INTERNATIONAL STANDARD

ISO/IEC 19794-8

First edition
2006-10-01

Information technology — Biometric data interchange formats —

Part 8:
Finger pattern skeletal data

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

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

Reference number
ISO/IEC 19794-8:2006(E)

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Foreword

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

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

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

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

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

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

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

Introduction

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

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

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

— interoperability among fingerprint recognition vendors based on a small data record is allowed;

— proliferation of low-cost commercial fingerprint sensors with limited coverage, dynamic range, or resolution is supported;

— a data record that can be used to store biometric information on a variety a storage media (including but not limited to, portable devices and smart cards) is defined;

— adoption of biometrics in applications requiring interoperability is encouraged.

It is recommended that biometric data protection techniques in ANSI/X9 X9.84 or ISO/IEC 15408 are used to safeguard the biometric data defined herein for confidentiality, integrity and availability.

Information technology — Biometric data interchange formats —

Part 8:
Finger pattern skeletal data

1 Scope

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

2 Conformance

A system conforms to this part of ISO/IEC 19794 if it satisfies the mandatory requirements herein for extraction and description of the skeleton described in Clause 6 and the generation of the data record as described in Clause 7.

Since any finger skeletal data extraction and comparison algorithm supporting the described finger skeletal data interchange formats may be used, interoperability testing is of extreme importance, especially for environments in which components of different manufacturers interact.

3 Normative references

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

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

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

ISO/IEC 19784-1:2006, *Information technology — Biometric application programming interface — Part 1: BioAPI specification*

4 Terms and definitions

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

4.1
biometrics
automated recognition of individuals based on their behavioural and biological characteristics

4.2
biometric algorithm
sequence of instructions that tell a biometric system how to solve a particular problem

NOTE An algorithm will have a finite number of steps and is typically used by the biometric engine (i.e. the biometric system software) to compute whether a biometric sample and template are a match.

4.3
biometric data
biometric sample at any stage of processing, biometric reference, biometric feature or biometric property

4.4
biometric information template
constructed data object in a card containing information needed by the outside world for a verification process

NOTE See ISO/IEC 7816-11.

4.5
biometric reference
one or more stored biometric samples, biometric templates or biometric models attributed to a subject and used for comparison

EXAMPLES Face image on a passport; fingerprint minutiae template on a national ID card; Gaussian mixture model, for speaker recognition, in a database.

4.6
biometric sample
analog or digital representation of biometric characteristics prior to feature extraction process and obtained from a biometric device

4.7
biometric system
automated system capable of

1. capturing a biometric sample from a subject;
2. extracting a biometric feature from that sample;
3. comparing the biometric feature with that contained in the biometric reference;
4. deciding how well they match; and
5. indicating whether or not an identification or verification of identity has been achieved

4.8
biometric template
set of stored biometric features comparable directly to biometric features of a presented biometric sample

NOTE 1 A biometric reference consisting of an image, or other captured biometric sample in its original, enhanced or compressed form, is not a biometric template.

NOTE 2 The biometric features are not considered to be a biometric template unless they are stored for reference.

4.9
bit-depth
number of bits used to represent a data element

4.10
capture
method of taking a biometric sample from the subject

4.11
cell
rectangular region defined by a uniform and non-overlapping division of the image

4.12
closed-set identification
biometric application that ranks the biometric references in the enrolment database in order of decreasing similarity against a presented biometric sample

4.13
comparison
estimation, calculation or measurement of similarity or dissimilarity between biometric sample(s) and biometric reference(s)

4.14
core
singular point in the fingerprint, where the curvature of the ridges reaches a maximum[1)]

NOTE For simplicity, the core can be considered as a U-turn, sometimes enclosing a few ridge endings. It serves as an approximation of the centre of the fingerprint image.

4.15
delta
structure where three fields of parallel ridge lines meet[1)]

NOTE From Danuta Z. Loesch, "Quantative dermatoglyphics – classification, genetics, and pathology", Oxford Monographs on Medical Genetics No. 10, Oxford University Press 1983, ISBN 0-19-261305-7, page 7.

4.16
dimension
number of pixels in an acquired biometric sample in either the x- or y- direction

4.17
enrolment
process of creating and storing, for an individual, a data record associated with an individual and including biometric reference(s) and, typically, non-biometric data

4.18
friction ridge
structure on the skin of the fingers and toes, the palms and soles of the feet, which makes contact with an incident surface under normal touch

NOTE On the fingers, the unique patterns formed by the friction ridges make up fingerprints.

4.19
identification
biometric system function that performs a one-to-many search

NOTE An identification function may be used to verify a claim of enrolment in an enrolment database without a specified biometric reference identifier.

4.20
latent
fingerprint collected from an intermediate surface, rather than directly via a live capture from the finger itself

4.21
live capture
process of capturing a biometric sample by an interaction between a subject and a biometric system

[1)] The definitions of core and delta in ISO/IEC 19794-3 and this part of ISO/IEC 19794 are identical. However there is a different definition in ISO/IEC 19794-2. Although both definitions try to define the same thing, this difference has occurred for historical reasons.

4.22
minutia
friction ridge characteristic, occurring at a point where a single friction ridge deviates from an uninterrupted flow, that is used to individualize a fingerprint

NOTE 1 Deviation may take the form of ending, division, or a more complicated “composite” type.

NOTE 2 The plural of minutia is minutiae.

4.23
one-to-many search
comparison process in which a biometric sample set of one individual is compared against the biometric references of more than one individual to return a set of comparison scores

NOTE 1 A biometric identification function performs a one-to-many search.

NOTE 2 In the case of a multimodal biometric system, biometric sample and biometric reference in the above definition comprise individual biometric samples/references of the component modalities.

NOTE 3 The degree of similarity may be specified on the basis of comparison score and/or rank.

4.24
open-set identification
biometric application that determines a possibly empty candidate list by collecting one or more biometric samples from an individual and searching the enrolment database for similar biometric references

4.25
record
reference and other information about the subject

NOTE E.g. to access permissions.

4.26
resolution
number of pixels (picture elements) per unit distance in the image of the fingerprint

4.27
ridge bifurcation
minutia assigned to the location at which a friction ridge splits into two ridges or, alternatively, where two separate friction ridges combine into one

4.28
ridge ending
minutia assigned to the location at which a friction ridge terminates or begins

4.29
skeleton
line representation of an object that is one pixel thick through the “middle” of the object and preserves the topology of the object

4.30
swipe
method of fingerprint collection where the finger is manually moved across a one-dimensional sensor to produce the two-dimensional image

4.31
sweat pore
minute opening in the dermis, allowing loss of fluid as a part of the temperature control of the body

4.32
user
client to any biometric vendor

NOTE The user must be differentiated from the end-user (subject) and is responsible for managing and implementing the biometric application rather than actually interacting with the biometric system.

4.33
valley
area surrounding a friction ridge, which does not make contact with an incident surface under normal touch

4.34
verification
verify
process of comparing a submitted biometric sample against the biometric reference template of a single enrolee whose identity is being claimed, to determine whether it matches the enrolee's template

cf. **identification**

5 Abbreviated terms

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

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

6 Determination of finger pattern skeletal data

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

6.1 Minutia

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

6.1.1 Minutia type

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

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

- Virtual endings are necessary to describe skeleton lines ending at the image boundary or at border lines to those areas where there is insufficient image quality to determine ridges and real minutiae points (see Figure A.3). They are also needed to finish the encoding of a closed loop (Table A.1). Virtual endings have been assigned the 2-bit value 00.

- In rare cases a skeleton line description will require the insertion of a virtual minutia point on a ridgeline. For example, such points will be required to begin an encoding of a closed loop for which no real minutiae exist, as well as to describe ridges with high curvature at a sufficient accuracy (see note about maximal curvature in 6.2.4). These are called “virtual continuation” and have been assigned the 2-bitvalue 11 (Table A1).

6.1.2 Minutia location and coordinate system

The coordinate system used to express the position of the minutiae points of a fingerprint shall be a Cartesian coordinate system. Points shall be represented by their x and y coordinates, where x increases to the right and x increases downward (opposite of the pointing direction of the finger), when viewing on a latent print of the finger (see Figure 1). Note that this is in agreement with most imaging and image processing use. When viewing on the finger, x increases from right to left as shown in Figure 1. All x and y values are non-negative. For the skeletal pattern record format, the resolution is specified in the record header, see 7.3.7. For the skeletal pattern card format, the resolution of the x and y coordinates of the minutia shall be in metric units. The granularity is one bit per five hundredth of a millimetre in the normal format and one tenth of a millimetre in the compact format:

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

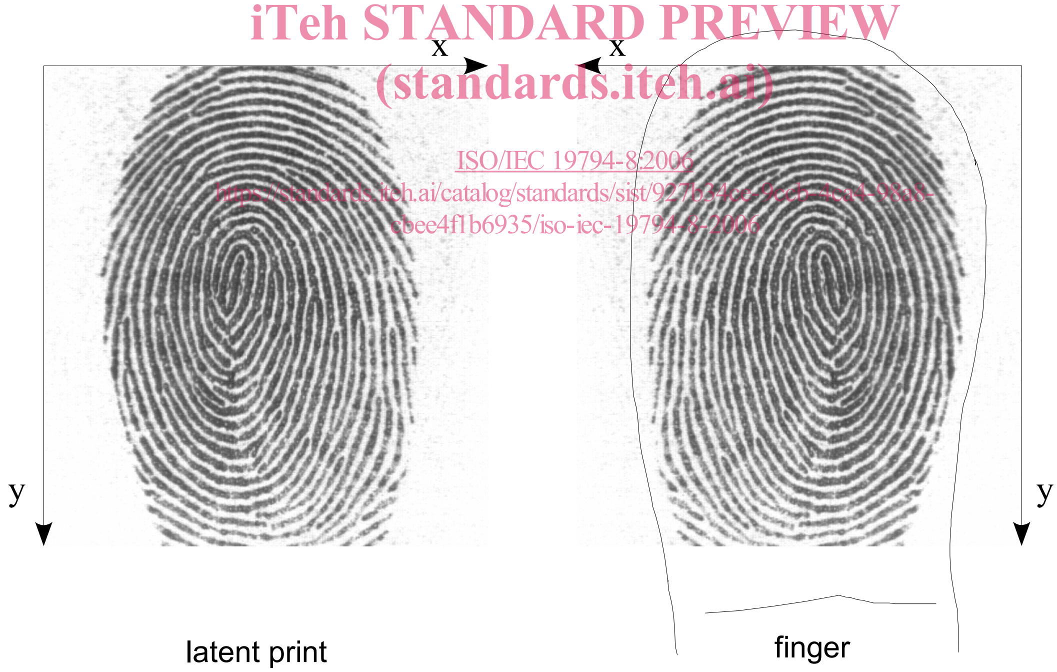

Figure 1 — Coordinate system

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

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

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

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

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

6.1.3 Angle conventions

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

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

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

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

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

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

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

The definition of the minutia position and direction is identical with ISO/IEC 19794-2 card format (Format type '0004' or '0006') with

— minutia placement on a ridge bifurcation encoded as a ridge skeleton bifurcation point, and

— minutia placement on a ridge skeleton endpoint.

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

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

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

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

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

6.2 Encoding the skeleton ridge line by a direction code

6.2.1 Direction code

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

— minutia type (2 bits: 00 virtual ending, 01 ridge ending, 10 ridge bifurcation, 11 virtual continuation);

— minutia direction (bit-depth defined in the record header, range: 0-360 degrees scaled according to bit-depth);

— x-coordinate (bit-depth defined in the record header);

— y-coordinate (bit-depth defined in the record header);

— number of direction elements following (8 bits).

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

— direction change (bit-depth and resolution defined in the record header, data type is a signed integer - the smallest negative number 10…0 is not used for direction change); (e.g. for bit-depth of 4 and 32 directions on 180° the signed integer range from –7 to 7 is scaled to the angle range from –39,375° to +39,375°;

  — or in situations of high ridge line curvature one may wish to store direction elements at higher spatial resolution. Therefore one can switch between two different resolution levels. With the smallest negative number 10…0 the resolution level is switched between normal or high. A line encoding will always start at normal resolution. On the first occurrence of 10…0 in a line code switch to high resolution level in using half the step length, on the second occurrence switch back normal resolution and full step length etc. (Table A.2).

— the direction change is repeated until the line end is reached;

— minutia type of line end (2 bits: 00 virtual ending, 01 ridge end, 10 ridge bifurcation, 11 virtual continuation).

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

— The relative minutia position l/S_n is scaled to the range 0-3 via min(3, floor($4l/S_n$)) and stored as unsigned integer of length 2 bits, where l is the distance between the start of the last line element and the minutia, and S_n the step length of the last line element (Figure 2).

— If the skeleton line ends at a true minutia (type number 01 or 10) or is interrupted by a virtual continuation (type number 11) a byte-aligned minutia description follows. In order to keep the alignment overhead small it is done in the following manner: If the previously stored minutia type of the line end is already starting byte aligned, the minutia data is completed by appending its direction and position. On unaligned ending type, it is repeated at the start of the next byte followed by direction and position.

Thus the encoding continues with the following:

— if the previously stored minutia type of the line end is not starting byte aligned, it is repeated at the start of the next byte. Any unused bits caused by this alignment are filled with zeros;

— minutia direction (bit-depth defined in the record header, range 0-360 degrees scaled according to bit-depth);

— x-coordinate (bit-depth defined in the record header);

— y-coordinate (bit-depth defined in the record header).

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

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

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

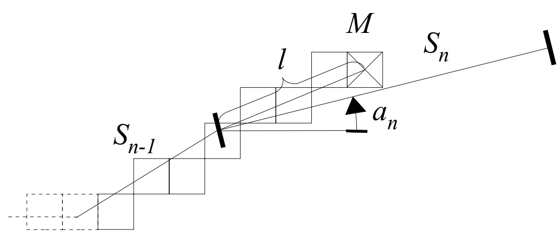

Figure 2 — The relative minutia position on a polygon line element is the ratio l/S_n, where S_n is the length of the line element passing the minutia M and l is the distance between the start of S_n and minutia M. α_n is the angle of S_n.

6.2.2 General skeleton line encoding rules

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

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

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

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

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

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

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

— The reconstructed skeleton line polygon element shall be inside the area of the ridge it is describing for most part of its length, i. e. at least 50%. A threshold in the range of 5% may be appropriate (best practice). This value depends on the reconstruction and comparison quality requirements of the application.