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Information technology — Extensible biometric data interchange formats —

Part 2: Finger minutiae data

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Contents

Page

Foreword

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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.

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.

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

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.

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.

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*

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-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 $\partial S = \{x \in S : x \text{ is four-neighbour of } q, q \notin S\}$ 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

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.

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.

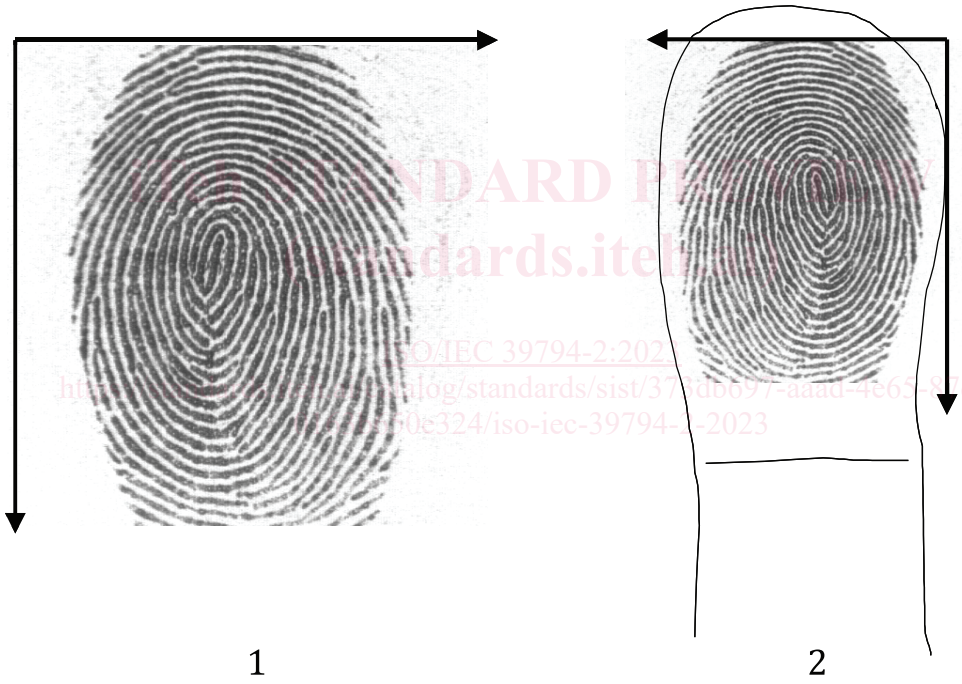
6.4 Minutia location

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.



Key

1 fingerprint image

2 finger

Figure 1 — Coordinate System

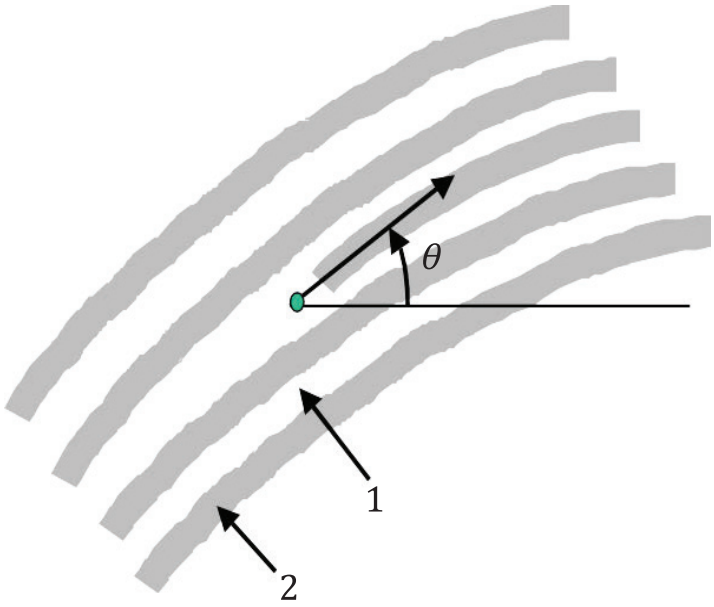
For the finger minutiae ASN.1 format (8.1 and Clause A.1) and the XML format (8.2 and Clause A.2), the X and Y coordinates of the minutiae are stored in the FeatureCoordinateBlock and measured in pixel units, with the spatial sampling rate given in the SpatialSamplingRateBlock.

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

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

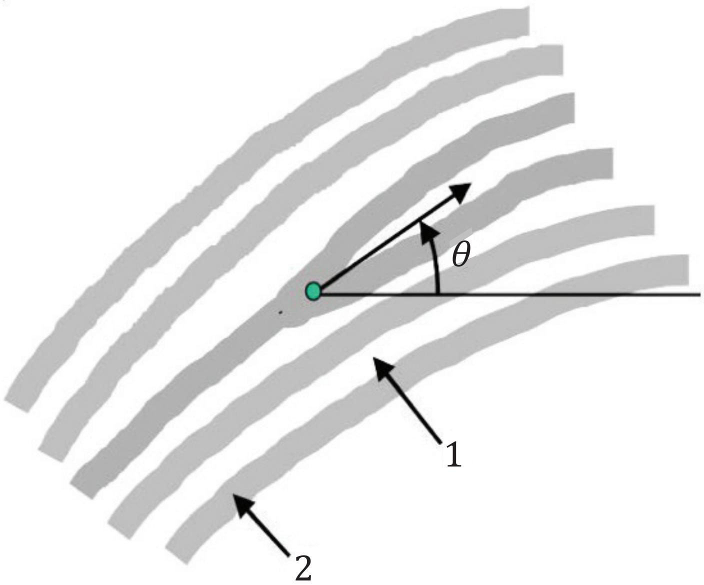
1 valley

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).



Key

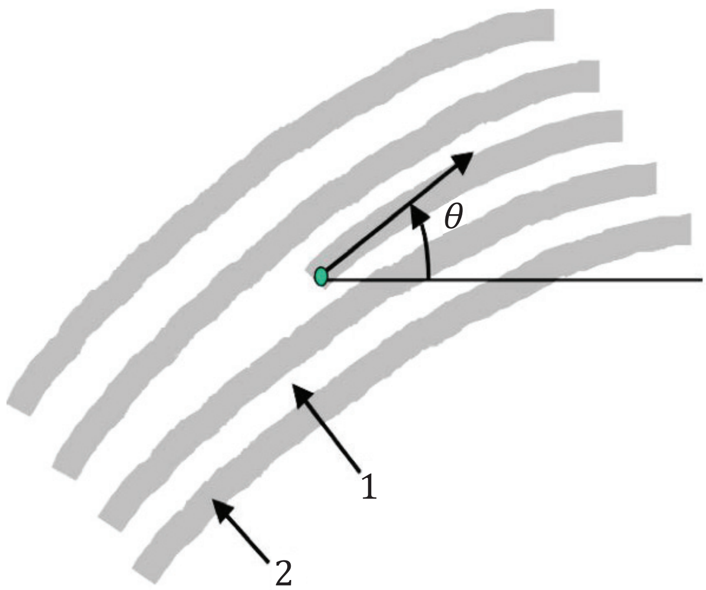
1 valley

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)

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).

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