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Information technology — Extensible biometric data interchange formats —

Part 2:
Finger minutiae data

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of document should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives or www.iec.ch/members_experts/refdocs).

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

A list of all parts in the ISO/IEC 39794 series can be found on the ISO and IEC websites.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html and www.iec.ch/national-committees.

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Introduction

Biometric data interchange formats enable the interoperability of different biometric systems. The first generation of biometric data interchange formats was published between 2005 and 2007 in the first edition of the ISO/IEC 19794 series. From 2011 onwards, the second generation of biometric data interchange formats was published in the form of second editions of the established parts and the first editions of a number of new parts of the ISO/IEC 19794 series. In the second generation of biometric data interchange formats, new useful data elements such as data elements related to biometric sample quality were added, the header data structures were harmonized across all parts of the ISO/IEC 19794 series, and XML encoding was added in addition to the binary encoding.

In anticipation of the future need for additional data elements and to avoid future compatibility issues, ISO/IEC JTC 1/SC 37 has developed the ISO/IEC 39794 series as a third generation of biometric data interchange formats, defining extensible biometric data interchange formats capable of including future extensions in a defined manner. Extensible specifications in ASN.1 (Abstract Syntax Notation One) and the distinguished encoding rules of ASN.1 form the basis for encoding biometric data in binary tag-length-value formats. XML Schema Definitions form the basis for encoding biometric data in XML (eXtensible Markup Language).

This third generation of finger minutia data interchange formats complements ISO/IEC 19794-2:2005 and ISO/IEC 19794-2:2011. The first generation of biometric data interchange formats, which has been adopted in mass deployments, will be retained in the standards catalogue as long as required.

This document is intended for those applications requiring the exchange of fingerprint minutiae data. It will provide implementers with the flexibility to accommodate minutiae captured from dissimilar devices, varying image sizes, spatial sampling rates and different grey-scale depths. Use of the finger minutiae will allow each vendor to implement their own algorithms to determine whether two fingerprint records are from the same finger.

This document supports both binary and XML encoding, to support a spectrum of user requirements. With XML, this document meets the requirements of modern IT architectures. With binary encoding, this document is also able to be used in bandwidth- or storage-constrained environments.

For use on integrated circuit cards and other tokens (see ISO/IEC 7816-11 and ISO/IEC 24787-1:—[1]), this document also specifies an on-card biometric comparison format and on-card comparison parameters based on extensible tag-length-value (TLV) encoding. ISO/IEC 24787-1 specifies the encapsulation of biometric data in on-card biometric comparison format into TLV-structured verification data for on-card biometric comparison.

This document defines specifics of the extraction of key points (called minutiae) from fingerprint ridge patterns. These specifics include a description of the types of minutiae identified, the method used for the placement of minutiae on an image, a definition of the coordinate system used, and the methods used to calculate the angle associated with each minutia.

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1) Under preparation. Stage at the time of publication: ISO/IEC DIS 24787-1:2023.

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Information technology — Extensible biometric data interchange formats —

Part 2:
Finger minutiae data

1 Scope

This document specifies:

- generic extensible data interchange formats for the representation of finger minutia data:
  - a tagged binary data format based on an extensible specification in ASN.1,
  - a textual data format based on an XML schema definition that is capable of holding the same information as the tagged binary format, and
  - an on-card biometric comparison format based on extensible TLV encoding;
- on-card biometric comparison parameters based on extensible TLV encoding for constructing valid probe data in the on-card biometric comparison format;
- examples of data record contents;
- application-specific requirements, recommendations and best practices in determining minutiae location, direction and type; and
- conformance test assertions and conformance test procedures applicable to this document.

NOTE Whereas ISO/IEC 39794-4 covers finger, palm, toe and foot image data, this document covers only finger minutiae and is not applicable to palms, toes or feet.

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2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 39794-1, *Information technology — Extensible biometric data interchange formats — Part 1: Framework*

ISO/IEC 8825-1, *Information technology — ASN.1 encoding rules — Part 1: Specification of Basic Encoding Rules (BER), Canonical Encoding Rules (CER) and Distinguished Encoding Rules (DER)*

ISO/IEC 19785-3, *Information technology — Common Biometric Exchange Formats Framework — Part 3: Patron format specifications*

ISO/IEC 2382-37, *Information technology — Vocabulary — Part 37: Biometrics*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 2382-37, ISO/IEC 39794-1 and the following apply.

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ISO and IEC maintain terminology databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
image spatial sampling rate
number of pixels per unit distance in the image

Note 1 to entry: This can be the result of processing a captured image. The original captured scanned image can have been subsampled, scaled, down-sampled or otherwise processed.

3.2
palm
friction ridge skin on the side and underside of the hand

3.3
fingerprint image
representation of an area of friction skin on the fleshy surface of a finger located horizontally between the two edges of the fingernail and vertically between the first joint and the tip of a finger

Note 1 to entry: It contains a unique pattern of friction ridge and valley information commonly referred to as a "fingerprint".

3.4
friction ridge
ridge present on the skin of the fingers and toes, the palms of the hands and the soles of the feet, which makes contact with an incident surface under normal touch

Note 1 to entry: On the fingers, the unique patterns formed by the friction ridges make up fingerprints.

3.5
minutia
point where a single friction ridge deviates from an uninterrupted flow

Note 1 to entry: Deviation can take the form of ending, bifurcation, or a more complicated "composite" type.

3.6
typeline
one of the two innermost friction ridges that start parallel, diverge, and surround or tend to surround the pattern area

3.7
delta
point on a ridge at or nearest to the point of divergence of two typelines and located at or directly in front of the point of divergence

3.8
core
topmost point on the innermost recurving ridgeline of a fingerprint

Note 1 to entry: Generally, the core is placed upon or within the innermost recurve of a loop.

3.9
four-neighbour of pixel *p*
pixel that is the top, bottom, left, or right neighbour of pixel *p*

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EXAMPLE The pixels *e*, *f*, *g* and *h* in the following table are four-neighbours of pixel *p*.

a	e	b
h	p	f
d	g	c

3.10
four-path from pixel p_0 to pixel p_n
sequence of pixels (p_0, p_1, p_2, ..., p_n) such that p_i is a four-neighbour of $p_{i\text{-}1}$

3.11
four-connected set of pixels
set *S* of pixels such that for any two pixels $p, q \in S$, there exists a four-path from *p* to *q*

3.12
eight-neighbour of a pixel *p*
pixel that is a four-neighbour or a diagonal (top-left, top-right, bottom-left, or bottom-right) neighbour of pixel *p*

EXAMPLE The pixels *a*, *b*, *c*, *d*, *e*, *f*, *g* and *h* in the table are eight-neighbours of pixel *p*.

a	e	b
h	p	f
d	g	c

3.13
eight-path from pixel p_0 to pixel p_n
sequence of pixels (p_0, p_1, p_2, ..., p_n) such that p_i is an eight-neighbour of p_i–1

3.14
eight-connected set of pixels
set *S* of pixels such that for any two pixels $p, q \in S$ there exists an eight-path from *p* to *q*

3.15
border ∂S of a set of pixels *S*
subset $\partial S = \{x \in \mathrm{S} : x \text{ is four-neighbour of } q, q \notin S\}$ of pixels of *S* that are four-neighbours of pixels outside *S*

3.16
loop
type of fingerprint classification pattern where the friction ridges arrange themselves in the form of a lasso, making a backward turn without a twist

3.17
whorl
type of fingerprint classification pattern where the friction ridges form a revolution around the centre

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4 Symbols and abbreviated terms

For the purposes of this document, the abbreviations given in ISO/IEC 39794-1 and the following apply.

AC	alternating current
AFIS	automated fingerprint identification system
BIT	biometric information template
DO	data object
EL	electroluminescent
ICC	integrated circuit card
ICS	implementation conformance statement
ppcm	pixels per centimetre
ppi	pixels per inch
ppmm	pixels per millimetre
RF	radio frequency
TIR	total internal reflection
TLV	tag-length-value

5 Conformance

A biometric data block conforms to this document if it satisfies all of the normative requirements related to:

— its data structure, data values and the relationships between its data elements as specified throughout Clauses 7 and 8 and Annex A of this document; and

— the relationship between its data values and the input biometric data from which the biometric data block was generated as specified in Clause 6.

NOTE A biometric data block will always conform to only one of the following formats:

— tagged binary encoding as specified in 8.1, or

— XML encoding as specified in 8.2, or

— binary encoding for on-card biometric comparison as specified in 8.3.

A system that produces biometric data blocks is conformant to this document if all biometric data blocks that it outputs conform to this document (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 blocks that cover all possible aspects of this document, but only those that are claimed to be supported by the system in the ICS.

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

Conformance test methodology shall be in accordance with Annex B.

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6 Modality-specific information

6.1 Purpose

This clause defines the placement of minutiae on the fingerprint. Compatible minutiae extraction is required for interoperability between different finger comparators for the purposes of comparing an individual against previously collected and stored finger biometric data. Interoperability is based on the definition of the finger minutiae extraction rules, the definition of the ASN.1 format (8.1 and Clause A.1), the definition of the XML encoding format (8.2 and Clause A.2), and the on-card biometric comparison format (8.3) that are common to many finger comparators for acceptable comparing accuracy, while allowing for extended data to be attached for use with equipment with which they are compatible.

6.2 Minutia description

The establishment of a common feature-based representation shall rely on agreement over the fundamental notion for representing a fingerprint. Minutiae are points located at the places in the fingerprint image where friction ridges end or split into two ridges. Describing a fingerprint in terms of the location and direction of these ridge endings and bifurcations provides sufficient information to reliably determine whether two fingerprint records are from the same finger.

The specifications of minutia location and minutia direction described in the following subclauses accomplish this. See Figures 2 to 4 for illustrations of the following definitions.

6.3 Minutia kind

6.3.1 General

There are two major kinds of minutiae: a "ridge skeleton end point" and a "ridge skeleton bifurcation point" or split point. There are also other kinds of "points of interest" in the friction ridges. These occur much less frequently and are more difficult to define precisely. More complex kinds of minutiae are usually a combination of the basic kinds defined above. Some points are neither a ridge ending nor a bifurcation. Therefore, this document defines an additional kind named "other", which shall be used for such a case. The "other" minutiae kind shall not be used for minutiae that are ridge endings or ridge bifurcations.

Therefore, the following kinds of minutiae are distinguished:

— ridge ending,

— ridge bifurcation,

— other.

A ridge ending may alternatively be referred to as a valley bifurcation depending on the method to determine its position (6.4.3 and 6.4.5).

6.3.2 Unique minutia

A minutia shall be encoded once. A minutia is uniquely identified by the location and angle.

6.3.3 Encoding trifurcations

The location at which a ridge splits into three separate ridges is a trifurcation. If it is encoded, it shall be encoded as two bifurcations with identical (X,Y) values and different orientation angle values.

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6.4 Minutia location

6.4.1 General

The minutia location is represented by its horizontal and vertical position. The minutiae determination strategy considered in this document relies on skeletons derived from a digital fingerprint image. The ridge skeleton is computed by thinning down the ridge area to single-pixel-wide lines. The valley skeleton is computed by thinning down the valley area to single-pixel-wide lines. If other methods are applied, they should approximate the skeleton method, i.e. location and angle of the minutia should be equivalent to the skeleton method.

6.4.2 Coordinate system

The coordinate system used to express the minutiae of a fingerprint shall be a Cartesian coordinate system. Points shall be represented by their X and Y coordinates. The origin of the coordinate system shall be the upper left corner of the original image with X increasing to the right and Y increasing downward. This is in agreement with most imaging and image processing use. When viewed on the finger, X increases from right to left as shown in Figure 1. All X and Y values are non-negative.

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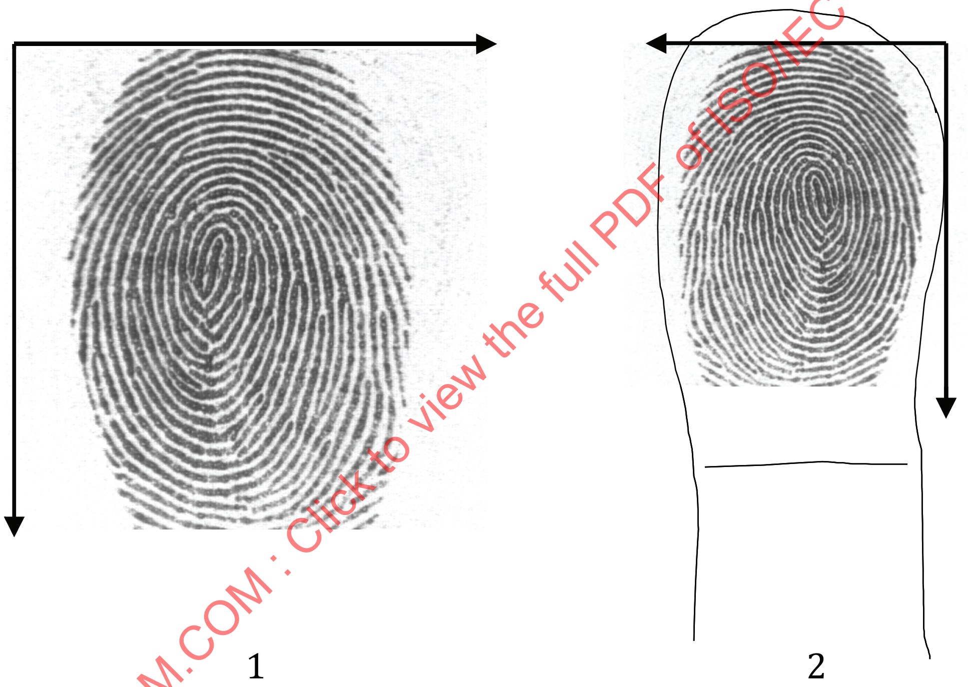

Key

1 fingerprint image

2 finger

Figure 1 — Coordinate System

For the finger minutiae ASN.1 format (8.1 and Clause A.1) and the XML format (8.2 and Clause A.2), the X and Y coordinates of the minutiae are stored in the FeatureCoordinateBlock and measured in pixel units, with the spatial sampling rate given in the SpatialSamplingRateBlock.

For the on-card biometric comparison format (8.3), the X and Y coordinates shall be measured in fixed metrical units of one bit per one tenth of a millimetre, or 10^{-1} mm as described in 8.3.4.

6.4.3 Minutia location of a ridge ending (encoded as valley skeleton bifurcation point)

The location of a ridge ending (encoded as valley skeleton bifurcation point) shall be defined as the point of forking of the medial skeleton of the valley area immediately in front of the ridge ending. If the

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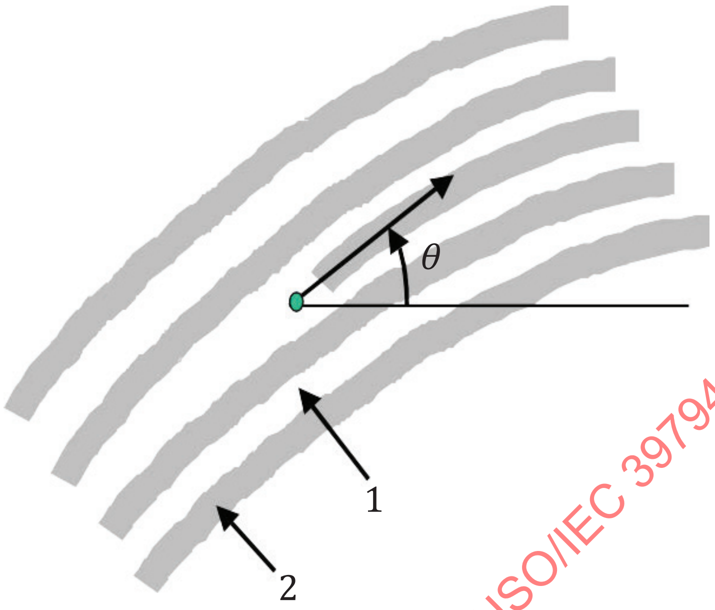
valley area were thinned down to a single-pixel-wide skeleton, the point where the three skeletal lines intersect is the location of the minutia. In simpler terms, it is the point where the valley bifurcates, or (equivalently) where the three thinned valley lines intersect (see Figure 2).



Key

1 valley

2 ridge

Figure 2 — Location and direction of a ridge ending (encoded as valley skeleton bifurcation point)

6.4.4 Minutia location of a ridge bifurcation

The location of a ridge bifurcation shall be defined as the point of forking of the medial skeleton of the ridge. If the ridges were thinned down to a single-pixel-wide skeleton, the point where the three skeletal lines intersect is the location of the minutia. In simpler terms, it is the point where the ridge bifurcates, or (equivalently) where the three skeletal lines of the thinned ridge intersect (see Figure 3).

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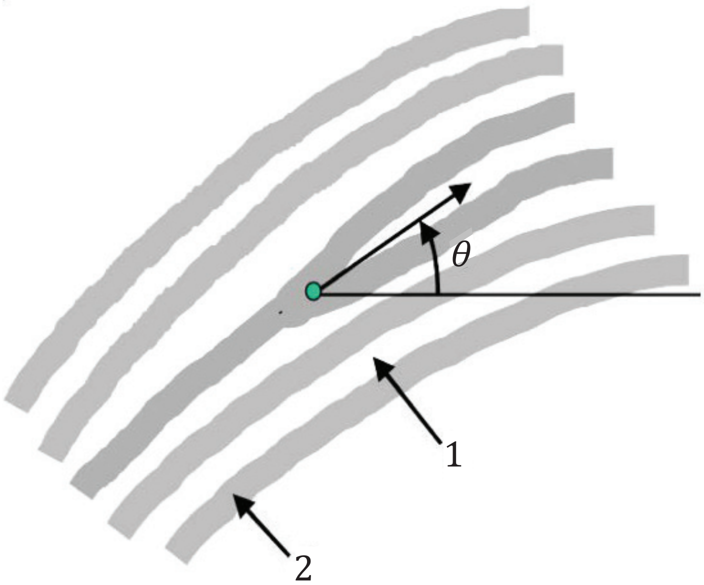


Key

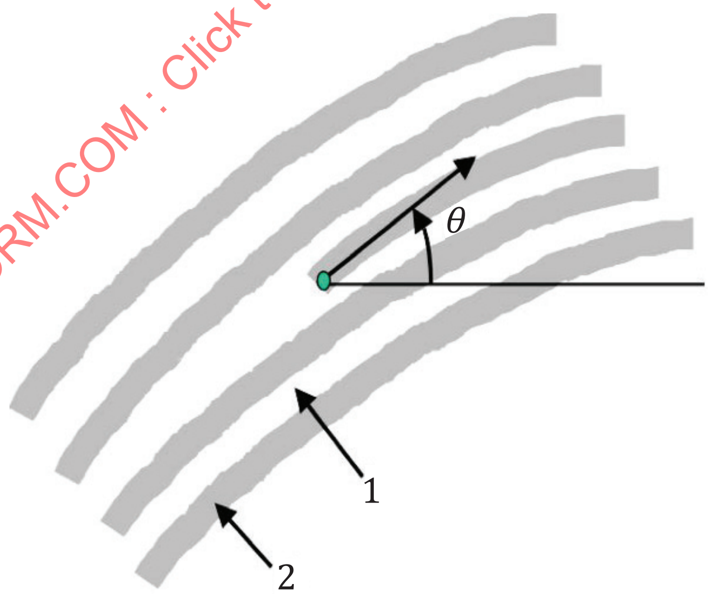
1 valley

2 ridge

Figure 3 — Location and direction of a ridge bifurcation

6.4.5 Minutia location of a ridge ending (encoded as ridge skeleton endpoint)

The location of a ridge ending (encoded as ridge skeleton endpoint) shall be defined as the centre point of the ending ridge. If the ridges in the digital fingerprint image were thinned down to a single-pixel-wide skeleton, the position of the minutia would be the coordinates of the skeleton point with only one neighbour pixel belonging to the skeleton (see Figure 4).



Key

1 valley

2 ridge

Figure 4 — Location and direction of a ridge ending (encoded as ridge skeleton endpoint)

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6.4.6 Usage of the minutia placement

Depending on the specific algorithms implemented, for tagged binary encoding, XML encoding and on-card biometric comparison format, the following are used:

— valley skeleton bifurcations or ridge skeleton endpoints for locating minutiae on ridge endings; and

— ridge skeleton bifurcations for locating minutiae on ridge bifurcations.

For on-card biometric comparison, a card will request from the card usage system biometric probe data in the format compliant to its algorithm. The requested format is either implicitly known to the card usage system or can be retrieved in the biometric information template (BIT; see ISO/IEC 19785-3 and ISO/IEC 7816-11).

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6.5 Minutiae direction

6.5.1 Angle conventions

The minutia angle is measured increasing counter-clockwise starting from the horizontal axis to the right.

In the finger minutiae ASN.1 format (8.1 and Clause A.1) and the XML format (8.2 and Clause A.2), the angle of a minutia stored in the MinutiaBlock is scaled to fit the granularity of 1,406 25 (360/256) degrees per least significant bit.

The angle coding for the on-card biometric comparison format (8.3) is scaled to fit the granularity of 5,625 (360/64) degrees per least significant bit as described in 8.3.6.

6.5.2 Minutia direction of a ridge ending (encoded as valley skeleton bifurcation point)

A ridge ending (encoded as valley skeleton bifurcation point) has three arms of valleys meeting in one point. Two valleys enclosing the ridge ending line encompass an acute angle. The direction of a valley bifurcation is measured as the angle the tangent of the ending ridge forms with the horizontal axis to the right (see Figure 2).

6.5.3 Minutia direction of a ridge bifurcation

A ridge bifurcation has three arms of ridges meeting in one point. Two ridges enclosing the ending valley encompass an acute angle. The direction of a ridge bifurcation is measured as the angle the tangent of the ending valley forms with the horizontal axis to the right (see Figure 3).

6.5.4 Minutia direction of a ridge ending (encoded as ridge skeleton endpoint)

The direction of a ridge ending (encoded as ridge skeleton endpoint) is defined as the angle that the tangent to the ending ridge encompasses with the horizontal axis to the right (see Figure 4).

6.6 Core and delta placement

Core and delta points are designated points of interest in a fingerprint. A fingerprint may have 0, 1 or more cores and 0, 1 or more deltas. The location of the core and delta positions are defined as follows.

— 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.

— Delta position: Three points of divergence are each placed between the two ridges at the location where the ridges begin to diverge, i.e. 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 position is at the point on a ridge at, or in front of, and nearest the

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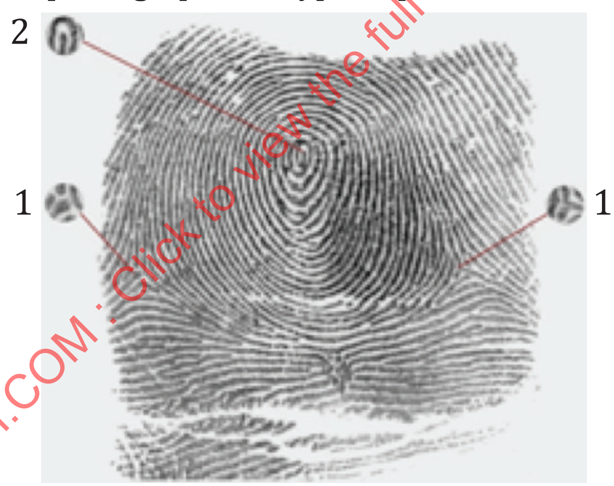
centre of the divergence of the ridges that start parallel, diverge and surround or tend to surround the pattern area of the fingerprint image.

Core and delta point placement are illustrated in Figure 5.

NOTE Cores and deltas represent singularities in the ordinary direction field of the fingerprint image. Hence, angle information of cores and deltas cannot fit smoothly into the direction values of all points in the neighbourhood.

a) Example fingerprint of type loop with core and delta



b) Example fingerprint of type whorl with core and deltas

Key

1 delta

2 core

Figure 5 — Example fingerprints of type loop and whorl with placement of core and delta points

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7 Abstract data elements

7.1 Purpose

This clause describes the contents of data elements defined in this document. These descriptions are independent of the encoding of the data elements. The full naming conventions for ASN.1 module components and component types definitions, naming conventions for XML schema elements and element types definitions, and ASN.1 and XML schema definition extensions applied as per the ISO/IEC 39794 series are specified in ISO/IEC 39794-1.

The tagged binary encoding as well as the XML encoding are given in 8.1, 8.2 and Annex A.

The structure of the abstract data elements is described in Figure 6.

Abstract data elements defined in this clause are used by tagged binary encoding (8.1) and XML encoding (8.2) extensible biometric formats, which are typically used outside the ICC environment. These abstract elements are not utilized in the same way as in on-card biometric comparison binary format based on TLV encoding (see 8.3).

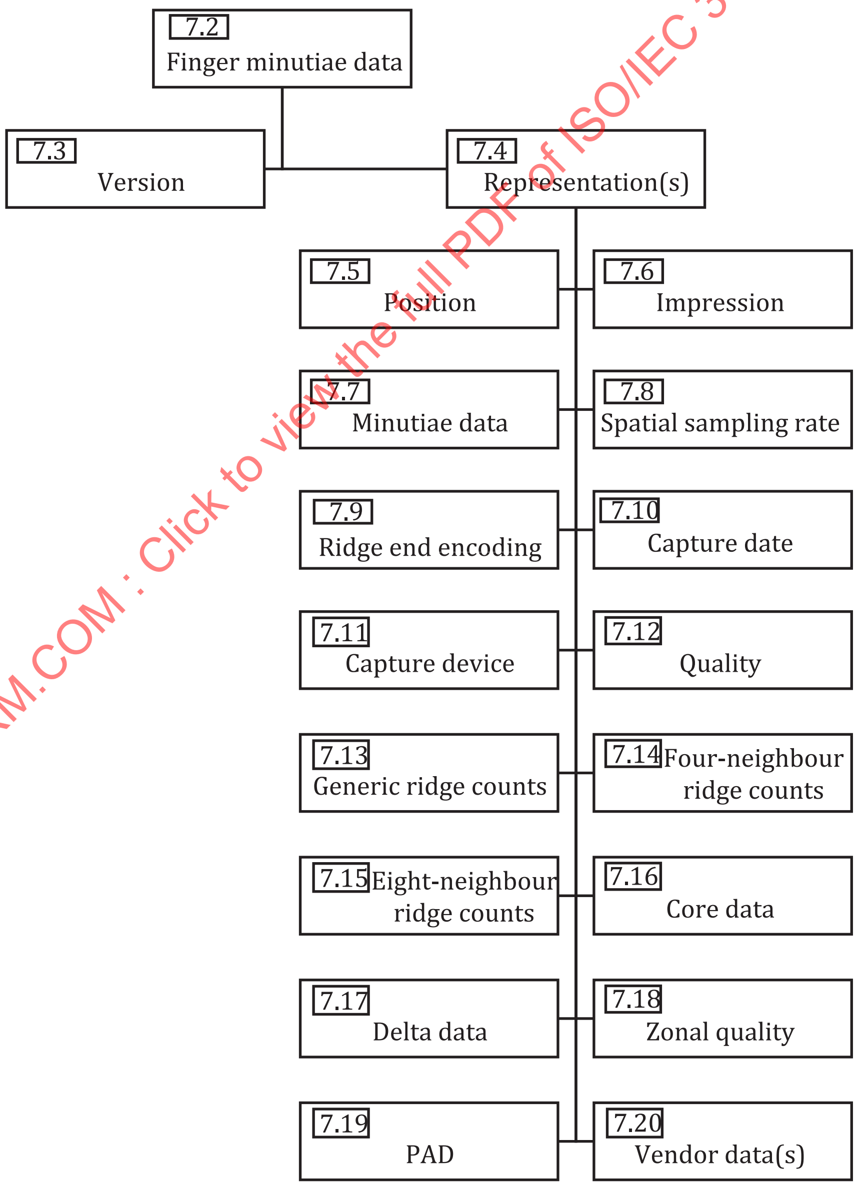

Figure 6 — Overall structure of finger minutiae data

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7.2 Finger minutiae data

Abstract values: See Figure 6.

Contents: This data element is the container for all data associated with finger minutiae.

7.3 Version

Abstract values: See ISO/IEC 39794-1.

Contents: The generation number of this document shall be 3. The year shall be the year of the publication of this document.

7.4 Representation block

Abstract values: See Figure 6.

Contents: This data element is the container for all data associated with finger minutiae, except for the version block information.

7.5 Position

Abstract values: See Table 1.

Contents: This data element establishes which finger region is encoded in the image data. For example, a right index finger image is described with a position of "right-IndexFinger" in an ASN.1 encoding. The position encodings are specified to improve interoperability with existing standards, notably the ANSI/NIST ITL standard family.

Table 1 — Description for finger position values

Abstract value	Description
unknownPosition	Unknown finger
rightThumbFinger	Right thumb
rightIndexFinger	Right index finger
rightMiddleFinger	Right middle finger
rightRingFinger	Right ring finger
rightLittleFinger	Right little finger
leftThumbFinger	Left thumb
leftIndexFinger	Left index finger
leftMiddleFinger	Left middle finger
leftRingFinger	Left ring finger
leftLittleFinger	Left little finger

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7.6 Impression

Abstract values: See Table 2.

Contents: This data element establishes how the finger interacted with the capture system at the time of capture. The impression encodings are specified to improve inter-operability with existing standards, notably the ANSI/NIST ITL standard family.

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Table 2 — Description for finger impression values

Abstract value	Description
plainContact	A stationary subject's finger in contact with a fixed scanning surface (or platen).
rolledContact	A laterally rolled subject's finger in contact with a fixed scanning surface (or platen).
latentImage	A residue from a subject's finger left on a surface that has been captured.
swipeContact	A moving subject's finger (typically vertically) in contact with a fixed thin scanning bar.
stationarySubjectContactlessPlain	A subject's finger captured without contact in such a way that the image is not representative of a roll or other 3D structure, and in which the subject is expected to remain mostly motionless.
stationarySubjectContactlessRolled	A subject's finger captured without contact in such a way that the image is representative of a roll or other 3D structure, and in which the subject is expected to remain mostly motionless. A multi camera system that captures many views of a fingerprint and stitches them together to create a rolled image would fall into this category.
other	Unspecified.
unknown	Unknown.
movingSubjectContactlessRolled	A subject's finger captured without contact in such a way that the image is representative of a roll or other 3D structure, and in which the subject is expected to move to perform an effective capture. A system in which a subject performs a rolling action above or inside a capture system (without platen contact) would fall into this category.
movingSubjectContactlessPlain	A subject's finger captured without contact in such a way that the image is not representative of a roll or other 3D structure, and in which the subject is expected to move to perform an effective capture. A contactless swipe sensor in which the subject slides their fingers above a capture system would fall into this category.

7.7 Minutiae data

Abstract values: See Table 3.

Contents: This data element contains the encoded minutiae data. It is a sequence of minutia blocks shown in Table 3.

Table 3 — Minutia block

Element	Description
coordinateBlock	x-coordinate
	y-coordinate
angle	orientation of the minutia
kind	ridge ending, bifurcation or other
index	minutia index (optional)
quality	quality score of the minutia (optional)

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7.8 Spatial sampling rate

Abstract values: See Table 4.

Contents: This data element specifies the spatial sampling rate of the original image from which the minutiae have been extracted. It consists of two elements:

— the number of samples or pixels per unit distance, and

— the unit of measure for which the number of samples is related (either inch or cm).

If this element is not present, the image's spatial sampling rate is established at 500 pixels per inch (ppi), or equivalently 197 pixels per centimetre (ppcm).

Table 4 — Spatial sampling rate block

Element	Description
samplesPerUnit	number of pixels per unit
unitDimension	unit dimension (inch or cm)

7.9 Ridge end encoding

Abstract values: See Table 5.

Contents: This data element specifies whether ridge endings are encoded as ridge skeleton end points or valley bifurcation points.

Table 5 — Description of ridge end encoding

Abstract value	Description
TRUE	ridge endings are encoded as valley bifurcations
FALSE	ridge endings are encoded as ridge skeleton end points

7.10 Capture date and time

See ISO/IEC 39794-1.

7.11 Capture device

7.11.1 Capture device model identifier

See ISO/IEC 39794-1.

7.11.2 Certification identifier blocks

See ISO/IEC 39794-1.

7.11.3 Certification schemes for finger images

Abstract values: See Table 6.

Contents: The certification scheme identifiers are defined by ISO/IEC JTC 1/SC 37. A list of current certification scheme identifiers for certification schemes in ISO/IEC 39794-4:2019, Annex D, is contained in Table 6.

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Table 6 — Certification scheme identifiers

Certification scheme identifier	Reference
1	ISO/IEC 39794-4:2019, Clause D.1 — Image quality specification for AFIS systems
2	ISO/IEC 39794-4:2019, Clause D.2 — Image quality specification for personal verification
3	ISO/IEC 39794-4:2019, Clause D.3 — Requirements and test procedures for optical fingerprint scanners
4 to 65535	Reserved by SC 37 for future use

7.11.4 Capture device technology identifier

Abstract values: See Table 7.

Contents: This data element establishes the class of capture device technology used to acquire the captured biometric sample. See Table 7 for a description of the abstract values. The technology encodings are specified to improve interoperability with existing standards, notably ISO/IEC 39794-4.

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Table 7 — Description for finger image capture device technology identifier

abstract value	Description
unknownTechnology	Capture device technology information was not captured or has been lost.
otherTechnology	Capture device technology information is known, but does not correspond to any specified values.
scannedInkOnPaper	Subjects ink their fingerprints and apply them to paper (cardstock) which can then be imaged/scanned. Card scanners should encode their technology type as scannedInkOnPaper.
opticalTIRBrightField	Contact Prism such that ridges absorb light from the illumination system.
opticalTIRDarkField	Contact Prism such that ridges reflect light from the illumination system.
opticalImage	Differences in the ridge detail are captured by an optical capture system.
opticalLowFrequency3DMapped	A 3D model of the shape of the finger is used to project reflected light from ridges onto a flattened (2D) model of the finger.
opticalHighFrequency3DMapped	A 3D model that is sensitive to the 3D distances between ridges and valleys is used to project reflected light from ridges onto a flattened (2D) model of the finger.
capacitive	A contact sensor that utilizes the difference in charge between touching ridges and non-touching valleys. The sensor acts as one plate of the capacitor, the non-conducting epidermis as a dielectric, and the conducting dermis as the other plate. There are active and passive versions of the technology.
capacitiveRF	A low radio frequency (RF) signal is applied to the ridge detail and reflections are sensed by the detector array, with each pixel operating like a tiny antenna.
electroLuminescence	A contact technology in which the ridges and an alternating current (AC) signal cause an electroluminescent (EL) panel to emit light which is captured by an imaging system.
reflectedUltrasonic	High frequency sound signals are applied to the ridge detail and the acoustic response is sensed by the detector array, with each pixel operating like a tiny microphone.
impediographicUltrasonic	A contact technology in which the absorption of ultrasonic energy is measured by changes in the impedance of a piezo-electric material.

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Table 7 *(continued)*

abstract value	Description
thermal	Thermal differences between contact ridges and ambient temperature in valleys are used by a detector array, with each pixel operating like a tiny thermometer.
directPressure	Sensors which operate by measuring the pressure difference between ridges and valleys, as the valleys are not involved in any direct force on the surface of the sensor. The pressure is measured by a detector array, with each pixel operating like a tiny scale. In practice, these sensors are electronic binary switches that use time and/or spatial diversity to achieve greyscale detail.
indirectPressure	A contact technology in which the pressure of the fingerprint ridge skin against a deformable material is assessed optically to produce a finger image.
liveTape	A technology in which one-time use tape is used on live finger skin to collect friction ridge detail and the tape is then subsequently imaged by traditional photography.
latentImpression	A powder is applied to a surface that a fingerprint has touched. The oil residue of the finger attaches to the powder. This is then photographed and post-processed to produce a latent finger image.
latentPhoto	A printed photograph of a latent impression is subsequently imaged (with a scanner or camera).
latentMolded	A mold of a latent is fabricated and utilized to construct an artificial finger which is then used with a PAD-disabled scanner to produce a latent finger image.
latentTracing	An older legacy latent finger capture process in which a hand-drawn or computer-drawn tracing is subsequently imaged by a flatbed scanner or photographed.
latentLift	A powder is applied to a surface that a fingerprint has touched. The oil residue of the finger attaches to the powder. Transparent tape is then placed over the latent and is photographed after the tape is removed or lifted.
activeThermal	Active thermal sensors which operate by injecting a pulsed heat signal and measuring heat dissipation or heat conductivity rather than (passive) thermal sensors measuring temperature.

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7.12 Biometric sample quality blocks

See ISO/IEC 39794-1.

7.13 Generic ridge counts

Abstract values: See Table 8.

Contents: This data element includes generic ridge count information as a sequence of ridge count elements. Each ridge count element specifies:

— a first minutia index, and

— a second minutia index.

The number of ridges crossed when drawing a straight line between the first and second minutia.

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Table 8 — Generic ridge count block

Element	Description
minutiaIndex1	index of first minutia
minutiaIndex2	index of second minutia
ridgeCount	number of ridges crossed between the two minutiae

7.14 Four neighbour ridge counts

Abstract values: See Table 9.

Contents: This data element includes four-neighbour ridge count data expressed as a sequence of four-neighbour ridge count blocks. The image area around a centre minutia is split into four quadrants and the ridge count is recorded for the closest minutia in every quadrant.

Table 9 — Four neighbour ridge count block

Element	Description
centerMinutiaIndex	index of the centre minutia for this block
topRightMinutiaCountBlock	index of the nearest top-right neighbour minutia and ridge count to centre minutia
bottomRightMinutiaCountBlock	index of the nearest bottom-right neighbour minutia and ridge count to centre minutia
bottomLeftMinutiaCountBlock	index of the nearest bottom-left neighbour minutia and ridge count to centre minutia
topLeftMinutiaCountBlock	index of the nearest top-left neighbour minutia and ridge count to centre minutia

7.15 Eight neighbour ridge counts

Abstract values: See Table 10.

Contents: This data element includes eight-neighbour ridge count information. The image area around a centre minutia is split into eight equally sized fragments and the ridge count is recorded for the closest minutia in every octant.

Table 10 — Eight neighbour ridge count block

Element	Description
centerMinutiaIndex	index of the centre minutia for this block
octant0CountBlock	index of the nearest neighbour minutia in octant and ridge count to centre minutia
octant1CountBlock	index of the nearest neighbour minutia in octant and ridge count to centre minutia
octant2CountBlock	index of the nearest neighbour minutia in octant and ridge count to centre minutia
octant3CountBlock	index of the nearest neighbour minutia in octant and ridge count to centre minutia
octant4CountBlock	index of the nearest neighbour minutia in octant and ridge count to centre minutia
octant5CountBlock	index of the nearest neighbour minutia in octant and ridge count to centre minutia

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Table 10 *(continued)*

Element	Description
octant6CountBlock	index of the nearest neighbour minutia in octant and ridge count to centre minutia
octant7CountBlock	index of the nearest neighbour minutia in octant and ridge count to centre minutia

7.16 Core data

Abstract values: See Table 11.

Contents: This data element includes core information. A fingerprint can have one or two cores, each having coordinates and an optional orientation angle.

Table 11 — Core data block

Element	Description
coordinateBlock	X-coordinate
	Y-coordinate
angle	orientation of the core (optional)

7.17 Delta data

Abstract values: See Table 12.

Contents: This data element includes delta information. A fingerprint can have multiple deltas, each having position coordinates and an optional block of three angles.

Table 12 — Delta data block

Element	Description
coordinateBlock	X-coordinate
	Y-coordinate
angles (optional)	angle 1
	angle 2
	angle 3

7.18 Zonal quality

Abstract values: See Table 13.

Contents: This data element contains zonal quality information. The fingerprint is segmented into several cells. Zonal quality data is a sequence of algorithm identifier, cell dimensions and cell quality blocks.

Table 13 — Zonal quality block

Element	Description
algorithmIDBlock	identifier for registered quality algorithm
cellWidth	width of the cell
cellHeight	height of the cell
cellQualityBlocks	sequence of cell quality values (optional)

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7.19 PAD data block

See ISO/IEC 39794-1.

7.20 Vendor specific data

See extended data blocks in ISO/IEC 39794-1.

This data element contains vendor-specific proprietary data associated with the friction ridge. As this is an interoperable data interchange format, this data element shall not be used to contain data that can be provided with other elements of this document.

8 Encoding

8.1 Tagged binary encoding

Clause A.1 specifies an ASN.1 schema in which the abstract data elements of Clause 7 are constrained by types defined by the ASN.1 standard (ISO/IEC 8824-1), ASN.1 types defined by ISO/IEC 39794-1, or by ASN.1 types defined in this document.

The tagged binary encoding of finger minutiae data shall be obtained by applying the ASN.1 distinguished encoding rules (DER), in accordance with ISO/IEC 8825-1, to a value of the type FingerMinutiaeDataBlock defined in the given ASN.1 module. The DER encoding of each data object has three parts: tag octets that identify the data object, length octets that give the number of subsequent value octets, and the value octets.

The ASN.1 module in Clause A.1 can be retrieved from https://standards.iso.org/iso-iec/39794/-2/ed-1.

See Annex C for the encoding sample.

8.2 XML encoding

Clause A.2 specifies an XSD schema, in which the abstract data elements of Clause 7 are constrained by types defined by the XML standard, XML types defined by 39794-1, or by XML types defined in this standard.

An XML document encoding finger minutiae data shall obey the given XSD.

The XSD in Clause A.2 can be retrieved from https://standards.iso.org/iso-iec/39794/-2/ed-1.

See Annex C for the encoding sample.

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8.3 On-card biometric comparison format

8.3.1 Overview

The finger minutiae on-card biometric comparison format is for use with integrated-circuit cards and other tokens. Its main area of application is on-card biometric comparison (see ISO/IEC 24787-1 and ISO/IEC 7816-11) of finger minutiae data.

The finger minutiae on-card biometric comparison format is more compact than the tagged binary encoding defined in 8.1. It fixes the spatial sampling rate to 10 ppmm to encode each minutia coordinate in only one byte and omits information about the structure and contents of the finger minutiae data, which is included in the tagged binary encoding. Information necessary for the comparison process is stored in a separate comparison parameters data object as defined in 8.3.9.

Table 14 depicts the structure of a finger minutiae data block in on-card comparison format (see ISO/IEC 24787-1 and ISO/IEC 7816-11 for comparison).

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All multibyte quantities are represented in Big-Endian format, i.e. the more significant bytes of any multibyte quantity are stored at lower addresses in memory than (and are transmitted before) less significant bytes. All numeric values are fixed-length integer quantities and unsigned quantities.

Table 14 — Biometric data template

Tag	Length	Value					Presence
$7F2E_{\text{Hex}}$	var.	Biometric data template					
		Tag	**Length**	**Value**			
		91_{Hex}	var.	Ridge count data according to 8.3.8.2			Optional
		92_{Hex}	var.	Core point data according to 8.3.8.3			Optional
		93_{Hex}	var.	Delta point data according to 8.3.8.3			Optional
		94_{Hex}	var.	Zonal quality data according to 8.3.8.4			Optional
		95_{Hex}	1	Impression type according to 8.3.8.5			Optional
		96_{Hex}	5	Quality block			Optional
				Quality block vendor id (2 bytes)	Quality algorithm id. (2 bytes)	Quality score or error code	
		$B6_{\text{Hex}}$	var.	Quality blocks			Optional
				Tag	**Length**	**Value**	
				96_{Hex}	5	Quality block 1	Mandatory if DO with tag $B6_{\text{Hex}}$ is present
				...	...	...	
				96_{Hex}	5	Quality block n	optional
		82_{Hex} / $A2_{\text{Hex}}$	var.	Biometric data with vendor specific format			Optional
		81_{Hex}	var.	Finger minutiae data			
				Field	Size (bits)	Valid values	Multiple Instances
				X coordinate	8	[0,255]	
				Y coordinate	8	[0,255]	
				Minutiae Type	2		
				Minutiae angle	6	[0,63]	
		$A1_{\text{Hex}}$	var.	Constructed finger minutiae data in standard format			If DOs with tags 82_{Hex}/$A2_{\text{Hex}}$ and at least one of the DOs with tags 91_{Hex} to 95_{Hex} are present
				Tag	**Length**	**Value**	
				81_{Hex}	var.	Primitive finger minutiae data in standard format	Mandatory if DO with tag $A1_{\text{Hex}}$ is present
				91_{Hex}	var.	Ridge count data	At least one of the DOs with tags 91_{Hex} to 95_{Hex}
				92_{Hex}	var.	Core point data	
				93_{Hex}	var.	Delta point data	

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Table 14 *(continued)*

Tag	Length	Value					Presence
				94_{Hex}	var.	Zonal quality data	
				95_{Hex}	1	Impression type	

8.3.2 Minutia placement

This on-card biometric comparison format requires that all ridge endings shall be encoded as either valley bifurcation points or ridge skeleton end points as defined in 6.4.3 and 6.4.5 respectively. If valley bifurcations are used, then the CBEFF BDB format type identifier 0005_{Hex} shall be used in the BIT defined in ISO/IEC 19785-3. If ridge skeleton end points are used, then the CBEFF BDB format type identifier 0006_{Hex} shall be used.

8.3.3 Encoding

Using the on-card biometric comparison format, three bytes are needed to encode each minutia. Table 15 illustrates the layout of the bits and bytes for minutiae position, type and angle descriptors.

Table 15 — On-card biometric comparison format

X coordinate	Y coordinate	type, *t*	angle, θ
1 byte	1 byte	2 bits	6 bits

8.3.4 Minutia position

The 8-bit X coordinate of the minutia shall be recorded in the first byte. The 8-bit Y coordinate shall be placed in the following byte. The coordinates shall be expressed such that each unit is equal to 10^{-1} mm. Ridge endings shall be encoded as ridge skeleton end points or valley bifurcation points.

NOTE The maximum value for the X and Y coordinates is 25,5 mm with the on-card biometric comparison format.

8.3.5 Minutia type

The type of minutia (type *t* in Table 15) will be recorded in the most significant two bits of the byte whose less significant bits contain the angle value for the minutiae. The bits “00” will represent a minutia of type “other”, “01” will represent a ridge ending and “10” will represent a ridge bifurcation. Type “11” is reserved by JTC 1/SC 37 for future use.

8.3.6 Minutia angle

The angle of the minutia shall be recorded in six bits in units of 5,625 (360/64) degrees. The value shall be a non-negative value between 0 and 63, inclusive. For example, an angle value of 16 represents 90,0 degrees. Angle information shall be present for each minutia, regardless of type.

NOTE Minutiae of “other” type can represent either a ridge ending or ridge bifurcation when the minutia type cannot reliably be determined.

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8.3.7 Number of minutiae and truncation

8.3.7.1 General aspects

The minutiae data of a finger consist of *n* minutiae encoded as shown in Table 15. The number *n* depends on:

— the minimum number of minutiae required according to the security level;

— the maximum number of minutiae accepted by a specific card, e.g. due to buffer restrictions and computing capabilities.

The maximum number of minutiae accepted is therefore an implementation-dependent value and shall be indicated in the BIT, if the default value is not used.

A card can also require a special ordering of the minutiae presented in the biometric probe data. The ordering scheme shall be indicated in the BIT (see ISO/IEC 19785 and ISO/IEC 7816-11), if the default value is not used.

8.3.7.2 Removing minutiae for card processing

If the number of minutiae exceeds the maximum number the card indicates it can accept, then minutiae shall be removed according to one of the following two options.

— Minutiae with the largest Euclidean distance from the centre of mass shall be removed first. The centre of mass shall be computed before any minutiae are removed.

— If minutia quality data is available, minutiae of the lowest quality are removed first. When any two minutiae share the same quality value, the one with the largest Euclidean distance from the centre of mass of a minutia set shall be removed first. The centre of mass shall be computed before any minutiae are removed. For minutiae that have the same quality and Euclidean distances, remove ridge ending first, and for minutiae of the same type, remove minutia with largest angle first.

Removal shall be conducted before any needed sorting of the minutiae.

This procedure shall apply to both the enrolment of a reference template, and the preparation of a verification template.

8.3.7.3 Lack of minutiae

If the number of minutiae is fewer than the minimum number indicated by the card, the following options should be considered:

— re-acquisition of a sample from the subject;

— use of a different finger;

— prompt user or operator.

The implementation shall not assign fictional minutiae.

8.3.8 Usage of extended data for the on-card comparison format

8.3.8.1 Data objects for extended data

In the card format also, extended data beyond the finger minutiae may be present. In this case the usage of the biometric data template (tag $7F2E_{Hex}$) as described in ISO/IEC 7816-11 and defined in ISO/IEC 7816-6 is mandatory. Table 14 shows the biometric data template with its embedded data objects. If vendor-defined data are appended, then the biometric data in standardized format (DOs with tags 81_{Hex} and 91_{Hex} to 95_{Hex}) shall be encapsulated in the DO with tag $A1_{Hex}$, see Table 14.

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8.3.8.2 Ridge count data format

The minimum value for the extended data area length field of a ridge count extended data area is 5 bytes. This consists of 2 bytes for type, 2 bytes for length, and one byte to identify a ridge count extraction method. This format provides optional information about the number of fingerprint ridges between pairs of minutiae. Each ridge count is associated with a pair of minutiae. No ridge information may be contained that is associated with minutiae not included in the corresponding minutiae area. Ridge counts shall not include the ridges represented by either of the associated minutiae. Refer to Figure 7 for clarification; the ridge count between minutiae A and B is 1, while the ridge count between minutiae B and C is 2.

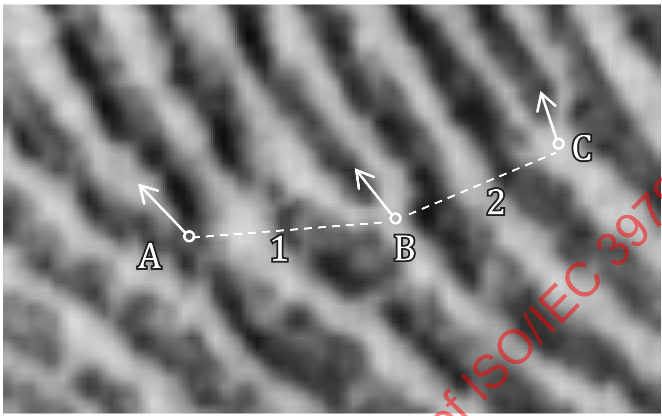

Figure 7 — Example ridge count data

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8.3.8.2.1 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 central minutia (a minutiae used as the reference to generate the subsequent ridge counts relevant for the ridge count extraction method) are frequently extracted in one of two ways: by extracting the ridge count to the nearest neighbouring minutia in each of four angular regions (or quadrants), or by extracting the ridge count to the nearest neighbouring minutia in each of eight angular regions (or octants). The ridge count extraction method field shall indicate the extraction method used, as shown in Table 16. It is not necessary for all minutiae in the minutiae data area to have ridge count data associated with each minutia.

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 central minutia shall be listed together;

— the central minutia shall be the first minutia referenced in the 3-byte ridge count data;

— the listing of the central minutiae of each 3-byte data block shall be ordered and the order of the listing of neighbouring minutiae for each central minutia are not defined by the standard.

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Table 16 — Ridge count extraction (RCE) 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 central minutia used, ridge count data is extracted to the nearest neighbouring minutia in four quadrants, and ridge counts for each central minutia are listed together.
02_{Hex}	Eight-neighbour (octants)	For each central minutia used, ridge count data is extracted to the nearest neighbouring minutia in eight octants, and ridge counts for each central minutia are listed together.

8.3.8.2.1.1 Eight-neighbour ridge count extraction method

Ridge count information for the eight-neighbour ridge count extraction method shall be extracted as follows.

— Each central minutia used shall be assigned its own unique "neighbourhood" consisting of eight octants (angular sectors of 45 degrees) of a (theoretical) circle centred on the location of the minutia. The octants shall be numbered counterclockwise from zero to seven with octant number zero locally centre-aligned with the direction of the minutiae. Figure 8 provides an example of a central minutiae whose "tail" is aligned toward the "South-Southwest" direction. The zero octant spans the arc of 22,5 degrees on either side of "South-Southwest". The "tail" bisects the zero octant.

— For each octant, a ridge count is produced by counting the number of ridges crossed by a (theoretical) straight line between the central minutia and the minutia nearest to it (i.e. its "nearest neighbour") in that octant, including the ridge on which the nearest neighbouring minutia lies (i.e. the number of intervening ridges plus one).

Note that the ridge(s) defining the minutia are considered part of the minutia. For example, if the central minutia is a ridge ending, and if the straight line passing from it to a nearest neighbouring minutia in another octant crosses over the ridge the central minutia is on, that crossover does not increment the count.

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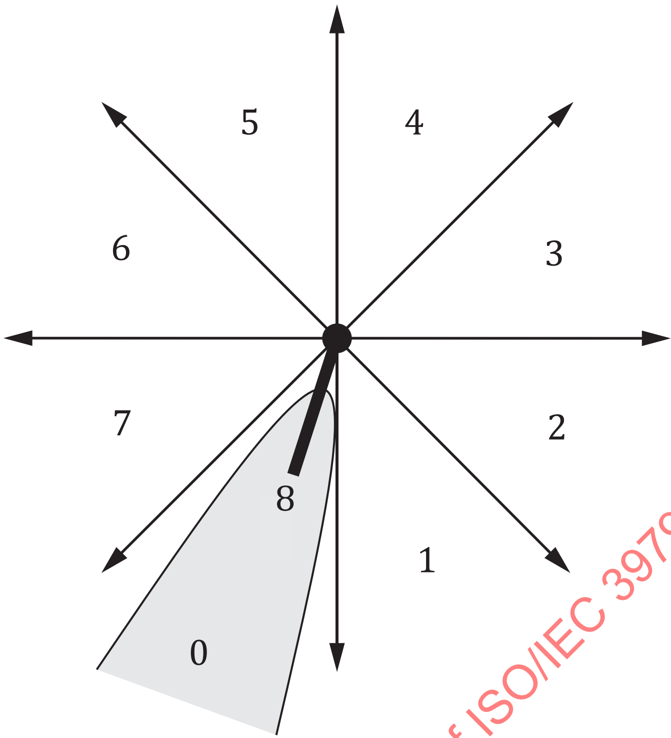

Key

0	octant 0
1	octant 1
2	octant 2
3	octant 3
4	octant 4
5	octant 5
6	octant 6
7	octant 7
8	ridge

Figure 8 — Eight-minutiae neighbourhood

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Due to the curving of ridges, the straight line between a minutia and its neighbour might cross a ridge twice (or more). In this case, the same ridge shall not be counted more than once, unless the straight line which connects the central minutia to its nearest neighbour minutia passes through at least the centre of one valley before entering back into the same ridge. A ridge shall not be counted unless the straight line passes at least to the centre of the ridge thickness.

8.3.8.2.1.2 Four-neighbour ridge count extraction method

Ridge count information for the four-neighbour ridge count extraction method shall be extracted as follows.

a) Each central minutia used shall be assigned its own unique “neighbourhood” consisting of four quadrants (angular sectors of 90 degrees) of a (theoretical) circle centred on the location of the minutia. The quadrants shall be numbered counterclockwise from one to four. The central minutia shall be locally aligned on the ‘Y’ axis between quadrant 3 and 4. Figure 9 provides an example of a central minutiae whose “tail” is aligned toward the “South” direction. The “tail” bisects the two lower quadrants.

b) For each quadrant, a ridge count is produced by counting the number of ridges crossed by a (theoretical) straight line between the central minutia and the minutia nearest to it (i.e. its “nearest neighbour”) in that quadrant, including the ridge on which the nearest neighbour minutia lies (i.e. the number of intervening ridges plus one).

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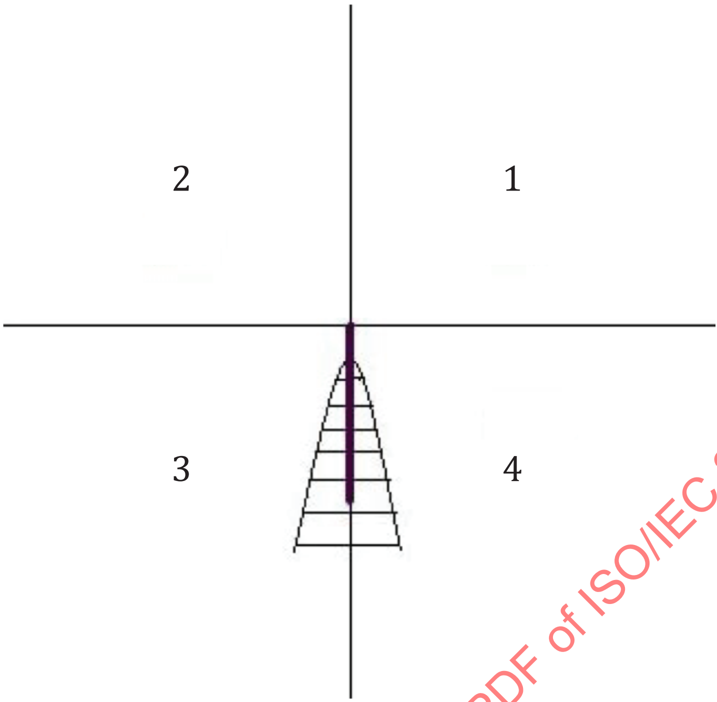
The ridge(s) defining the minutia are considered part of the minutia. For example, if the central minutia is a ridge ending, and if the straight line passes through one of the ridge segments forming the ridge ending, the latter is not counted as being separate from the minutia and does not increment the count.



Key

1 quadrant 1

2 quadrant 2

3 quadrant 3

4 quadrant 4

Figure 9 — Four-minutiae neighbourhood

Note also that due to the curving of ridges, the straight line between a minutia and its neighbour might cross a ridge twice (or more). In this case the same ridge shall not be counted more than once, unless the straight line which connects the central minutia to its nearest neighbour minutia passes through at least the centre of one valley before entering back into the same ridge. A ridge shall not be counted unless the straight line passes at least to the centre of the ridge thickness.

8.3.8.2.2 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 minutia area 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 neighbouring minutiae in it, a ridge count data 3-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, as shown in Table 17. 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.

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Table 17 — Example ridge count data (non-specific extraction method, RCE method = 00_{Hex})

Minutia index #1	Minutia index #2	Ridge count
01_{Hex}	02_{Hex}	05_{Hex}
01_{Hex}	06_{Hex}	09_{Hex}
01_{Hex}	07_{Hex}	02_{Hex}
02_{Hex}	04_{Hex}	13_{Hex}
02_{Hex}	09_{Hex}	$0D_{Hex}$
05_{Hex}	03_{Hex}	03_{Hex}
09_{Hex}	15_{Hex}	08_{Hex}

8.3.8.2.3 Ridge count format summary

The ridge count data format shall be as shown in Figure 10.

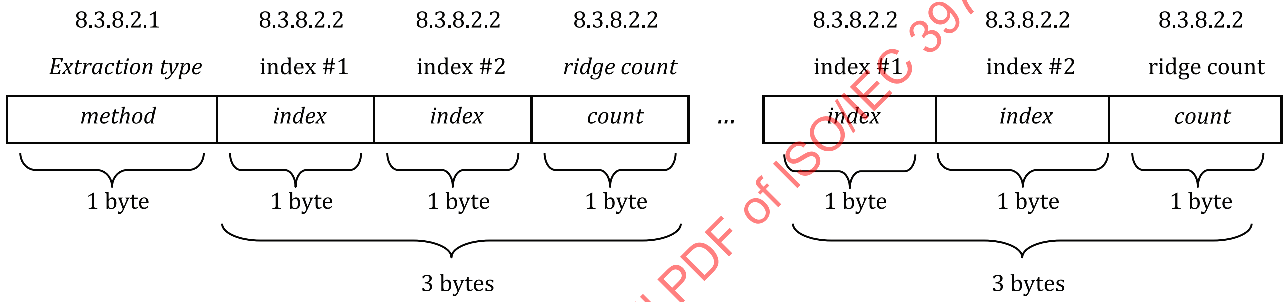

Figure 10 — Ridge count data format

8.3.8.3 Core and delta data format

8.3.8.3.1 General

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 can optionally include angular information. The required data entries for core and delta point placement are defined in the following subclauses.

NOTE The capability to precisely and consistently compute core and delta orientation has not been demonstrated and will require dedicated research and development to ensure interoperability.

8.3.8.3.2 Core information

8.3.8.3.2.1 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 high-order (most significant) 4 bits are reserved by JTC 1/SC 37 for future use and shall be set to 0.

8.3.8.3.2.2 Core information type

The core information type shall be recorded in the first two bits of the upper byte 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 fields shall not be present for the cores.

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8.3.8.3.2.3 Core position

The X coordinate of the core shall be recorded in the lower fourteen bits of the first two bytes of each core description. The Y coordinate shall be placed in the lower fourteen bits of the following two bytes. The high-order (most significant) 2 bits of the Y coordinate are reserved by JTC 1/SC 37 for future use and shall be set to 0. The coordinates shall be expressed in pixels at the spatial sampling rate of 10 ppmm.

8.3.8.3.2.4 Core angle

If present, the angle of the core shall be recorded in one byte in units of 1,406 25 (360/256) degrees. The core angle is measured increasing counterclockwise 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 0 (8.3.8.3.2.2) then this field shall not be present.

8.3.8.3.3 Delta information

8.3.8.3.3.1 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 high-order (most significant) 4 bits are reserved by JTC 1/SC 37 for future use and shall be set to 0.

8.3.8.3.3.2 Delta information type

The delta information type shall be recorded in the first two bits of the upper byte 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 the deltas.

8.3.8.3.3.3 Delta position

The X coordinate of the delta shall be recorded in the lower fourteen bits of the first two bytes of each delta description. The Y coordinate shall be placed in the lower fourteen bits of the following two bytes. The high-order (most significant) 2 bits the Y coordinate are reserved by JTC 1/SC 37 for future use and shall be set to 0. The coordinates shall be expressed in pixels at the spatial sampling rate of 10 ppmm.

8.3.8.3.3.4 Delta angles

If present, each of the three angle attributes of the delta shall each be recorded in one byte in units of 1,406 25 (360/256) degrees. The delta angle is measured increasing counterclockwise 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 0 (8.3.8.3.3.2) 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.

8.3.8.3.4 Core and delta format summary

The core and delta format shall be as shown in Figure 11 and Figure 12 respectively.

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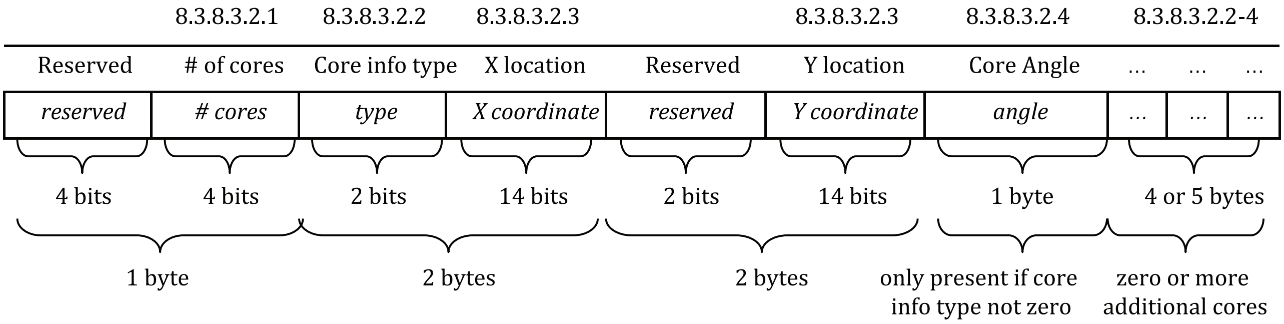

Figure 11 — Core data format

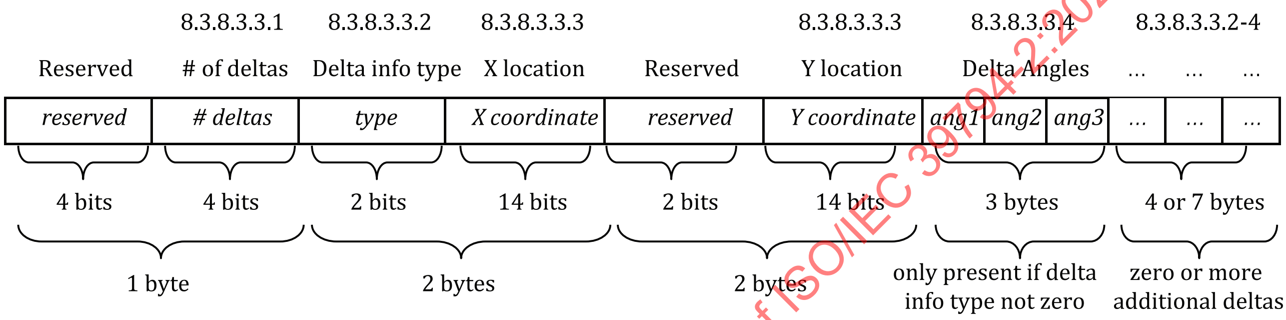

Figure 12 — Delta data format

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8.3.8.4 Zonal quality data modified for on-card comparison minutiae formats

8.3.8.4.1 Zonal quality data format summary

For the finger minutiae card formats, the image size in X and Y direction is not provided. Hence, the placement of the cells described in this clause is unknown. This information has to be provided in a header for the zonal quality data. Figure 13 shows the structure of zonal quality data in the finger minutiae on-card biometric comparison format.

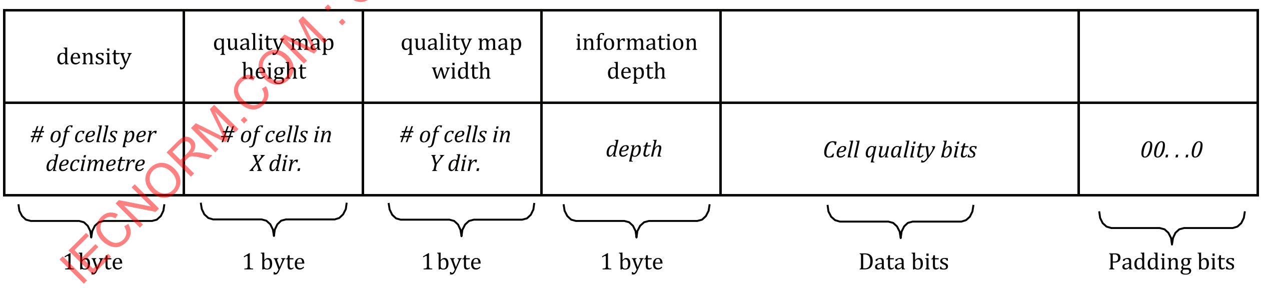

Figure 13 — Zonal quality data format

The first byte of the zonal quality data shall contain the spatial sampling rate of the quality map in cells per decimetre. The next two bytes shall contain the number of cells in the quality map in X and Y direction. The fourth byte gives the bit depth used for each cell. These header bytes shall be followed by the quality indication for each cell.

8.3.8.4.2 Density of cells in the quality map

This value shall indicate the number of cells in the quality map per decimetre. The density shall be uniform in X and Y direction. Permissible values are 20 to 255. The recommended value is 125 cells per decimetre.

8.3.8.4.3 Quality map width and height

The number of cells in X direction shall be stored in one byte. Permissible values are 1 to 255. The number of cells in Y direction shall be stored in one byte. Permissible values are 1 to 255.

8.3.8.4.4 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. Permissible values are 0, 1, 2, 4 and 8. With an information depth of 0, a rectangular image area of sufficient quality is defined by the width and height and the spatial sampling rate of the quality map.

8.3.8.4.5 Cell quality data

The quality of the fingerprint image in each cell shall be represented by one or more bits, as indicated in 8.3.8.4.5. 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

The cell quality shall be packed into bytes. The last byte used to encode the zonal quality data shall be left justified with unused bits set to 0.

In cases where the size in the X-direction is not divisible by the cell width, the number of cells shall be extended to include the rightmost region. The number of cells is then the rounded quotient of image width divided by cell width.

In cases where the size in the Y-direction is not divisible by the cell height, the number of cells shall be extended to include the bottommost region. The number of cells is then the rounded quotient of image height divided by cell height.

8.3.8.5 Impression type

The impression type of the finger images from which the minutiae data was derived shall be recorded in this 1-byte field. The codes for this byte are shown in Table 18. These codes are compatible with Table 9 of ANSI/NIST-ITL 1-2011: Update 2015.

Table 18 — Finger impression codes

Code	Description	Usage
0	Plain contact	
1	Rolled contact	
2	Nonlive-scan plain	no longer in use
3	Nonlive-scan rolled	no longer in use
4	Latent image	
5	Latent tracing	no longer in use
6	Latent photo	no longer in use
7	Latent lift	no longer in use
8	Swipe contact	
9	Vertical roll	no longer in use
10 to 23	Reserved by JTC 1/SC 37 for future use	
24	Stationary subject contactless plain	
25	Stationary subject contactless rolled	

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Table 18 *(continued)*

Code	Description	Usage
26 to 27	Reserved by JTC 1/SC 37 for future use	
28	Other impression	
29	Unknown impression	
41	Moving subject contactless rolled	
42	Moving subject contactless plain	

NOTE The impression type supports enrolment of the same finger multiple times, once with each sensor. The ON-CARD BIOMETRIC COMPARISON engine can perform the comparison of the verification template with the enrolled template of the same type. If no impression type is present, the ON-CARD BIOMETRIC COMPARISON algorithm will try to compare with whatever template is stored for the finger to compare.

8.3.9 Biometric comparison parameters

Biometric comparison parameters are used to indicate implementation-specific values to be observed by the outside world when computing and structuring the biometric probe data. They can be encoded as DOs embedded in a comparison parameter template as defined in ISO/IEC 19785-3:2020, Clause 11 (legacy format with biometric comparison parameters DO). Table 19 lists the DO biometric comparison parameters.

Table 19 — DO Biometric comparison parameters

Tag	Length	Value		
B1$_{Hex}$	var.	Biometric comparison parameters template		
		Tag	**Length**	**Value**
		81$_{Hex}$	2	Number of minutiae, see Table 20
		82$_{Hex}$	1	Minutiae order, see Table 21 and Table 22
		83$_{Hex}$	1	Feature handling indicator, see Table 23

8.3.9.1 Number of minutiae

For the indication of the minimum and maximum value of minutiae expected by the card, the DO number of minutiae as shown in Table 20 shall be used.

Table 20 — Data object for number of minutiae

Tag	Length	Value
81$_{Hex}$	2	min (1 byte, binary coding) || max (1 byte, binary coding)

If this DO is not present in the BIT, the default values apply.

8.3.9.2 Minutiae order

8.3.9.2.1 Data object for minutiae ordering

For the indication of the ordering scheme for minutiae, the DO Minutiae order as shown in Table 21 shall be used.

Table 21 — Data object for minutiae order

Tag	Length	Value
82$_{Hex}$	1	See Table 22

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Table 22 — Values for minutiae order indication

b8	b7	b6	b5	b4	b3	b2	b1	Meaning
0	0	0	0	0	0	0	0	No ordering required (default value)
						0	1	Ordered ascending
						1	0	Ordered descending
			0	0	1			Cartesian x-y[a]
			0	1	0			Cartesian y-x
			0	1	1			Angle[b]
			1	0	0			Polar, root = centre of mass
		1	0	0	0	0	0	X or Y coordinate extension for on- card biometric comparison format
x	x	x						000, other values are RFU

[a] Ordered by ascending/descending X-coordinate, if equal by ascending/descending Y-coordinate.

[b] The angle represents the orientation of the minutia.

The minutiae shall be ordered according to the procedures described in 8.3.9.2.2 to 8.3.9.2.8.

8.3.9.2.2 Ordered ascending

"Ordered ascending" means that the ordered sequence begins with the minutia from the original minutiae set that has the smallest value of the indicated item. The value of this item increases with every successive minutia to the maximum value in the last minutia of the ordered sequence.

8.3.9.2.3 Ordered descending

"Ordered descending" means that the ordered sequence begins with the minutia from the original minutiae set that has the largest value of the indicated item. The value of this item decreases with every successive minutia to the minimum value in the last minutia of the ordered sequence.

8.3.9.2.4 Cartesian X-Y

Cartesian X-Y stands for an ordering scheme, where first the X-coordinate is compared and used for ordering. When ordering by ascending Cartesian X-Y coordinates, the minutia with minimum X-coordinate becomes the first minutia in the ordered sequence. The minutia with the second smallest X-coordinate becomes the second minutia in the ordered sequence. This process continues until the minutia with maximum X-value becomes the last minutia in the ordered sequence. If the X-coordinates in two or more minutiae are equal, the Y-coordinate is compared for ordering.

8.3.9.2.5 Cartesian Y-X

Cartesian Y-X stand for an ordering scheme, where first the Y-coordinate is compared and used for ordering. If the Y-coordinates in two or more minutiae are equal, the X-coordinate is compared for ordering.

8.3.9.2.6 Angle

Sorting a minutiae list by angle is achieved as follows. The angle of a minutia begins with value 0 to the right horizontal axis and increases counterclockwise. When ordering by increasing angle, the minutia with the minimum angle value in the ordered sequence becomes the first minutia in the ordered sequence. The minutia with the second smallest angle value becomes the second minutia in the ordered sequence. This process continues until the last minutia in the ordered sequence is defined as the minutia with maximum angle value. No rules for sub-ordering are defined if the angle values in two

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or more minutiae are equal. Any possible ordering sequence of the minutiae with the same angle value is allowed in this case.

8.3.9.2.7 Polar

Polar is an ordering sequence by ascending or descending polar coordinates. First of all, a virtual coordinate root is defined as the centre of mass of all minutiae. The polar coordinates of every minutia are computed as the relative distance and angle to this root coordinate. Without loss of generality, the process of ascending ordering with polar coordinates is described. The minutia with minimum Euclidean distance to the root becomes the first minutia in the ordered sequence. The minutia with the second smallest distance to the root becomes the second minutia in the ordered sequence. This process continues until the minutia with maximum distance to the root becomes the last minutia in the ordered sequence. If the root-distance of two minutiae or more is equal, the angle of these minutiae is compared. The minutia with the smallest angle as defined in 6.5.1 becomes the next minutia in the ordered sequence.

The position of the centre of mass of the minutiae shall be computed as the point specified by the means of the coordinates in X and Y.

$$x_{cm} = (x_1 + x_2 + ... + x_n) / n$$

$$y_{cm} = (y_1 + y_2 + ... + y_n) / n$$

where

cm is the centre of mass;

n is the number of minutiae.

8.3.9.2.8 X or Y coordinate extension

The extracted X coordinates are sorted in ascending order and encoded in 2 bytes, but only the least significant byte is sent in the minutiae format to the card (equal to a mod(256) computation). The card can reconstruct the original sequence of values by adding 256 on all following entries when a violation of the ascending order occurs.

EXAMPLE

Original sequence:	60	276 277 333 581 797 860 986 1000
Transmitted sequence:	60	20 21 77 69 29 92 218 232

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

		0 256 256 256 512 768 768 768 768
Reconstructed sequence:	60	276 277 333 581 797 860 986 1000

The same construction principle may alternately be applied also for the Y coordinate. Using this construction on X and Y together is not possible.

NOTE 1 Images with height larger than 256 pixels can occur when a four-finger slap impression is segmented below the first interphalangeal crease.

NOTE 2 It is assumed that the distance between two neighbour minutiae is less than 256.

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8.3.9.3 Indication of card capabilities

If a card with on-card biometric comparison supports one or more of the extended data, then the capabilities shall be indicated in the DO "Biometric comparison algorithm parameters" (tag $B1_{Hex}$ within the BIT, as defined in ISO/IEC 19785-3) using the DO "Feature handling indicator" (tag 83_{Hex}, value field 1 byte). The encoding of the feature handling indicator is defined in Table 23.

Table 23 — Encoding of 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					Impression type
		1						Quality DO(s) in BDT supported
x	x							RFU (default: 0)

9 Registered format type identifiers

The registrations listed in Table 24 have been made with the Biometric Registration Authority (see ISO/IEC 19785-1) to identify the finger minutiae data interchange formats defined in this document. The format owner is ISO/IEC JTC 1/SC 37 with the registered format owner identifier 257 (0101_{Hex}).

Table 24 — Format type identifiers

CBEFF BDB format type identifier	Short name	Full object identifier
48 (0030_{Hex})	g3-binary-finger-minutiae	{ iso(1) registration-authority(1) cbeff(19785) biometric-organization(0) jtc1-sc37(257) bdbs(0) g3-binary-finger-minutiae(48) }
49 (0031_{Hex})	g3-xml-finger-minutiae	{ iso(1) registration-authority(1) cbeff(19785) biometric-organization(0) jtc1-sc37(257) bdbs(0) g3-xml-finger-minutiae(49) }
5 (0005_{Hex})	finger-minutiae-card-compact-valley-bifurcations	{iso registration-authority cbeff(19785) organization(0) jtc1-sc37(257) bdbs(0) finger-minutiae-card-compact-valley-bifurcations(5)}
6 (0006_{Hex})	finger-minutiae-card-compact-ridge-endings	{iso registration-authority cbeff(19785) organization(0) jtc1-sc37(257) bdbs(0) finger-minutiae-card-compact-ridge-endings(6)}

NOTE 1 The CBEFF BDB format type identifier 5 (0005_{Hex}) indicates the on-card comparison format using valley bifurcations. The CBEFF BDB format type identifier 6 (0006_{Hex}) indicates the on-card comparison format using ridge endings.

NOTE 2 The on-card comparison format defined in this document is the same as the one with the same CBEFF BDB format type identifiers defined in ISO/IEC 19794-2:2005 and ISO/IEC 19794-2:2011.

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Annex A
(normative)

Formal specifications

A.1 ASN.1 module for tagged binary encoding

```
ISO-IEC-39794-2-ed-1-v1 {iso(1) standard(0) iso-iec-39794(39794) part-2(2) ed-1(1) v1(1)
iso-iec-39794-2(0)}

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IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY
WAY OUT OF THE USE OF THE CODE COMPONENTS, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH
DAMAGE.

DEFINITIONS IMPLICIT TAGS ::= BEGIN

   IMPORTS
      RegistryIdBlock,
      CertificationIdBlocks,
      ScoreOrError,
      CaptureDateTimeBlock,
      QualityBlocks,
      PADDataBlock,
      ExtendedDataBlocks,
      VersionBlock
   FROM ISO-IEC-39794-1-ed-1-v1;

   PositionCode ::= ENUMERATED {
      unknownPosition(0),
      rightThumbFinger(1),
      rightIndexFinger(2),
      rightMiddleFinger(3),
      rightRingFinger(4),
      rightLittleFinger(5),
      leftThumbFinger(6),
      leftIndexFinger(7),
      leftMiddleFinger(8),
      leftRingFinger(9),
      leftLittleFinger(10)
```

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```
}

PositionExtensionBlock ::= SEQUENCE {
   fallback [0] PositionCode,
   ...
}

Position ::= CHOICE {
   code [0] PositionCode,
   extensionBlock [1] PositionExtensionBlock
}

ImpressionCode ::= ENUMERATED {
   plainContact(0),
   rolledContact(1),
   latentImage(4),
   swipeContact(8),
   stationarySubjectContactlessPlain(24),
   stationarySubjectContactlessRolled(25),
   otherImpression(28),
   unknownImpression(29),
   movingSubjectContactlessRolled(41),
   movingSubjectContactlessPlain(42),
}

ImpressionExtensionBlock ::= SEQUENCE {
   fallback [0] ImpressionCode,
   ...
}

Impression ::= CHOICE {
   code [0] ImpressionCode,
   extensionBlock [1] ImpressionExtensionBlock
}

CaptureDeviceTechnologyIdCode ::= ENUMERATED {
   unknownCaptureDeviceTechnology(0),
   otherCaptureDeviceTechnology(1),
   scannedInkOnPaper(2),
   opticalTIRBrightField(3),
   opticalTIRDarkField(4),
   opticalImage(5),
   opticalLowFrequency3DMapped(6),
   opticalHighFrequency3DMapped(7),
   capacitive(9),
   capacitiveRF(10),
   electroLuminescence(11),
   reflectedUltrasonic(12),
   impediographicUltrasonic(13),
   thermal(14),
   directPressure(15),
   indirectPressure(16),
   liveTape(17),
   latentImpression(18),
   latentPhoto(19),
   latentMolded(20),
   latentTracing(21),
   latentLift(22),
   activeThermal(23)
}

CaptureDeviceTechnologyIdExtensionBlock ::= SEQUENCE {
   fallback [0] CaptureDeviceTechnologyIdCode,
   ...
}

CaptureDeviceTechnologyId ::= CHOICE {
   code [0] CaptureDeviceTechnologyIdCode,
   extensionBlock [1] CaptureDeviceTechnologyIdExtensionBlock
}
```

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```
CaptureDeviceBlock ::= SEQUENCE {
   modelIdBlock [0] RegistryIdBlock,
   technologyId [1] CaptureDeviceTechnologyId OPTIONAL,
   certificationIdBlocks [2] CertificationIdBlocks OPTIONAL,
   ...
}

CommentBlock ::= VisibleString

CommentBlocks ::= SEQUENCE OF CommentBlock

FeatureDimension ::= INTEGER (0..16383)

FeatureCoordinateBlock ::= SEQUENCE {
   x [0] FeatureDimension,
   y [1] FeatureDimension
}

MinutiaKindCode ::= ENUMERATED {
   ridgeEnding(0),
   ridgeBifurcation(1),
   other(2)
}

MinutiaKindExtensionBlock ::= SEQUENCE {
   fallback [0] MinutiaKindCode,
   ...
}

MinutiaKind ::= CHOICE {
   code [0] MinutiaKindCode,
   extensionBlock [1] MinutiaKindExtensionBlock
}

MinutiaIndex ::= INTEGER (1..254)

MinutiaBlock ::= SEQUENCE {
   coordinateBlock [0] FeatureCoordinateBlock,
   angle [1] INTEGER (0..255),
   kind [2] MinutiaKind,
   index [3] MinutiaIndex OPTIONAL,
   quality [4] ScoreOrError OPTIONAL
}

MinutiaBlocks ::= SEQUENCE OF MinutiaBlock

RidgeCountBlock ::= SEQUENCE {
   minutiaIndex1 [0] MinutiaIndex,
   minutiaIndex2 [1] MinutiaIndex,
   ridgeCount [2] INTEGER (0..255)
}

RidgeCountBlocks ::= SEQUENCE OF RidgeCountBlock

RelativeRidgeCountBlock ::= SEQUENCE {
   relativeMinutiaIndex [0] MinutiaIndex,
   ridgeCount [1] INTEGER (0..255)
}

FourNeighborRidgeCountBlock ::= SEQUENCE {
   centerMinutiaIndex [0] MinutiaIndex,
   topRightMinutiaCountBlock [1] RelativeRidgeCountBlock OPTIONAL,
   bottomRightMinutiaCountBlock [2] RelativeRidgeCountBlock OPTIONAL,
   bottomLeftMinutiaCountBlock [3] RelativeRidgeCountBlock OPTIONAL,
   topLeftMinutiaCountBlock [4] RelativeRidgeCountBlock OPTIONAL
}

EightNeighborRidgeCountBlock ::= SEQUENCE {
   centerMinutiaIndex [0] MinutiaIndex,
   octant0CountBlock [1] RelativeRidgeCountBlock OPTIONAL,
   octant1CountBlock [2] RelativeRidgeCountBlock OPTIONAL,
```

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```
   octant2CountBlock [3] RelativeRidgeCountBlock OPTIONAL,
   octant3CountBlock [4] RelativeRidgeCountBlock OPTIONAL,
   octant4CountBlock [5] RelativeRidgeCountBlock OPTIONAL,
   octant5CountBlock [6] RelativeRidgeCountBlock OPTIONAL,
   octant6CountBlock [7] RelativeRidgeCountBlock OPTIONAL,
   octant7CountBlock [8] RelativeRidgeCountBlock OPTIONAL
}

FourNeighborRidgeCountBlocks ::= SEQUENCE OF FourNeighborRidgeCountBlock

EightNeighborRidgeCountBlocks ::= SEQUENCE OF EightNeighborRidgeCountBlock

CoreDataBlock ::= SEQUENCE {
   coordinateBlock [0] FeatureCoordinateBlock,
   angle [1] INTEGER (0..255) OPTIONAL
}

CoreDataBlocks ::= SEQUENCE OF CoreDataBlock

DeltaAngleBlock ::= SEQUENCE {
   angle1 [0] INTEGER (0..255),
   angle2 [1] INTEGER (0..255),
   angle3 [2] INTEGER (0..255)
}

DeltaDataBlock ::= SEQUENCE {
   coordinateBlock [0] FeatureCoordinateBlock,
   angles [1] DeltaAngleBlock OPTIONAL
}

DeltaDataBlocks ::= SEQUENCE OF DeltaDataBlock

CellQualityBlock ::= INTEGER (0..255)

CellQualityBlocks ::= SEQUENCE OF CellQualityBlock

ZonalQualityBlock ::= SEQUENCE {
   algorithmIdBlock [0] RegistryIdBlock,
   cellWidth [1] INTEGER (0..255),
   cellHeight [2] INTEGER (0..255),
   cellQualityBlocks [3] CellQualityBlocks OPTIONAL
}

ZonalQualityBlocks ::= SEQUENCE OF ZonalQualityBlock

UnitDimensionCode ::= ENUMERATED {
   inch(0),
   cm(1)
}

SpatialSamplingRateBlock ::= SEQUENCE {
   samplesPerUnit [0] INTEGER (0..65535),
   unitDimension [1] UnitDimensionCode
}

RepresentationBlock ::= SEQUENCE {
   position [0] Position,
   impression [1] Impression,
   minutiaBlocks [2] MinutiaBlocks,
   captureDateTimeBlock [3] CaptureDateTimeBlock OPTIONAL,
   captureDeviceBlock [4] CaptureDeviceBlock OPTIONAL,
   qualityBlocks [5] QualityBlocks OPTIONAL,
   spatialSamplingRateBlock [6] SpatialSamplingRateBlock OPTIONAL,
   ridgeEndingIsValleyBifurcation [7] BOOLEAN OPTIONAL,
   genericRidgeCountBlocks [8] RidgeCountBlocks OPTIONAL,
   fourNeighborRidgeCountBlocks [9] FourNeighborRidgeCountBlocks OPTIONAL,
   eightNeighborRidgeCountBlocks [10] EightNeighborRidgeCountBlocks OPTIONAL,
   coreDataBlocks [11] CoreDataBlocks OPTIONAL,
   deltaDataBlocks [12] DeltaDataBlocks OPTIONAL,
   zonalQualityBlocks [13] ZonalQualityBlocks OPTIONAL,
   pADDataBlock [14] PADDataBlock OPTIONAL,
```

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```
      commentBlocks [15] CommentBlocks OPTIONAL,
      vendorSpecificDataBlocks [16] ExtendedDataBlocks OPTIONAL,
      ...
   }

   RepresentationBlocks ::= SEQUENCE OF RepresentationBlock

   FingerMinutiaeDataBlock ::= [APPLICATION 2] SEQUENCE {
      versionBlock [0] VersionBlock,
      representationBlocks [1] RepresentationBlocks,
      ...
   }

END
```

A.2 XML schema definition for XML encoding

```
<?xml version="1.0" encoding="utf-8" ?>
<-!--
Use of ISO/IEC copyright in this Schema is licensed for the purpose of developing,
implementing, and using software based on this Schema, subject to the following
conditions:

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NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR
PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER
IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY
WAY OUT OF THE USE OF THE CODE COMPONENTS, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH
DAMAGE.
-->
<xs:schema version="1.1"
        xmlns:xs="http://www.w3.org/2001/XMLSchema"
        xmlns:cmn="http://standards.iso.org/iso-iec/39794/-1"
        xmlns="http://standards.iso.org/iso-iec/39794/-2"
        targetNamespace="http://standards.iso.org/iso-iec/39794/-2"
        elementFormDefault="qualified"
        attributeFormDefault="unqualified">

    <xs:import schemaLocation="iso-iec-39794-1-ed-1-v1.xsd" namespace="http://standards.
iso.org/iso-iec/39794/-1" />

    <xs:complexType name="PositionCodeType">
        <xs:choice>
            <xs:element name="unknownPosition" type="xs:int" fixed="0" />
            <xs:element name="rightThumbFinger" type="xs:int" fixed="1" />
            <xs:element name="rightIndexFinger" type="xs:int" fixed="2" />
            <xs:element name="rightMiddleFinger" type="xs:int" fixed="3" />
            <xs:element name="rightRingFinger" type="xs:int" fixed="4" />
            <xs:element name="rightLittleFinger" type="xs:int" fixed="5" />
            <xs:element name="leftThumbFinger" type="xs:int" fixed="6" />
            <xs:element name="leftIndexFinger" type="xs:int" fixed="7" />
```

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```
            <xs:element name="leftMiddleFinger" type="xs:int" fixed="8" />
            <xs:element name="leftRingFinger" type="xs:int" fixed="9" />
            <xs:element name="leftLittleFinger" type="xs:int" fixed="10" />
        </xs:choice>
    </xs:complexType>

    <xs:complexType name="PositionExtensionBlockType">
        <xs:sequence>
            <xs:element name="fallback" type="PositionCodeType"/>
            <xs:any namespace="##other" processContents="lax"/>
        </xs:sequence>
    </xs:complexType>

    <xs:complexType name="PositionType">
        <xs:choice>
            <xs:element name="code" type="PositionCodeType" />
            <xs:element name="extensionBlock" type="PositionExtensionBlockType" />
        </xs:choice>
    </xs:complexType>

    <xs:complexType name="ImpressionCodeType">
        <xs:choice>
            <xs:element name="plainContact" type="xs:int" fixed="0" />
            <xs:element name="rolledContact" type="xs:int" fixed="1" />
            <xs:element name="latentImage" type="xs:int" fixed="4" />
            <xs:element name="swipeContact" type="xs:int" fixed="8" />
            <xs:element name="stationarySubjectContactlessPlain" type="xs:int" fixed="24"
/>
            <xs:element name="stationarySubjectContactlessRolled" type="xs:int" fixed="25"
/>
            <xs:element name="otherImpression" type="xs:int" fixed="28" />
            <xs:element name="unknownImpression" type="xs:int" fixed="29" />
            <xs:element name="movingSubjectContactlessRolled" type="xs:int" fixed="41" />
            <xs:element name="movingSubjectContactlessPlain" type="xs:int" fixed="42" />
        </xs:choice>
    </xs:complexType>

    <xs:complexType name="ImpressionExtensionBlockType">
        <xs:sequence>
            <xs:element name="fallback" type="ImpressionCodeType"/>
            <xs:any namespace="##other" processContents="lax"/>
        </xs:sequence>
    </xs:complexType>

    <xs:complexType name="ImpressionType">
        <xs:choice>
            <xs:element name="code" type="ImpressionCodeType" />
            <xs:element name="extensionBlock" type="ImpressionExtensionBlockType" />
        </xs:choice>
    </xs:complexType>

    <xs:complexType name="CaptureDeviceTechnologyIdCodeType">
        <xs:choice>
            <xs:element name="unknownCaptureDeviceTechnology" type="xs:int" fixed="0" />
            <xs:element name="otherCaptureDeviceTechnology" type="xs:int" fixed="1" />
            <xs:element name="scannedInkOnPaper" type="xs:int" fixed="2" />
            <xs:element name="opticalTIRBrightField" type="xs:int" fixed="3" />
            <xs:element name="opticalTIRDarkField" type="xs:int" fixed="4" />
            <xs:element name="opticalImage" type="xs:int" fixed="5" />
            <xs:element name="opticalLowFrequency3DMapped" type="xs:int" fixed="6" />
            <xs:element name="opticalHighFrequency3DMapped" type="xs:int" fixed="7" />
            <xs:element name="capacitive" type="xs:int" fixed="9" />
            <xs:element name="capacitiveRF" type="xs:int" fixed="10" />
            <xs:element name="electroLuminescence" type="xs:int" fixed="11" />
            <xs:element name="reflectedUltrasonic" type="xs:int" fixed="12" />
            <xs:element name="impediographicUltrasonic" type="xs:int" fixed="13" />
            <xs:element name="thermal" type="xs:int" fixed="14" />
            <xs:element name="directPressure" type="xs:int" fixed="15" />
            <xs:element name="indirectPressure" type="xs:int" fixed="16" />
            <xs:element name="liveTape" type="xs:int" fixed="17" />
            <xs:element name="latentImpression" type="xs:int" fixed="18" />
```

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```
            <xs:element name="latentPhoto" type="xs:int" fixed="19" />
            <xs:element name="latentMolded" type="xs:int" fixed="20" />
            <xs:element name="latentTracing" type="xs:int" fixed="21" />
            <xs:element name="latentLift" type="xs:int" fixed="22" />
            <xs:element name="activeThermal" type="xs:int" fixed="23" />
        </xs:choice>
    </xs:complexType>

    <xs:complexType name="CaptureDeviceTechnologyIdExtensionBlockType">
        <xs:sequence>
            <xs:element name="fallback" type="CaptureDeviceTechnologyIdCodeType"/>
            <xs:any namespace="##other" processContents="lax"/>
        </xs:sequence>
    </xs:complexType>

    <xs:complexType name="CaptureDeviceTechnologyIdType">
        <xs:choice>
            <xs:element name="code" type="CaptureDeviceTechnologyIdCodeType" />
            <xs:element name="extensionBlock"
type="CaptureDeviceTechnologyIdExtensionBlockType" />
        </xs:choice>
    </xs:complexType>

    <xs:complexType name="CaptureDeviceBlockType">
        <xs:sequence>
            <xs:element name="modelIdBlock" type="cmn:RegistryIdBlockType" />
            <xs:element name="technologyId" type="CaptureDeviceTechnologyIdType"
minOccurs="0" />
            <xs:element name="certificationIdBlocks" type="cmn:CertificationIdBlocksType"
minOccurs="0" />
            <xs:any minOccurs="0" namespace="##other" processContents="lax" />
        </xs:sequence>
    </xs:complexType>

    <xs:simpleType name = "CommentBlockType" >
        <xs:restriction base="xs:string"/>
    </xs:simpleType>

    <xs:complexType name="CommentBlocksType">
        <xs:sequence>
            <xs:element name="commentBlock" type="CommentBlockType" maxOccurs="unbounded"
/>
        </xs:sequence>
    </xs:complexType>

    <xs:simpleType name="FeatureDimensionType">
        <xs:restriction base="xs:unsignedInt">
            <xs:minInclusive value="0" />
            <xs:maxInclusive value="16383" />
        </xs:restriction>
    </xs:simpleType>

    <xs:complexType name="FeatureCoordinateBlockType">
        <xs:sequence>
            <xs:element name="x" type="FeatureDimensionType" />
            <xs:element name="y" type="FeatureDimensionType" />
        </xs:sequence>
    </xs:complexType>

    <xs:complexType name="MinutiaKindCodeType">
        <xs:choice>
            <xs:element name="ridgeEnding" type="xs:int" fixed="0" />
            <xs:element name="ridgeBifurcation" type="xs:int" fixed="1" />
            <xs:element name="other" type="xs:int" fixed="2" />
        </xs:choice>
    </xs:complexType>

    <xs:complexType name="MinutiaKindExtensionBlockType">
        <xs:sequence>
            <xs:element name="fallback" type="MinutiaKindCodeType"/>
            <xs:any namespace="##other" processContents="lax"/>
```

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```
        </xs:sequence>
    </xs:complexType>

    <xs:complexType name="MinutiaKindType">
        <xs:choice>
            <xs:element name="code" type="MinutiaKindCodeType" />
            <xs:element name="extensionBlock" type="MinutiaKindExtensionBlockType" />
        </xs:choice>
    </xs:complexType>

    <xs:simpleType name="MinutiaIndexType">
        <xs:restriction base="xs:unsignedByte">
            <xs:minInclusive value="1" />
            <xs:maxInclusive value="254" />
        </xs:restriction>
    </xs:simpleType>

    <xs:complexType name="MinutiaBlockType">
        <xs:sequence>
            <xs:element name="coordinateBlock" type="FeatureCoordinateBlockType" />
            <xs:element name="angle" type="xs:unsignedByte" />
            <xs:element name="kind" type="MinutiaKindType" />
            <xs:element name="index" type="MinutiaIndexType" minOccurs="0" />
            <xs:element name="quality" type="cmn:ScoreOrErrorType" minOccurs="0" />
        </xs:sequence>
    </xs:complexType>

    <xs:complexType name="MinutiaBlocksType">
        <xs:sequence>
            <xs:element name="minutiaPointBlock" type="MinutiaBlockType"
maxOccurs="unbounded" />
        </xs:sequence>
    </xs:complexType>

    <xs:complexType name="RidgeCountBlockType">
        <xs:sequence>
            <xs:element name="minutiaIndex1" type="MinutiaIndexType" />
            <xs:element name="minutiaIndex2" type="MinutiaIndexType" />
            <xs:element name="ridgeCount" type="xs:unsignedByte" />
        </xs:sequence>
    </xs:complexType>

    <xs:complexType name="RidgeCountBlocksType">
        <xs:sequence>
            <xs:element name="ridgeCountBlock" type="RidgeCountBlockType"
maxOccurs="unbounded" />
        </xs:sequence>
    </xs:complexType>

    <xs:complexType name="RelativeRidgeCountBlockType">
        <xs:sequence>
            <xs:element name="relativeMinutiaIndex" type="MinutiaIndexType" />
            <xs:element name="ridgeCount" type="xs:unsignedByte" />
        </xs:sequence>
    </xs:complexType>

    <xs:complexType name="FourNeighborRidgeCountBlockType">
        <xs:sequence>
            <xs:element name="centerMinutiaIndex" type="MinutiaIndexType" />
            <xs:element name="topRightMinutiaCountBlock"
type="RelativeRidgeCountBlockType" minOccurs="0" />
            <xs:element name="bottomRightMinutiaCountBlock"
type="RelativeRidgeCountBlockType" minOccurs="0" />
            <xs:element name="bottomLeftMinutiaCountBlock"
type="RelativeRidgeCountBlockType" minOccurs="0" />
            <xs:element name="topLeftMinutiaCountBlock" type="RelativeRidgeCountBlockType"
minOccurs="0" />
        </xs:sequence>
    </xs:complexType>

    <xs:complexType name="EightNeighborRidgeCountBlockType">
```

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```
        <xs:sequence>
            <xs:element name="centerMinutiaIndex" type="MinutiaIndexType" />
            <xs:element name="octant0CountBlock" type="RelativeRidgeCountBlockType"
minOccurs="0" />
            <xs:element name="octant1CountBlock" type="RelativeRidgeCountBlockType"
minOccurs="0" />
            <xs:element name="octant2CountBlock" type="RelativeRidgeCountBlockType"
minOccurs="0" />
            <xs:element name="octant3CountBlock" type="RelativeRidgeCountBlockType"
minOccurs="0" />
            <xs:element name="octant4CountBlock" type="RelativeRidgeCountBlockType"
minOccurs="0" />
            <xs:element name="octant5CountBlock" type="RelativeRidgeCountBlockType"
minOccurs="0" />
            <xs:element name="octant6CountBlock" type="RelativeRidgeCountBlockType"
minOccurs="0" />
            <xs:element name="octant7CountBlock" type="RelativeRidgeCountBlockType"
minOccurs="0" />
        </xs:sequence>
    </xs:complexType>

    <xs:complexType name="FourNeighborRidgeCountBlocksType">
        <xs:sequence>
            <xs:element name="fourNeighborRidgeCountBlock"
type="FourNeighborRidgeCountBlockType" maxOccurs="unbounded" />
        </xs:sequence>
    </xs:complexType>

    <xs:complexType name="EightNeighborRidgeCountBlocksType">
        <xs:sequence>
            <xs:element name="eightNeighborRidgeCountBlock"
type="EightNeighborRidgeCountBlockType" maxOccurs="unbounded" />
        </xs:sequence>
    </xs:complexType>

    <xs:complexType name="CoreDataBlockType">
        <xs:sequence>
            <xs:element name="coordinateBlock" type="FeatureCoordinateBlockType" />
            <xs:element name="angle" type="xs:unsignedByte" minOccurs="0" />
        </xs:sequence>
    </xs:complexType>

    <xs:complexType name="CoreDataBlocksType">
        <xs:sequence>
            <xs:element name="coreDataBlock" type="CoreDataBlockType"
maxOccurs="unbounded" />
        </xs:sequence>
    </xs:complexType>

    <xs:complexType name="DeltaAngleBlockType">
        <xs:sequence>
            <xs:element name="angle1" type="xs:unsignedByte" />
            <xs:element name="angle2" type="xs:unsignedByte" />
            <xs:element name="angle3" type="xs:unsignedByte" />
        </xs:sequence>
    </xs:complexType>

    <xs:complexType name="DeltaDataBlockType">
        <xs:sequence>
            <xs:element name="coordinateBlock" type="FeatureCoordinateBlockType" />
            <xs:element name="angles" type="DeltaAngleBlockType" minOccurs="0" />
        </xs:sequence>
    </xs:complexType>

    <xs:complexType name="DeltaDataBlocksType">
        <xs:sequence>
            <xs:element name="deltaDataBlock" type="DeltaDataBlockType"
maxOccurs="unbounded" />
        </xs:sequence>
    </xs:complexType>
```

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```
    <xs:simpleType name="CellQualityBlockType">
        <xs:restriction base="xs:unsignedByte">
            <xs:minInclusive value="0" />
            <xs:maxInclusive value="255" />
        </xs:restriction>
    </xs:simpleType>

    <xs:complexType name="CellQualityBlocksType">
        <xs:sequence>
            <xs:element name="cellQualityBlock" type="CellQualityBlockType"
maxOccurs="unbounded" />
        </xs:sequence>
    </xs:complexType>

    <xs:complexType name="ZonalQualityBlockType">
        <xs:sequence>
            <xs:element name="algorithmIdBlock" type="cmn:RegistryIdBlockType" />
            <xs:element name="cellWidth" type="xs:unsignedByte" />
            <xs:element name="cellHeight" type="xs:unsignedByte" />
            <xs:element name="cellQualityBlocks" type="CellQualityBlocksType"
minOccurs="0" />
        </xs:sequence>
    </xs:complexType>

    <xs:complexType name="ZonalQualityBlocksType">
        <xs:sequence>
            <xs:element name="zonalQualityBlock" type="ZonalQualityBlockType"
maxOccurs="unbounded" />
        </xs:sequence>
    </xs:complexType>

    <xs:complexType name="UnitDimensionCodeType">
        <xs:choice>
            <xs:element name="inch" type="xs:int" fixed="0" />
            <xs:element name="cm" type="xs:int" fixed="1" />
        </xs:choice>
    </xs:complexType>

    <xs:complexType name="SpatialSamplingRateBlockType">
        <xs:sequence>
            <xs:element name="samplesPerUnit" type="xs:unsignedShort" />
            <xs:element name="unitDimension" type="UnitDimensionCodeType" />
        </xs:sequence>
    </xs:complexType>

    <xs:complexType name="RepresentationBlockType">
        <xs:sequence>
            <xs:element name="position" type="PositionType" />
            <xs:element name="impression" type="ImpressionType" />
            <xs:element name="minutiaBlocks" type="MinutiaBlocksType" />
            <xs:element name="captureDateTimeBlock" type="cmn:CaptureDateTimeBlockType"
minOccurs="0" />
            <xs:element name="captureDeviceBlock" type="CaptureDeviceBlockType"
minOccurs="0" />
            <xs:element name="qualityBlocks" type="cmn:QualityBlocksType" minOccurs="0" />

            <xs:element name="spatialSamplingRateBlock"
type="SpatialSamplingRateBlockType" minOccurs="0" />


            <xs:element name="ridgeEndingIsValleyBifurcation" type="xs:boolean"
minOccurs="0" />

            <xs:element name="genericRidgeCountBlocks" type="RidgeCountBlocksType"
minOccurs="0" />
            <xs:element name="fourNeighborRidgeCountBlocks"
type="FourNeighborRidgeCountBlocksType" minOccurs="0" />
            <xs:element name="eightNeighborRidgeCountBlocks"
type="EightNeighborRidgeCountBlocksType" minOccurs="0" />

            <xs:element name="coreDataBlocks" type="CoreDataBlocksType" minOccurs="0" />
```

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```
            <xs:element name="deltaDataBlocks" type="DeltaDataBlocksType" minOccurs="0" />

            <xs:element name="zonalQualityBlocks" type="ZonalQualityBlocksType"
minOccurs="0" />

            <xs:element name="pADDataBlock" type="cmn:PADDataBlockType" minOccurs="0" />
            <xs:element name="commentBlocks" type="CommentBlocksType" minOccurs="0" />
            <xs:element name="vendorSpecificDataBlocks" type="cmn:ExtendedDataBlocksType"
minOccurs="0"/>

            <xs:any minOccurs="0" namespace="##other" processContents="lax" />
        </xs:sequence>
    </xs:complexType>

    <xs:complexType name="RepresentationBlocksType">
        <xs:sequence>
            <xs:element name="representationBlock" type="RepresentationBlockType"
maxOccurs="unbounded" />
        </xs:sequence>
    </xs:complexType>

    <xs:complexType name="FingerMinutiaeDataBlockType">
        <xs:sequence>
            <xs:element name="versionBlock" type="cmn:VersionBlockType" />
            <xs:element name="representationBlocks" type="RepresentationBlocksType" />

            <xs:any minOccurs="0" namespace="##other" processContents="lax" />
        </xs:sequence>
    </xs:complexType>

    <xs:element name="fingerMinutiaeData" type="FingerMinutiaeDataBlockType" />
</xs:schema>
```

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Annex B
(normative)

Conformance test methodology

B.1 Overview

This annex specifies elements of the conformance testing methodology, test assertions and test procedures as applicable to this document.

To provide sufficient information about the IUT for the testing laboratory to properly conduct a conformance test and for an appropriate declaration of conformity to be made, the supplier of the IUT shall provide the information in Table B.1 and also complete the columns "IUT support" and "Supported range" in Table B.2. All tables shall be provided to the testing laboratory prior to or at the same time as the IUT is provided to the testing laboratory.

Table B.1 — Identification of the supplier and the IUT

Supplier name and address	
Contact point for queries about the ICS	
Implementation name	
Implementation version	
Any other information necessary for full identification of the implementation	
Is tagged binary encoding supported (Yes or No)	
Is XML encoding supported (Yes or No)	
Are any mandatory requirements of the standard not fully supported (Yes or No)	
Date of statement	

The encodings supported by this document are established by formal schema. Validating documents with the schemas will assure all level 1 conformance issues. Furthermore, this document does not address level 3 conformance, leaving only a few level 2 test assertions to be provided.

As specified in ISO/IEC 39794-1, this document specifies a table of optional elements that the IUT claims to support and to which a testing laboratory can attest.

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Table B.2 — IUT optional element claimed support

Reference	Provision summary	Level	Status	Format type applicability		IUT support	Supported range	Test result
				Tagged binary encoding	XML encoding			
Annex A	A representation block may contain unknown extensions.	1 and 2	O	Y	Y			
Annex A	A representation block may contain an ImageSizeBlock.	1 and 2	O	Y	Y			
Annex A	A representation block may contain a CaptureDateTimeBlock.	1 and 2	O	Y	Y			
Annex A	A representation block may contain captureDeviceBlock.	1 and 2	O	Y	Y			
Annex A	A representation block may contain QualityBlocks.	1 and 2	O	Y	Y			
Annex A	A representation block may contain a SpatialSamplingRateBlock.	1 and 2	O	Y	Y			
Annex A	A representation block may contain minutiaPointBlocks.	1 and 2	O	Y	Y			
Annex A	A representation block may contain a ridgeEndingIsValleyBifurcation field.	1 and 2	O	Y	Y			

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Table B.2 *(continued)*

Reference	Provision summary	Level	Status	Format type applicability		IUT support	Supported range	Test result
				Tagged binary encoding	XML encoding			
Annex A	A representation block may contain genericRidgeCountBlocks.	1 and 2	O	Y	Y			
Annex A	A representation block may contain fourNeighborRidgeCountBlocks.	1 and 2	O	Y	Y			
Annex A	A representation block may contain eightNeighborRidgeCountBlocks.	1 and 2	O	Y	Y			
Annex A	A representation block may contain coreDataBlocks.	1 and 2	O	Y	Y			
Annex A	A representation block may contain deltaDataBlocks.	1 and 2	O	Y	Y			
Annex A	A representation block may contain zonalQualityBlocks.	1 and 2	O	Y	Y			
ISO/IEC 39794-1	A PAD data block may contain a PAD decision.	1 and 2	O	Y	Y			
ISO/IEC 39794-1	A PAD data block may contain PAD score blocks.	1 and 2	O	Y	Y			

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Table B.2 *(continued)*

Reference	Provision summary	Level	Status	Format type applicability		IUT support	Supported range	Test result
				Tagged binary encoding	XML encoding			
ISO/IEC 39794-1	A PAD data block may contain PAD extended data blocks.	1 and 2	O	Y	Y			
ISO/IEC 39794-1	A PAD data block may contain a context of capture field.	1 and 2	O	Y	Y			
ISO/IEC 39794-1	A PAD data block may contain a level of supervision surveillance field.	1 and 2	O	Y	Y			
ISO/IEC 39794-1	A quality block may contain unknown extensions.	1 and 2	O	Y	Y			

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B.2 Conformance test assertions

Table B.3 details the level 2 conformance tests that a testing organization can perform on an IUT.

Level 1 and 2 requirements and options shall be tested by decoding tagged binary data blocks under test based on the ASN.1 module that specifies the tagged binary data format or validation of XML documents under test against the XML schema definition that specifies the textual data format, respectively.

Table B.3 — Level 2 conformance tests

Test number	Level	Element name	Operator	Operand	Test note	Status	IUT support	Test result
X1	1	Version.generation	EQ	3		M		
X2								
X2								

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Annex C
(informative)

Encoding examples

C.1 Sample ASN.1 encoding for finger minutia data

An example encoding can be retrieved from https://standards.iso.org/iso-iec/39794/-2/ed-1/en/.

C.2 Sample XML encoding for finger minutia data

```
<?xml version="1.0"?>
<fmr:fingerMinutiaeData xmlns:c‶n="https://standards.iso.org/iso-iec/39794-1"
xmlns:f‶r="https://standards.iso.org/iso-iec/39794-2">
  <fmr:versionBlock>
    <cmn:generation>3</cmn:generation>
    <cmn:year>2020</cmn:year>
  </fmr:versionBlock>
  <fmr:representationBlocks>
    <fmr:representationBlock>
      <fmr:position>
        <fmr:code>
          <fmr:rightIndexFinger/>
        </fmr:code>
      </ fmr:position>
      < fmr:impression>
        < fmr:code>
          <fmr:rolledContact/>
        </fmr:code>
      </fmr:impression>
      <fmr:minutiaBlocks>
        <fmr:minutiaBlock>
          <fmr:coordinateBlock>
            <fmr:x>14</fmr:x>
            <fmr:y>5</fmr:y>
          </fmr:coordinateBlock>
          <fmr:angle>149</fmr:angle>
          <fmr:kind>
            < fmr:code>
              < fmr:ridgeBifurcation/>
            </ fmr:code>
          </fmr:kind>
          <fmr:index>1</fmr:index>
          <fmr:quality>
            <cmn:score>44</cmn:score>
          </fmr:quality>
        </fmr:minutiaBlock>
        <fmr:minutiaBlock>
          <fmr:coordinateBlock>
            <fmr:x>13</fmr:x>
            <fmr:y>15</fmr:y>
          </fmr:coordinateBlock>
          <fmr:angle>160</fmr:angle>
          <fmr:kind>
            < fmr:code>
              < fmr:ridgeBifurcation/>
            </ fmr:code>
          </fmr:kind>
          <fmr:index>2</fmr:index>
          <fmr:quality>
```

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```
      <cmn:score>76</cmn:score>
    </fmr:quality>
  </fmr:minutiaBlock>
</fmr:minutiaBlocks>
<fmr:captureDateTimeBlock>
  <cmn:year>2018</cmn:year>
  <cmn:month>12</cmn:month>
  <cmn:day>30</cmn:day>
  <cmn:hour>13</cmn:hour>
</fmr:captureDateTimeBlock>
<fmr:captureDeviceBlock>
  <fmr:modelIdBlock>
    <cmn:organization>200</cmn:organization>
    <cmn:id>33</cmn:id>
  </fmr:modelIdBlock>
  <fmr:technologyId>
    <fmr:code>
      <fmr:opticalTIRBrightField/>
    </fmr:code>
  </fmr:technologyId>
  <fmr:certificationIdBlocks>
    <cmn:certificationIdBlock>
      <cmn:organization>31</cmn:organization>
      <cmn:id>31</cmn:id>
    </cmn:certificationIdBlock>
  </fmr:certificationIdBlocks>
</fmr:captureDeviceBlock>
<fmr:qualityBlocks>
  <cmn:qualityBlock>
    <cmn:algorithmIdBlock>
      <cmn:organization>11</cmn:organization>
      <cmn:id>11</cmn:id>
    </cmn:algorithmIdBlock>
    <cmn:scoreOrError>
      <cmn:score>44</cmn:score>
    </cmn:scoreOrError>
  </cmn:qualityBlock>
  <cmn:qualityBlock>
    <cmn:algorithmIdBlock>
      <cmn:organization>257</cmn:organization>
      <cmn:id>1</cmn:id>
    </cmn:algorithmIdBlock>
    <cmn:scoreOrError>
      <cmn:error>
        <cmn:code>
          <cmn:failureToAssess/>
        </cmn:code>
      </cmn:error>
    </cmn:scoreOrError>
  </cmn:qualityBlock>
</fmr:qualityBlocks>
<fmr:spatialSamplingRateBlock>
  <fmr:samplesPerUnit>100</fmr:samplesPerUnit>
  <fmr:unitDimension>
    <fmr:cm/>
  </fmr:unitDimension>
</fmr:spatialSamplingRateBlock>
<fmr:eightNeighborRidgeCountBlocks>
  <fmr:eightNeighborRidgeCountBlock>
    <fmr:centerMinutiaIndex>1</fmr:centerMinutiaIndex>
    <fmr:octant1CountBlock>
      <fmr:relativeMinutiaIndex>2</fmr:relativeMinutiaIndex>
      <fmr:ridgeCount>3</fmr:ridgeCount>
    </fmr:octant1CountBlock>
  </fmr:eightNeighborRidgeCountBlock>
  <fmr:eightNeighborRidgeCountBlock>
    <fmr:centerMinutiaIndex>2</fmr:centerMinutiaIndex>
    <fmr:octant5CountBlock>
      <fmr:relativeMinutiaIndex>1</fmr:relativeMinutiaIndex>
      <fmr:ridgeCount>3</fmr:ridgeCount>
    </fmr:octant5CountBlock>
```

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```
        </fmr:eightNeighborRidgeCountBlock>
      </fmr:eightNeighborRidgeCountBlocks>
      <fmr:pADDataBlock>
        <cmn:decision>
          <cmn:code>
            <cmn:attack/>
          </cmn:code>
        </cmn:decision>
        <cmn:scoreBlocks>
          <cmn:scoreBlock>
            <cmn:mechanismIdBlock>
              <cmn:organization>26</cmn:organization>
              <cmn:id>27</cmn:id>
            </cmn:mechanismIdBlock>
            <cmn:scoreOrError>
              <cmn:score>72</cmn:score>
            </cmn:scoreOrError>
          </cmn:scoreBlock>
        </cmn:scoreBlocks>
        < cmn:captureContext>
          < cmn:code>
            < cmn:verification/>
          </ cmn:code>
        </ cmn:captureContext>
        < cmn:supervisionLevel>
          < cmn:code>
            < cmn:unknown/>
          </ cmn:code>
        </cmn:supervisionLevel>
        <cmn:criteriaCategory>
          <cmn:code>
            <cmn:unknown/>
          </cmn:code>
        </cmn:criteriaCategory>
        <cmn:parameter>UEFEIHBhcmFtZXRlciBieXRlcw==</cmn:parameter>
        <cmn:challenges>
          <cmn:challenge>UEFEIHBhcmFtZXRlciBieXRlcw==</cmn:challenge>
        </cmn:challenges>
      </fmr:pADDataBlock>
      <fmr:commentBlocks>
        <fmr:commentBlock>ISO/IEC 39794-2 encoding example</fmr:commentBlock>
        <fmr:commentBlock>Small finger </fmr:commentBlock>
      </fmr:commentBlocks>
      <fmr:vendorSpecificDataBlocks>
        <cmn:extendedDataBlock>
          <cmn:dataTypeIdBlock>
            <cmn:organization>11</cmn:organization>
            <cmn:id>1</cmn:id>
          </cmn:dataTypeIdBlock>
          <cmn:data>PYzbL37NIXC/Ew==</cmn:data>
        </cmn:extendedDataBlock>
        <cmn:extendedDataBlock>
          <cmn:dataTypeIdBlock>
            <cmn:organization>11</cmn:organization>
            <cmn:id>2</cmn:id>
          </cmn:dataTypeIdBlock>
          <cmn:data>FThbfqHEACNGaQ==</cmn:data>
        </cmn:extendedDataBlock>
      </fmr:vendorSpecificDataBlocks>
    </fmr:representationBlock>
  </fmr:representationBlocks>
</fmr:fingerMinutiaeData>
```


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Annex D
(informative)

Detailed description of finger minutiae location, direction, type

D.1 General

Even if minutia data blocks generated by different algorithms conform to this document, different minutiae data blocks extracted from the same finger image can differ not only in the exact locations, the directions, and the types of those minutiae that they have in common, but also in the number of minutiae they contain, especially in blurred fingerprint regions where even the "manual" detection of minutiae is hard. The description of the minutia location in 6.4 refers to a single-pixel-wide skeleton of the friction ridges. The minutia direction is defined in 6.5 based on tangents to the skeleton. The skeletonization algorithm itself is not described. The method to determine the tangents is left open.

The scope of this annex is to provide a more precise definition of location, direction and type of minutiae in greyscale finger images and a detailed description of the quality field. It enhances the readability of this document and decreases the possibility of misinterpretation. The standardization of algorithms is out of scope of this annex.

D.2 Minutiae detection strategy

D.2.1 Overview: "Liberal-conservative" spectrum

Minutia detection algorithms can use different discriminative practices in the minutia detection strategy. A liberal minutia detection strategy is supposed to detect a large number of minutiae which will increase the probability of including spurious minutiae, while a conservative strategy will detect only a few minutiae and increase the probability of missing some. The following subclauses provide an explanation of some types of spurious (false) minutiae which can result from the use of a "liberal" strategy, but which can potentially remain undetected if a more "conservative" strategy is employed.

The Figures D.1 to D.5 show examples of applying a conservative or liberal minutia detection strategy to the same sample images. These examples are not intended to suggest a liberal or conservative strategy. The best detection strategy for a particular application depends on the business processes and the associated security requirements that the biometric components of the system are designed to support or enable.

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Figure D.1 — Liberal minutia detection (left) versus conservative minutia detection (right)

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

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

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

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

D.2.2 Fingerprint boundary

No minutia should be set outside the fingerprint boundary.

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

D.2.3 Sweat pore

No minutia should be set at a sweat pore. A pore can lie at the position of the forking of a friction ridge (bifurcation, see Figure D.15), but a sweat pore without connectivity to three legs should not be misinterpreted as a minutia.

D.2.4 Touching ridges

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

D.2.5 Incipient ridge

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

D.2.6 Crease

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

D.2.7 Core

No minutia should be set at a core.

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

NOTE Information about cores can be expressed in a standardized way in the extended data block (see 8.3.8.3.2).

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D.2.8 Delta

No minutia should be set at a delta.

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

NOTE Information about deltas can be expressed in a standardized way in the extended data block (see 8.3.8.3.3).

D.3 Minutia characteristics

D.3.1 Rationale

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

D.3.2 Minutia type

The minutia type cannot be determined reliably in some occasions.

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

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

D.3.3 Minutia location tools

D.3.3.1 Consideration of the spatial sampling rate of the underlying finger image

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

D.3.3.2 Skeletonization

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

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a) Captured raw image

b) Binary image (truncated)

Figure D.6 — Raw image vs. binary image

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D.3.3.3 Image skeletonization

Skeletonization is a standard procedure in graphing practice. It produces a single-pixel-wide skeleton from a binary image. Several skeletonization methods are reported in literature. The process yields either a four-connected or eight-connected skeleton. Figure D.7 shows a sample image and its skeleton.

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Figure D.7 — Binary image and ridge skeleton

As valley skeletons will also be used in this document, Figure D.8 depicts the valley skeleton of the same image.

Figure D.8 — Binary image and valley skeleton

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D.3.3.4 Ridge flow direction

Every fingerprint image has a well-defined directional image expressing the local dominant ridge flow direction. Methods to compute a directional image are reported in literature, e.g. Reference [10]. Figure D.9 shows a fingerprint image and its directional image.

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Figure D.9 — Raw image and pixel-wise directional image

Most current fingerprint minutiae detection algorithms work with a block-wise directional image rather than a pixel-wise one. The original directional image is therefore divided into blocks and the most common orientation within a block becomes the orientation for the whole block. Figure D.10 shows the block directional image.

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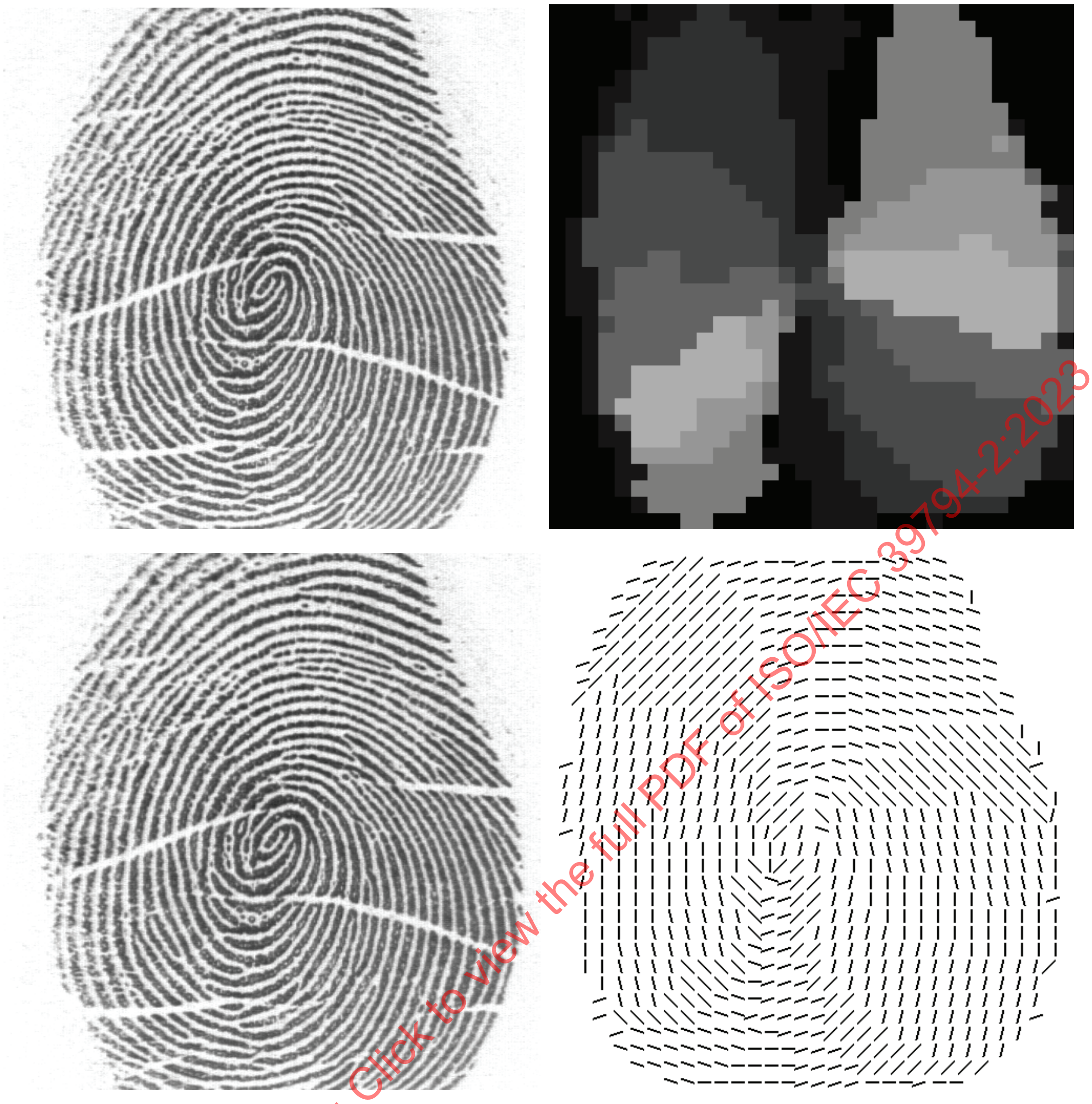

Figure D.10 — Raw image and block-wise directional image

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D.3.3.5 Ridge gradient method

The ridge gradient method relies on moving along the ridge line until a minutia condition occurs, which is either forking or ending of the ridge. It was originally reported for greyscale images,[11] but is described here for binary images to simplify the procedure, which has only a descriptive nature in this document.

D.3.3.6 Minutia location at a ridge skeleton endpoint

Friction ridges in a binary image have a well-defined border: Black pixels with at least one white pixel as four-neighbour are border pixels of a friction ridge. This ensures that the border is at least eight-connected. The border of a ridge skeleton endpoint is depicted in Figure D.11.

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