabled during the test. For this purpose the manufacturer may have to provide an adapted software for the scanner in which such software parts/algorithms are deactivated. The software has to operate with constant parameter settings during the test. Only for testing the gray scale range of fingerprint images dynamic algorithms which will be used in customer applications are allowed.

#### B.3.2.3 Requirements on the evaluation software

The software to evaluate the fingerprint digital image data has to compute image quality based on the two-dimensional spatial frequency power spectrum of the fingerprint digital image. The power spectrum, which is the square of the magnitude of the image's Fourier transform, contains information on the sharpness, contrast, and detail rendition of the image. These are components of visual image quality. Within the software, the power spectrum is normalized by image contrast, average gray level (brightness), and image size; a visual response function filter is applied, and the pixels per inch (ppi) spatial sampling rate scale of the fingerprint image is taken into account. The fundamental output is a single-number image quality value which is the sum of the filtered, scaled, weighted power spectrum values. The power spectrum normalizations allow valid comparisons between disparate fingerprint images. The software has to work as described in the following list:

- The software shall have the digital fingerprint image as input.
- It shall define a square window width of about 60% of fingerprint image width.
- It shall locate the left / right and bottom / top edges of the fingerprint.
- It shall define a set of overlapping windows covering the entire fingerprint area.
- It shall exclude very dense and very low structure areas within the fingerprint from further evaluation.
- It shall compute the 2-D power spectrum of each window and $|FFT|^2$.



 

- It shall be normalized by total energy and window size.
- It shall apply a Human Visual System (HVS) filter (inclusion of such a filter makes the final quality values more closely correspond to human observer assessments of relative quality).
- It shall use an initial image quality value per window, i.e. the 2-D normalized, filtered power spectrum values at non-zero frequencies are summed, resulting in a single quality number for the given sub image.
- It shall identify the window with the highest image quality.

It shall convert the image quality to the dc normalized image quality, that means it has to scale the fingerprint image to them range [0,100], where 0 is the worst quality, 100 is the best quality.

- The image quality overestimates dark areas within the fingerprint images and underestimates bright areas. This effect shall be compensated by multiplying the image quality value with the square of the average gray values.
- It shall check for special cases (very high contrast or very light, structured image) and adjust the image quality accordingly.
- It shall scale by ppi and normalize the image quality to the range [0,100].



#### B.3.2.4 Demands on the test targets

##### B.3.2.4.1 Test targets for optical fingerprint scanner working on the principle of frustrated total internal reflection in the bright field

Test targets have to be used, which are closely related to the functional principle of the fingerprint scanner. During the tests with these targets no intervention in the optical beam path of the scanner shall be performed. The targets have to be placed directly on the optical recording surface of the scanner. The targets are made as specular reflecting, structured or unstructured mirrors. Light emerging from the optical recording surface of the scanner will not only be reflected from the front surface of the target, but also from the back side of the target. To avoid these parasite reflections, a prism has to be placed on top of the target, to couple out this light. For this purpose, an immersion liquid has to be inserted between scanner and target and also between target and prism; the refractive index of this liquid has to be close to those of optical glasses (optical recording surface of the scanner, target, prism). This liquid layer has to contain neither dust nor air bubbles. It is recommended to use an immersion liquid with a reflective index of n~1,5.

##### B.3.2.4.2 Test targets for optical fingerprint scanner working on the principle of frustrated total internal reflection in the dark field

Test targets have to be used, which are closely related to the functional principle of the fingerprint scanner. During the tests with these targets no intervention in the optical beam path of the scanner shall be performed. The targets have to be placed directly on the optical recording surface of the scanner. For the optical coupling between scanner and target an immersion liquid has to be inserted; the refractive index of this liquid has to be identical with those of the optical recording surface of the scanner. This liquid layer has to contain neither dust nor air bubbles. It is recommended to use an immersion liquid with a reflective index of n~1,5.

The targets are made as diffusely reflecting areas. On these substrates defined gray levels (grayscales) can be generated by suitable exposure processes. The targets material is required to be liquid resistant. If the targets are laminated to protect them from liquid, care has to be taken that the lamination process does not change the optical properties of the targets.

### B.3.3 Requirements and test procedures

#### B.3.3.1 Investigation of the grayscale linearity

##### B.3.3.1.1 Requirements

When measuring a stepped series of uniform target reflectance patches (“step tablet”) that substantially covers the scanner’s gray range, the average value of each patch shall be within 7,65 gray-levels of a linear, least squares regression line fitted between target reflectance patch values (independent variable) and scanner output gray-levels of 8 bit spatial sampling rate (dependent variable).

##### B.3.3.1.2 Background

All targets used within this test case are expected to be scanned with the scanner operating in a linear input/output mode. Linearity enables valid comparisons of test measurements with requirements. For fingerprint scans, linearity produces a pristine image in a common reference base. From this base, users can then apply linear/non-linear processing, as needed for specific purposes, with the benefit that they are always able to get back to the base image. However, in a typical case, linearity may be waived for test target scans; i.e., a small amount of smooth, monotonic nonlinearity may be acceptable when it is substantially impractical and unrepresentative of operational use to force linearity on the scanner under test. Such cases require the submission of documentation along with the waiver request.

It is recognized that the fingerprint on the scanner may have less than ideal characteristics, in terms of average reflectance, discontinuities in average reflectance, low contrast or background clutter. Such problems may sometimes be minimized by applying nonlinear gray-level processing to the scanner captured image. For these reasons, linearity is not a requirement for the operational or test fingerprint scans.

##### B.3.3.1.3 Used targets

###### B.3.3.1.3.1 Test targets for optical fingerprint scanner working on the principle of frustrated total internal reflection in the bright field

For this test case targets with a metal coated surface may be used; within these targets different reflectivities are realized. Chromium or aluminium may be used; chromium can be very well deposited in different densities, but allows a maximum reflection of about 50%. Aluminium has a maximum reflectivities of about 85-92%, but it is difficult to depose it in different densities. As the reflectivities of the target surfaces cannot be correctly predicted, the reflectivities of all targets have to be measured accurately.

###### B.3.3.1.3.2 Test targets for optical fingerprint scanner working on the principle of frustrated total internal reflection in the dark field

For this test case targets with diffusely reflecting surfaces with different blackened test fields are used. Such targets are commercially used for testing the modulation transfer function (MTF) of flat bed scanners. According to the size of the recording surface the target is cut into pieces with two or more test fields. By this way multiple test fields can be placed simultaneously on the recording surface.

##### B.3.3.1.4 Test procedure

###### B.3.3.1.4.1 Test step 1

A series of fields with different reflection values have to be placed one after another on the fingerprint scanner and an image of each target has to be recorded. At least nine targets with different reflection values, which substantially cover the dynamic range of the scanner, have to be recorded.

###### B.3.3.1.4.2 Test step 2

Adjacent the average gray value of each target image shall be determined with a suitable software. The reflectivity and the resulting gray value of each target shall be determined as pair of values.

##### B.3.3.1.4.3 Test step 3

For those pairs of values a linear regression shall be performed. For each average gray value the difference to the resulting regression line shall be determined.

#### B.3.3.1.5 Requirement compliance

None of the calculated differences in test step 3 is allowed to be larger than 7,65 gray values.

### B.3.3.2 Investigation of the spatial sampling rate and geometrical accuracy

#### B.3.3.2.1 Requirements

Spatial sampling rate: The scanner's final output fingerprint image shall have a spatial sampling rate, in both sensor detector row and column directions, in the range: (R – 0,01R) to (R + 0,01R). The magnitude of R is either 500 ppi or 1000 ppi; a scanner may be certified at either one or both of these spatial sampling rate levels. The scanner's true optical spatial sampling rate shall be greater than or equal to R.

Across-Bar geometric accuracy: When scanning a 1,0 cy/mm, multiple parallel bar target, in both vertical bar and horizontal bar orientations, the absolute value of the difference (D), between the actual distance across parallel target bars (X), and the corresponding distance measured in the image (Y), shall not exceed the following values, for at least 99% of the tested cases in each print block measurement area and in each of the two directions

- for 500 ppi scanners: $D \leq 0{,}0007$, for $0{,}00 < X \leq 0{,}07$ and $D \leq 0{,}01X$, for $0{,}07 \leq X \leq 1{,}50$
- for 1000 ppi scanners: $D \leq 0{,}0005$, for $0{,}00 < X \leq 0{,}07$ and $D \leq 0{,}0071X$, for $0{,}07 \leq X \leq 1{,}50$

where $D = |Y-X|$, X = actual target distance, Y = measured image distance (D, X, Y are in inches)

Along-Bar geometric accuracy: When scanning a 1,0 cy/mm, multiple parallel bar target, in both vertical bar and horizontal bar orientations, the maximum difference in the horizontal or vertical direction, respectively, between the locations of any two points within a 1,5 inch segment of a given bar image, shall be less than 0,016 inches for at least 99% of the tested cases in each print block measurement area and in each of the two orthogonal directions.

#### B.3.3.2.2 Background

A multiple parallel bar target refers to a Ronchi target, which consists of an equal-width bar and space square wave pattern with high contrast ratio and sharp edge definition. For a 500 ppi system, the spatial sampling rate shall be between 495,0 and 505,0 ppi; for a 1000 ppi system, the spatial sampling rate shall be between 990,0 and 1010,0 ppi. The scanner's true optical spatial sampling rate may be greater than the required spatial sampling rate, in which case rescaling down to the required spatial sampling rate is performed for final output. However, the scanner's true optical spatial sampling rate cannot be less than the required spatial sampling rate; i.e. "up scaling", from less than the required ppi spatial sampling rate, to the required ppi spatial sampling rate, is not allowed. Across-bar geometric accuracy is measured across imaged 1,0 cy/mm Ronchi target bars that substantially cover the total image capture area. The 500ppi requirement corresponds to a positional accuracy of ± 1,0% for distances between 0,07 and 1,5 inches, and a constant ± 0,0007 inches (1/3 pixel) for distances less than or equal to 0,07 inches. The 1000ppi requirement corresponds to a positional accuracy of ± 0,71% for distances between 0,07 and 1,5 inches, and a constant ± 0,0005 inches (1/2 pixel) for distances less than or equal to 0,07 inches.

Along-bar geometric accuracy is measured along the length of imaged, 1,0 cy/mm Ronchi target bars that substantially cover the total image capture area. For a given horizontal bar, for example, the maximum difference between bar centre locations (in vertical direction), determined from bar locations measured at multiple points along a 1,5 inch bar segment length, is compared to the maximum allowable difference requirement (analogously for vertical bar). This requirement is to ensure that pincushion or barrel distortion over the primary area of interest; i.e., a single fingerprint is not too large.

#### B.3.3.2.3 Used targets

##### B.3.3.2.3.1 Test targets for optical fingerprint scanner working on the principle of frustrated total internal reflection in the bright field

The target has to cover at least 70% of the recording surface of the fingerprint scanner. The test structure is a grating with a constant period length of 1mm. The target can consist of directly reflecting structures, such as chromium stripes on a glass substrate. The light passing the glass substrate has to be coupled out by a prism which has to be placed on top of the target.

Alternatively to this chromium coated glass target a plastic foil printed with black lines can be used. In this case no prism on top of the target is required. Reflexion of the light is performed on the back side of the foil. The black printed areas of the foil absorb and scatter the light, thus these areas appear dark in the image. The usage of this target material is recommended for larger fingerprint scanning surfaces.

##### B.3.3.2.3.2 Test targets for optical fingerprint scanner working on the principle of frustrated total internal reflection in the dark field

The target has to cover at least 70% of the recording surface of the fingerprint scanner. The test structure is a grating with a constant period length of 1mm.

The target has to consist of diffuse bright reflecting material, on which dark structures are applied. These structures can be applied by a photographic process or by printing. Photographic or coated paper shall not be used as target material, because its optical properties can be influenced by wetting the material with immersion liquid. Thus, plastic material coated with photo emulsion as substrate is recommended; this material is insensitive against immersion liquid; the dark structures can be applied similar to the photographic process on paper.

#### B.3.3.2.4 Test procedure

##### B.3.3.2.4.1 Test step 1

The targets have to be placed with immersion liquid or similar on the recording surface of the fingerprint scanner. When using chromium coated glass targets the light passing the glass substrate has to be coupled out by a prism which has to be place on top of the target. When using black printed plastic foils as target this prism is not necessary. Each target has to be placed 4 times on the recording surface of the fingerprint scanner, two times with the lines in vertical direction (each time turned by 180°) and two times with the lines in horizontal direction (each time turned by 180°). By using this method, errors induced by the target and not by the fingerprint scanner can be detected.

After placing the target on the recording surface of the fingerprint scanner one has to ensure that the stripes of the target are parallel to the pixels of the scanner. To detect this, one has to look for aliasing effects at the edge of the stripes while looking at the recorded images on a high quality monitor.



##### B.3.3.2.4.2 Test step 2

The pixels coordinates of the edges of the stripe field in the recorded image are determined. These data and the picture dimensions are necessary for the evaluation by suitable software (see ‘Demand on the evaluation software’). This software determines within the specified measurement field the distance between neighbouring stripes, the average distance between six stripes and the coordinates of the central line of each stripe. As a unit, pixels shall be used.

##### B.3.3.2.4.3 Test step 3

Based on the results of test step 2 and the well known grating period of the test target (1 mm) the spatial sampling rate of the scanner at different positions within the image can be determined. This spatial sampling rate can be used to rescale the distance between the stripes from pixel to mm. Based on these values the difference between theoretical and measured distance between the stripes can be calculated for different measurement areas. From the position of the stripes and their lateral bend the scanner distortion can be measured.

#### B.3.3.2.5 Requirement compliance

The values listed under "Requirements" within this test case have to be completely met.

### B.3.3.3 Investigation of the contrast transfer function

#### B.3.3.3.1 Requirements

The spatial frequency response shall be measured using a binary grid target (Ronchi-Grating), denoted as contrast transfer function (CTF) measurement. When measuring the bar CTF, it shall meet or exceed the minimum modulation values defined by equation [EQ 1] or equation [EQ 2], in both the detector row and detector column directions, and over any region of the scanner's field of view. CTF values computed from equations [EQ 1] and [EQ 2] for nominal test frequencies are given in Table B.6. None of the CTF modulation values measured at specification spatial frequencies shall exceed 1,05. The output bar target image shall not exhibit any significant amount of aliasing.



**Table B.6 — Minimum and maximum modulation**

| Frequency [cy/mm] | Minimum Modulation for 500 ppi scanners | Minimum Modulation for 1000 ppi scanners | Maximum Modulation |
|---|---|---|---|
| 1,0 | 0,948 | 0,957 | 1,05 |
| 2,0 | 0,869 | 0,904 | 1,05 |
| 3,0 | 0,791 | 0,854 | 1,05 |
| 4,0 | 0,713 | 0,805 | 1,05 |
| 5,0 | 0,636 | 0,760 | 1,05 |
| 6,0 | 0,559 | 0,716 | 1,05 |
| 7,0 | 0,483 | 0,675 | 1,05 |
| 8,0 | 0,408 | 0,636 | 1,05 |
| 9,0 | 0,333 | 0,598 | 1,05 |
| 10,0 | 0,259 | 0,563 | 1,05 |
| 12,0 | --- | 0,497 | 1,05 |
| 14,0 | --- | 0,437 | 1,05 |
| 16,0 | --- | 0,382 | 1,05 |
| 18,0 | --- | 0,332 | 1,05 |
| 20,0 | --- | 0,284 | 1,05 |

It is not required that the bar target contain the exact frequencies listed in the previous table, however, the target does need to cover the listed frequency range and contain bar patterns close to each of the listed frequencies. The following equations are used to obtain the minimum acceptable CTF modulation values when using bar targets that contain frequencies not listed in the previous table.

- 500 ppi scanner, for f = 1,0 to 10,0 cy/mm: $CTF = 3{,}04105E\text{-}04 * f^2 – 7{,}99095E\text{-}02 * f + 1{,}02774$ [EQ 1]
- 1000 ppi scanner, for f = 1,0 to 20,0 cy/mm: $CTF = - 1{,}85487E\text{-}05 * f^3 + 1{,}41666E\text{-}03 * f^2 – 5{,}73701E\text{-}02 * f + 1{,}01341$ [EQ 2]

For a given bar target, the specification frequencies include all of the bar frequencies which that target has in the range 1 to 10 cy/mm (500 ppi scanner) or 1 to 20 cy/mm (1000 ppi scanner).

### B.3.3.3.2 Background

A multiple parallel bar target refers to a Ronchi target, which consists of an equal-width bar and space square wave pattern with high contrast ratio and sharp edge definition. These targets have to have all spatial frequencies in the range mentioned in the requirements section. All these gratings have to be place on one single target. Additionally, on this target there have to be large black and white structures to determine a CTF at a frequency of about 0 cy/mm. The spatial frequency of these structures has to be smaller than 3% of the Nyquist frequency. For all scanners these structures have to have a width of at least 1,7 mm. Each of the test field with the frequencies listed above have to have an adequate number and length of the gratings as listed in Table B.7:

**Table B.7 — Dimensions of the target structures**

| Spatial Frequency R [mm$^{-1}$] | Min. number of Stripes | Width of the stripes [mm] | Min. length of the stripes [mm] | R/R Nyquist (at 500ppi) | R/R Nyquist (at 1000ppi) |
|---|---|---|---|---|---|
| 0,3 | 1 | >1,700 | 2,50 | 3% | 1,5% |
| 1 | 4 | 0,500 | 2,50 | 10% | 5% |
| 2 | 5 | 0,250 | 1,25 | 20% | 10% |
| 3 | 5 | 0,167 | 0,85 | 30% | 15% |
| 4 | 5 | 0,125 | 0,63 | 40% | 20% |
| 5 | 10 | 0,100 | 0,50 | 50% | 25% |
| 6 | 10 | 0,083 | 0,42 | 60% | 30% |
| 7 | 10 | 0,071 | 0,36 | 70% | 35% |
| 8 | 10 | 0,063 | 0,32 | 80% | 40% |
| 9 | 10 | 0,056 | 0,28 | 90% | 45% |
| 10 | 10 | 0,050 | 0,25 | 100% | 50% |
| 12 | 10 | 0,042 | 0,25 | --- | 60% |
| 14 | 10 | 0,036 | 0,25 | --- | 70% |
| 16 | 10 | 0,032 | 0,25 | --- | 80% |
| 18 | 10 | 0,028 | 0,25 | -- | 90% |
| 20 | 10 | 0,025 | 0,25 | --- | 100% |



### B.3.3.3.3 Used targets

#### B.3.3.3.3.1 Test targets for optical fingerprint scanner working on the principle of frustrated total internal reflection in the bright field

The target can consist of directly reflecting structures, such as chromium stripes on a glass substrate. The target has to be structured as mentioned in the section above. The light passing the glass substrate has to be coupled out by a prism which has to be placed on top of the target (see 'Demands on the test targets').

Alternatively to this chromium coated glass target a plastic foil printed with black lines can be used as target. In this case no prism on top of the target is required. Reflection of the light is performed on the back side of the foil. The black printed areas of the foil absorb and scatter the light, thus these areas appear dark in the image. The usage of this target material is recommended for larger fingerprint scanning surfaces.

 