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Biometrics — Biometric Data Interchange Formats — Part 2: Finger Minutiae Data

Biométrie — Formats d'échanges de données biométriques — Partie 2: Dates des minuties du doigt

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Foreword

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ISO/IEC 19794-2 was prepared by Joint Technical Committee ISO/IEC JTC 1, Subcommittee SC 37, .

This second/third/... edition cancels and replaces the first/second/... edition (), [clause(s) / subclause(s) / table(s) / figure(s) / annex(es)] of which [has / have] been technically revised.

ISO/IEC 19794 consists of the following parts, under the general title *Biometrics — 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 Behavioural Data*

— *Part 8: Finger Pattern Skeletal Data*

Introduction

In the interest of implementing interoperable biometric recognition systems, this ISO/IEC Standard establishes a data interchange format for minutiae-based fingerprint capture and recognition equipment. Representation of fingerprint data using minutiae is a widely used technique in many application areas.

This Standard defines specifics of the extraction of key points (called *minutiae*) from fingerprint ridge patterns. Two types of data formats are then defined: one for general storage and transport, one for use in card-based systems; the card format has a standard and a compact expression.

Biometrics — Biometric Data Interchange Formats — Part 2: Finger Minutiae Data

1 Scope

This Standard specifies a concept and data formats for representation of fingerprints using the fundamental notion of minutiae. The standard is generic, in that it may be applied and used in a wide range of application areas where automated fingerprint recognition is involved. The Standard contains definitions of relevant terms, a description of how minutiae points shall be determined, data formats for containing the data for both general use and for use with cards, and conformance information. Guidelines and values for matching and decision parameters are provided in an informative Annex.

2 Conformance

A system conforms to this standard if it satisfies the mandatory requirements herein for extraction of minutiae points from a fingerprint image as described in Section 6 and the generation of a minutiae data format as described in Section 7 (for general data interchange use) or Section 8 (for use with cards).

3 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, subsequent amendments to or revisions of any of these publications apply to this standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

ISO/IEC CD3 19785-1:2003 – Biometrics – Common Biometric Exchange Formats Framework (CBEFF) – Part 1: Data Element Specification

ISO/IEC WD 19785-2:2003 – Biometrics – Common Biometric Exchange Formats Framework (CBEFF) – Part 2: Procedures of the Operation of the Biometric Registration Authority

ISO/IEC FCD 19784:2003– Information technology – BioAPI Specification

ANSI/NIST-ITL 1-2000 – *Standard Data Format for the Interchange of Fingerprint, Facial & Scar. Mark & Tattoo (SMT) Information*

ISO/IEC 7816-11 Identification Cards – Integrated circuits cards, Part 11: Personal verification through biometric methods

4 Terms and definitions

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

4.1
Algorithm
A sequence of instructions that tell a biometric system how to solve a particular problem. 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
Biometrics *[harmonized]*
[automated] recognition of [living] persons based on observation of behavioral and biological (anatomical and physiological) characteristics.

4.3
Biometric *[harmonized]*
Pertaining to the field of biometrics..

4.4
Biometric Data
Data encoding a feature or features used in biometric verification.

4.5
Biometric Information Template
A constructed data object in a card containing information needed by the outside world for a verification process, see ISO/IEC 7816-11

4.6
Biometric Sample *[harmonized]*
Information obtained from a biometric device, either directly or after further processing.

4.7
Biometric System
An automated system capable of:
1. capturing a biometric sample from an end user;
2. extracting biometric data from that sample;
3. comparing the biometric data with that contained in one or more reference templates;
4. deciding how well they match; and
5. indicating whether or not an identification or verification of identity has been achieved.

4.8
Capture
The process of taking a biometric sample from an end user.

4.9
Cell
A rectangular region defined by a uniform and non-overlapping division of the image.

4.10
Comparison
The process of comparing a biometric sample with a previously stored reference template or templates.

4.11
Claimant
A person submitting a biometric sample for verification or identification while claiming a legitimate or false identity.

4.12
Core
A core is the topmost point on the innermost recurving ridgeline of a fingerprint. Generally, the core is placed upon or within the innermost recurve of a loop.

4.13
Database
Any storage of biometric templates and related end user information.

4.14
Delta
A Delta is that point on a ridge at or nearest to the point of divergence of two type lines, and located at or directly in front of the point of divergence.

4.15
End User
A person who interacts with a biometric system to enroll or have his/her identity checked. Contrast with “User”.

4.16
Enrollment
The process of collecting biometric samples from a person and the subsequent preparation and storage of biometric reference templates representing that person's identity.

4.17
Extraction
The process of converting a captured biometric sample into biometric data so that it can be compared to a reference template; sometimes called "characterization".

4.18
Friction Ridge
The ridges present 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. On the fingers, the unique patterns formed by the friction ridges make up fingerprints.

4.19
Identification / Identify
The one-to-many process of comparing a submitted biometric sample against all of the biometric reference templates on file to determine whether it matches any of the templates and, if so, the identity of the enrollee whose template was matched. The biometric system using the one-to-many approach is seeking to find an identity amongst a database rather than verify a claimed identity. Contrast with ‘Verification’.

4.20
Live Capture
The process of capturing a biometric sample by an interaction between an end user and a biometric system.

4.21
Live-Scan Print
A fingerprint image that is produced by scanning or imaging a live finger to generate an image of the friction ridges.

4.22
Match / Matching
The process of comparing a biometric sample against a previously stored template and scoring the level of similarity.

4.23
Minutia (single) Minutiae (pl)
Friction ridge characteristics that are used to individualize a fingerprint. Minutiae occur at points where a single friction ridge deviates from an uninterrupted flow. Deviation may take the form of ending, division, or a more complicated “composite” type.

4.24
Population
The set of end-users for the application.

4.25
Record
The template and other information about the end-user (e.g. access permissions).

4.26
Resolution
The number of pixels (picture elements) per unit distance in the image of the fingerprint.

4.27
Ridge Bifurcation
The minutiae point 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
The minutiae point assigned to the location at which a friction ridge terminates or, alternatively, begins. A ridge ending is defined as the bifurcation of the adjacent valley - the location at which a valley splits into two valleys or, alternatively, at which two separate valleys combine into one.

4.29
Ridge Skeleton Endpoint
The minutiae point assigned to the location at which a ridge skeleton ends. A ridge skeleton endpoint is defined as the ending of the skeleton of a ridge.

4.30
Skeleton
The single-pixel-wide representation of a ridge or valley obtained by successive symmetric thinning operations. The skeleton is also known as the medial axis.

4.31
Template / Reference Template
Data, which represents the biometric measurement of an enrollee, used by a biometric system for comparison against subsequently submitted biometric samples. NOTE - this term is not restricted to mean only data used in any particular recognition method, such as template matching.

4.32
Typeline
Type Lines are the two innermost ridges that start parallel, diverge, and surround or tend to surround the pattern area.

4.33
User
The client to any biometric vendor. The user must be differentiated from the end user and is responsible for managing and implementing the biometric application rather than actually interacting with the biometric system.

4.34
Valley
The area surrounding a friction ridge, which does not make contact with an incident surface under normal touch; the area of the finger between two friction ridges.

4.35
Valley Bifurcation
The point at which a valley splits into two valleys or, alternatively, where two separate valleys combine into one.

4.36
Verification / Verify
The process of comparing a submitted biometric sample against the biometric reference template of a single enrollee whose identity is being claimed, to determine whether it matches the enrollee's template. Contrast with 'Identification'.

5 Symbols (and abbreviated terms)

The following abbreviations apply for the document:

BER	Basic Encoding Rules
BIT	Biometric Information Template
CBEFF	Common Biometric Exchange Formats Framework
DO	Data Object
FAR	False Acceptance Rate
FRR	False Rejection Rate
ICC	Integrated Circuit Card
RCE	Ridge Count Extraction
RFU	Reserved for Future Use
TLV	Tag-Length-Value

6 Minutiae Extraction

This section defines the placement of minutiae on the fingerprint. Compatible minutiae extraction is required for interoperability between different finger matchers for the purposes of matching an individual against a previously collected and stored finger record. The interoperability is based on defining the finger minutiae extraction rules, record formats and card formats that are common to many finger matchers for acceptable matching accuracy, while allowing for extended data to be attached for use with equipment that is compatible with it.

6.1 Principle

Establishment of a common feature-based representation must rest on agreement on 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 below accomplish this. See Figure 1 for an illustration of the definitions below.

6.2 Minutia Type

Each minutia point has a “type” associated with it. There are two major types of minutia: a “ridge skeleton end point” and a “ridge skeleton bifurcation point” or split point. There are other types of “points of interest” in the friction ridges that occur much less frequently and are more difficult to define precisely. More complex types of minutiae are usually a combination of the basic types defined above. Some points are neither a ridge ending nor a bifurcation. This standard therefore defines additionally a type named “other”, which shall be used in such a way that that the matching conditions specified in clause 6.5 apply. Therefore, the following types are distinguished:

- ridge ending (also identifiable as a valley skeleton bifurcation point);
- ridge bifurcation
- other.

A ridge ending may — alternatively — be regarded as a valley bifurcation depending on the method to determine its position (see below). The format type of the biometric information template indicates the use of ridge endings or valley bifurcations.

6.3 Minutia Location

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 minutiae should be equivalent to the skeleton method.

6.3.1 Coordinate System

The coordinate system used to express the minutia points 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. Note that 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.

The X and Y coordinates of the minutia points shall be in pixel units, with the spatial resolution of a pixel given in the "X Resolution" and "Y Resolution" fields of the format. X and Y resolutions are stated separately.

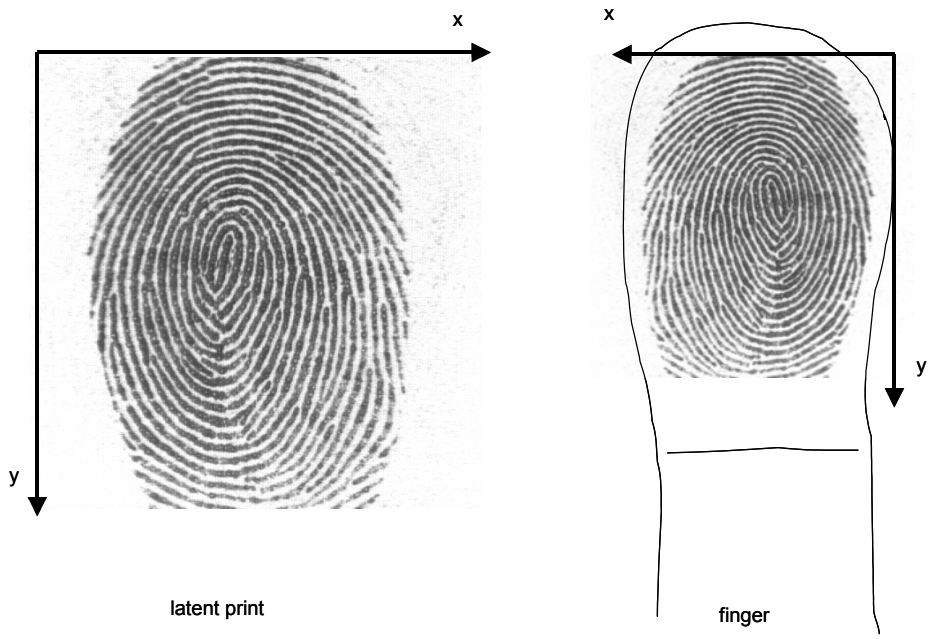


Figure 1 – Coordinate system

For the finger minutiae record format, the resolution of the coordinate system is specified in the record header, see 7.3.8 and 7.3.9. For the finger minutiae card format, the resolution of the X and Y coordinates of the minutia points shall be in metric units. The granularity is one bit per one hundredth of a millimeter in the normal format and one tenth of a millimeter in the compact format:

1 unit = 10^{-2} mm (normal format) or 10^{-1} mm (compact format).

6.3.2 Minutia Placement on a Ridge Ending (encoded as Valley Skeleton Bifurcation Point)

The minutia point for a ridge ending 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 legs intersect is the location of the minutia. In simpler terms, the point where the valley "Y"'s, or (equivalently) where the three legs of the thinned valley area intersect (see Fig. 2).

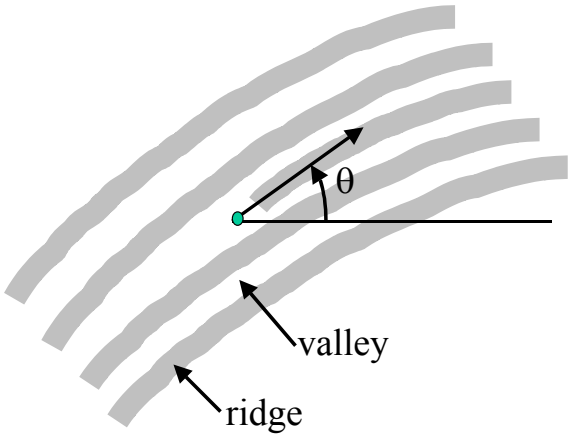


Figure 2 - Location and direction of a ridge ending (encoded as valley skeleton bifurcation point)

6.3.3 Minutiae Placement on a Ridge Bifurcation (encoded as a Ridge Skeleton Bifurcation Point)

The minutia point for 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 legs intersect is the location of the minutia. In simpler terms, the point where the ridge "Y"'s, or (equivalently) where the three legs of the thinned ridge intersect (see Figure 3).

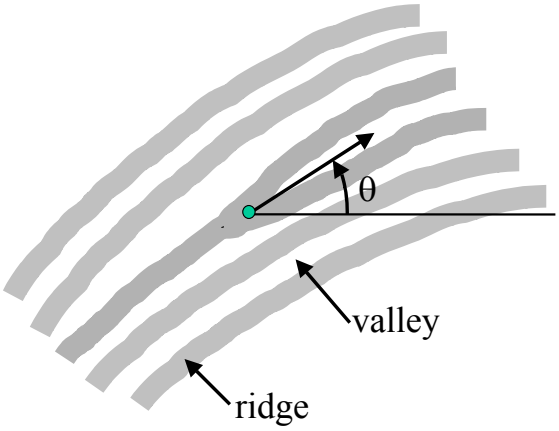


Figure 3 - Location and direction of a ridge bifurcation (encoded as ridge skeleton bifurcation point)

6.3.4 Minutiae Placement on a Ridge Skeleton Endpoint

The minutia point for a ridge skeleton endpoint shall be defined as the center 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 neighbor pixel belonging to the skeleton (see Figure 4).

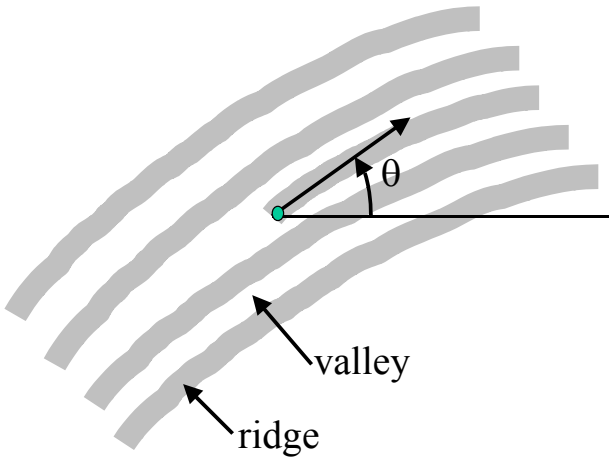


Figure 4 - Location and direction of a ridge skeleton endpoint

6.3.5 Minutiae Placement on Other Minutiae Types

For minutiae other than a bifurcation or ridge ending the position and angle calculations shall be done in such a way that the matching conditions in clause 6.5 apply.

6.3.6 Usage of the Minutiae Placement by the Record Formats and the Card Formats

The record formats use

- ridge ending and ridge bifurcation points.

The card formats use

- ridge ending and ridge bifurcation points, or

- ridge skeleton end points and ridge bifurcation points

depending on the specific algorithms implemented. In case of on-card matching, a card will request from the card usage system biometric verification 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, which contain the CBEFF data elements format owner and format type – see ISO/IEC 19785-1 and ISO/IEC 7816-11.

6.4 Minutia Direction

6.4.1 Angle Conventions

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

In the record formats, the angle of a minutia is scaled to fit the granularity of 1.40625 (360/256) degrees per least significant bit.

The angle coding for the card formats differ for the normal size and the compact size formats; refer to section 8.1 and 8.2.

6.4.2 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 encompass an acute angle. The tangent to the third valley lying opposite of the enclosed ridge defines the direction of a valley bifurcation. The direction is again measured as the angle the tangent forms with the horizontal axis to the right (see Figure 2).

6.4.3 Minutia Direction of a Ridge Bifurcation (encoded as Ridge Skeleton Bifurcation Point)

A ridge bifurcation (encoded as ridge skeleton bifurcation point) has three arms of ridges meeting in one point. Two ridges encompass an acute angle. The tangent to the third ridge lying opposite of the enclosed valley defines the direction of a ridge bifurcation. The direction is again measured as the angle the tangent forms with the horizontal axis to the right (see Figure 3).

6.4.4 Minutia Direction of a Ridge Skeleton End Point

The direction of a 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). Ridge skeleton end points are only used in one type of the card formats, whereas in the other type ridge ending and ridge birfurcation is used as in the record format.

6.5 Minutia Type Matching

In a matching process, the different minutiae types shall be matched according to the following Table 1. Matchers may choose to assign lower weights (or importance) to a match of type 00 to 01 or 10, than to a match of type 00 to 00, 01 to 01, or 10 to 10.

Table 1 - Minutiae Type Matching

Type of verification minutiae	Match with type of reference minutiae
00	00, 01, 10
01	00, 01
10	00, 10
00 = other 01 = ridge ending (encoded as valley skeleton bifurcation point), or ridge skeleton end point, see note 10 = ridge bifurcation (encoded as ridge skeleton bifurcation point)	

7 Finger Minutiae Record Format

7.1 Introduction

The minutiae record format shall be used to achieve interoperability between finger matchers providing a one-to-one verification. The minutia data shall be represented in a common format, containing both basic and extended data. With the exception of the Format Identifier and the Version number for the standard, which are null-terminated ASCII character strings, all data is represented in binary format. There are no record separators or field tags; fields are parsed by byte count.

7.2 Record Organization

The organization of the record is as follows:

- A fixed-length (24-byte) record header containing information about the overall record, including the number of fingers represented and the overall record length in bytes;
- A Single Finger record for each finger, consisting of:
- A fixed-length (4-byte) header containing information about the data for a single finger, including the number of minutiae;
- A series of fixed-length(6-byte) minutia point descriptions, including the position, type, angle and quality of the minutia point;
- One or more “extended” data areas for each finger, containing optional or vendor-specific information.

All multibyte quantities are represented in Big-Endian format; that is, 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 are unsigned quantities.

7.3 Record Header

There shall be one and only one record header for the minutiae record, to hold information describing the identity and characteristics of device that generated the minutiae data

7.3.1 Format Identifier

The Finger Minutiae Record shall begin with the three ASCII characters “FMR”. followed by a zero byte as a NULL string terminator.

7.3.2 Version Number

The version number for the version of this standard used in constructing the minutiae record shall be placed in four bytes. This version number shall consist of three ASCII numerals followed by a zero byte as a NULL string terminator. The first and second character will represent the major revision number and the third character will represent the minor revision number.

Upon approval of this specification, the version number shall be “ 20” (an ASCII space followed by an ASCII ‘2’ and an ASCII ‘0’).

7.3.3 Length of Record

The length of the entire record shall be recorded in four bytes.

7.3.4 Capture Equipment Certifications

This field contains four bits used to indicate that the capture equipment used to capture the original fingerprint image was compliant with a standard certification method for such equipment. Currently, only two bits are defined. If the most significant bit is ‘1’, the original capture equipment was certified to be compliant with the specifications in Annex D, copied from the US Federal Bureau of Investigation’s Image Quality Specifications, Appendix F. The least significant of the four bits is reserved for a future ISO finger image capture equipment certification. The two additional bits are reserved for future image quality certifications.

7.3.5 Capture Device Type ID

The capture device type ID shall be recorded in twelve bits. This ID is used to identify the type or model of capture device used to acquire the original biometric sample. A value of all zeros will be acceptable and will indicate that the capture device type ID is unreported. The vendor determines the value for this field. Applications developers may obtain the values for these codes from the vendor. Reporting the capture device type ID is optional but recommended. The value “unreported” may not be allowable in some applications.

7.3.6 Size of Scanned Image in X direction

The size of the original image in pixels in the X direction shall be contained in two bytes.

7.3.7 Size of Scanned Image in Y direction

The size of the original image in pixels in the Y direction shall be contained in two bytes.

7.3.8 X (horizontal) resolution

The resolution of the minutiae coordinate system shall be recorded in two bytes having the units of pixels per centimeter. The value of the sensor X resolution shall not be zero.

7.3.9 Y (vertical) resolution

The resolution of the minutiae coordinate system shall be recorded in two bytes having the units of pixels per centimeter. The value of the sensor Y resolution shall not be zero.

7.3.10 Number Of Finger Views

The total number of finger views contained in the minutiae record shall be recorded in one byte. In cases where there is more than one view of any finger, this number will be greater than the number of fingers.

7.3.11 Reserved Byte

This field is reserved for future use, and to align the end of the record header on a long-word (four byte) boundary. For the current version of the standard, this field shall be set to zero.

7.4 Single Finger Record Format

7.4.1 Finger Header

A finger header shall start each section of finger data providing information for that finger. There shall be one finger header for each finger contained in the finger minutiae record. The finger header will occupy a total of four bytes as described below. Note that it is permissible for more than one finger record to represent the same finger, with (presumably) different data, perhaps in the private area.

7.4.1.1 Finger Position

The finger position shall be recorded in one byte. The codes for this byte shall be as defined in Table 5 of ANSI/NIST-ITL 1-2000, “Data Format for the Interchange of Fingerprint Information”. This table is reproduced here in Table 2 for convenience. Only codes 0 through 10 shall be used; the “plain” codes are not relevant for this standard.

7.4.1.2 View Number

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

Table 2 - Finger Position Codes

Finger position	Code
Unknown finger	0
Right thumb	1
Right index finger	2
Right middle finger	3
Right ring finger	4
Right little finger	5
Left thumb	6
Left index finger	7
Left middle finger	8
Left ring finger	9
Left little finger	10
Plain right thumb	*11*
Plain left thumb	*12*
Plain right four fingers	*13*
Plain left four fingers	*14*

7.4.1.3 Impression Type

The impression type of the finger images that the minutiae data was derived from shall be recorded in four bits. The codes for this byte are shown in Table 3. These codes are compatible with Table 4 of ANSI/NIST-ITL 1-2000, "Data Format for the Interchange of Fingerprint Information", with the addition of the "swipe" type. The "swipe" type identifies data records derived from image streams generated by sliding the finger across a small sensor. Only codes 0 through 3 and 8 shall be used; the "latent" codes are not relevant for this standard.

Table 3 - Impression Type Codes

Description	Code
Live-scan plain	0
Live-scan rolled	1
Nonlive-scan plain	2
Nonlive-scan rolled	3
Latent impression	*4*
Latent tracing	*5*
Latent photo	*6*
Latent lift	*7*
Swipe	8

7.4.1.4 Finger Quality

The quality of the overall finger minutiae data shall be between 0 and 100 and recorded in one byte. This quality number is an overall expression of the quality of the finger record, and represents quality of the original image, of the minutia extraction and any additional operations that may affect the minutia record. A value of 0 shall represent the lowest possible quality and the value 100 shall represent the higher possible quality. The numeric values in this field will be set in accordance with the general guidelines contained in Section 2.1.42 of ANSI/INCITS 358-2002, "BioAPI H-Level Specification Version 1.1". The matcher may use this value to determine its certainty of verification.

7.4.1.5 Number of Minutiae

The number of minutiae recorded for the finger shall be recorded in one byte.

7.4.2 Finger Minutiae Data

The finger minutiae data for a single finger shall be recorded in blocks of six bytes per minutia point. The order of the minutiae is not specified.

7.4.2.1 Minutiae Type

The type of minutiae will be recorded in the first two bits of the upper byte of the X coordinate. There will be two bits reserved at the beginning of the upper byte of the Y coordinate for future use. The bits “00” will represent a minutia of “other” type, “01” will represent a ridge ending and “10” will represent a ridge bifurcation.

7.4.2.2 Minutiae Position

The X coordinate of the minutia shall be recorded in the rest of the first two bytes (fourteen bits). The Y coordinate shall be placed in the lower fourteen bits of the following two bytes. The coordinates shall be expressed in pixels at the resolution indicated in the record header. Note that position information shall be present for each minutia point, regardless of type, although position for minutiae of type “other” is vendor defined.

7.4.2.3 Minutiae Angle

The angle of the minutia shall be recorded in one byte in units of 1.40625 (360/256) degrees. The value shall be a non-negative value between 0 and 255, inclusive. For example, an angle value of 16 represents 22.5 degrees. Note that angle information shall be present for each minutia point, regardless of type, although angle for minutiae of type “other” is vendor defined.

7.4.2.4 Minutiae Quality

The quality of each minutia shall be recorded in one byte. The quality figure shall range from 100 as a maximum to 1 as a minimum. In interoperable use, only the relative values of minutiae quality values is meaningful; there is no guaranteed relationship between minutiae quality values assigned by different equipment suppliers. Any equipment that does not supply quality information for individual minutia points shall set all quality values to 0.

7.5 Extended Data

The extended data section of the finger minutiae record is open to placing additional data that may be used by the matching equipment. The size of this section shall be kept as small as possible, augmenting the data stored in the standard minutiae section. The extended data for each finger view shall immediately follow the standard minutiae data for that finger view and shall begin with the Extended Data Block Length field. More than one extended data area may be present for each finger and the extended data block length field will be the summation of the lengths of each extended data segment. The data block length is used as a signal for the existence of the extended data while the individual extended data length fields are used as indices to parse the extended data. Note that the extended data area cannot be used alone, without the standard portion of the minutiae record.

While the extended data area allows for inclusion of proprietary data within the minutiae format, this is not intended to allow for alternate representations of data that can be represented in open manner as defined in this standard. In particular, ridge count data, core and delta data or zonal quality information shall not be represented in proprietary manner to the exclusion of the publicly defined formats in this standard. Additional ridge count, core and delta or zonal quality information may be placed in a proprietary extended data area if the standard fields defined below are also populated. The intention of this standard is to provide inter-operability.

7.5.1 Common Extended Data Fields

7.5.1.1 Extended Data Block Length

All minutiae records shall contain the extended data block length. This field will signify the existence of extended data. A value of all zeros (0x0000 hexadecimal) will indicate that there is no extended data and that the file will end or continue with the next finger view. A nonzero value will indicate the length of all extended data starting with the next byte. The block length (7.5.1.1) will then be followed by the type identification code (7.5.1.2), length of data field (7.5.1.3) and the data area (7.5.1.4).

7.5.1.2 Extended Data Area Type Code

The type identification code shall be recorded in two bytes, and shall distinguish the format of the extended data area (as defined by the Vendor specified by the PID code in the CBEFF header). A value of zero in both bytes is a reserved value and shall not be used. A value of zero in the first byte, followed by a non-zero value in the second byte, shall indicate that the extended data section has a format defined in this standard. A non-zero value in the first byte shall indicate a vendor specified format, with a code maintained by the vendor. Refer to Table 3 for a summary of the type identification codes. If the Extended Data Block Length (7.5.1.1) for the finger view is zero, indicating no extended data, this field shall not be present.

Table 4 - Extended Data Area Type Codes

First byte	Second byte	Identification
0x00	0x00	reserved
0x00	0x01	ridge count data (Section 7.5.2)
0x00	0x02	core and delta data (Section 7.5.3)
0x00	0x03	zonal quality data (Section 7.5.4)
0x00	0x04-0xFF	reserved
0x01-0xFF	0x00	reserved
0x01-0xFF	0x01-0xFF	vendor-defined extended data

7.5.1.3 Extended Data Area Length

The length of the extended data section shall be recorded in two bytes. This value is used to skip to the next extended data if the matcher cannot decode and use this data. If the Extended Data Block Length (7.5.1.1) for the finger view is zero, indicating no extended data, this field shall not be present.

7.5.1.4 Data Section

The data field of the extended data is defined by the equipment that is generating the finger minutiae record, or by common extended data formats contained in this standard; see section 7.5.2, 7.5.3 and 7.5.4. If the Extended Data Block Length (7.5.1.1) for the finger view is zero, indicating no extended data, this field shall not be present.

7.5.2 Ridge Count Data Format

If the extended data area type code is 0x0001, the extended data area contains ridge count information. This format is provided to contain optional information about the number of fingerprint ridges between pairs of minutiae points. Each ridge count is associated with a pair of minutiae points contained in the minutiae data area defined in section 7.4.2; 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 points. Refer to Figure 5 for clarification; the ridge count between minutiae A and B is 1, while the ridge count between minutiae B and C is 2.

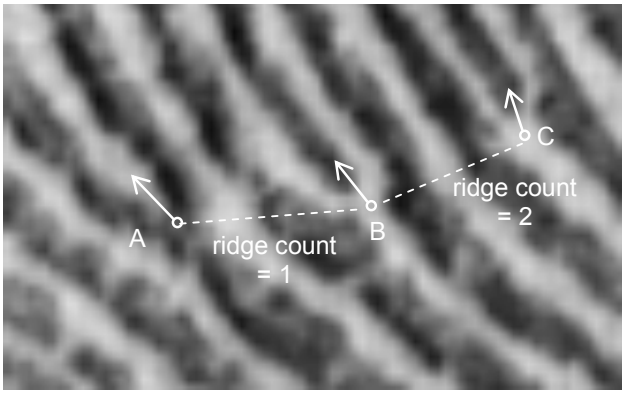


Figure 5 - Example Ridge Count data

7.5.2.1 Ridge Count Extraction Method

The ridge count data area shall begin with a single byte indicating the ridge count extraction method. Ridge counts associated with a particular center minutiae point are frequently extracted in one of two ways: by extracting the ridge count to the nearest neighboring minutiae in each of four angular regions (or quadrants), or by extracting the ridge count to the nearest neighboring minutiae in each of eight angular regions (or octants). The ridge count extraction method field shall indicate the extraction method used, as shown in Table 5.

Table 5 - Ridge Count Extraction Method Codes

RCE method field value	Extraction method	Comments
0x00	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-neighbor minutiae
0x01	Four-neighbor (quadrants)	For each center minutiae used, ridge count data was extracted to the nearest neighboring minutiae in four quadrants, and ridge counts for each center minutiae are listed together
0x02	Eight-neighbor (octants)	For each center minutiae used, ridge count data was extracted to the nearest neighboring minutiae in eight octants, and ridge counts for each center minutiae are listed together

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

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

Example - (Informative) If the extraction method code is 0x01, and ridge counts were extracted for minutiae numbers 5 and 22, the four ridge counts for minutiae number 22 could be listed first, followed by all four ridge counts for minutiae number 5.

7.5.2.2 Ridge Count Data

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

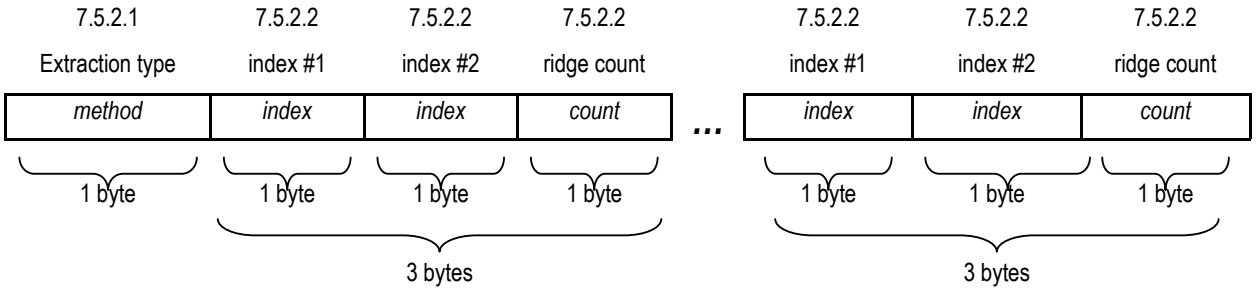
The ridge count data shall be listed in increasing order of the index numbers, as shown in Table 6. There is no requirement that the ridge counts be listed with the lowest index number first. Since the minutiae points are not listed in any specified geometric order, no assumption shall be made about the geometric relationships of the various ridge count items.

Table 6 - Example Ridge Count Data (non-specific extraction method, RCE method = 0x00)

Minutiae index #1	Minutiae index #2	Ridge count
0x01	0x02	0x05
0x01	0x06	0x09
0x01	0x07	0x02
0x02	0x04	0x13
0x02	0x09	0x0D
0x05	0x03	0x03
0x09	0x15	0x08

7.5.2.3 Ridge Count Format Summary

The ridge count data format shall be as follows:



7.5.3 Core and Delta Data Format

If the extended data area type code is 0x0002, the extended data area contains core and delta information. This format is provided to contain optional information about the placement and characteristics of the cores and deltas on the original fingerprint image. Core and delta points are determined by the overall pattern of ridges in the fingerprint. There may be zero or more core points and zero or more delta points for any fingerprint. Core and delta points may or may not include angular information. Core and delta point placement is illustrated in Figure 6.

The core and delta information shall be represented as follows. The first byte shall contain the core information type and the number of core points included; legal values are 0 or greater. This length byte shall be followed by the position and angular information for the cores. The next byte shall contain the delta information type and the number of delta points included; legal values are 0 or greater. This length byte shall be followed by the position and angular information for the deltas.

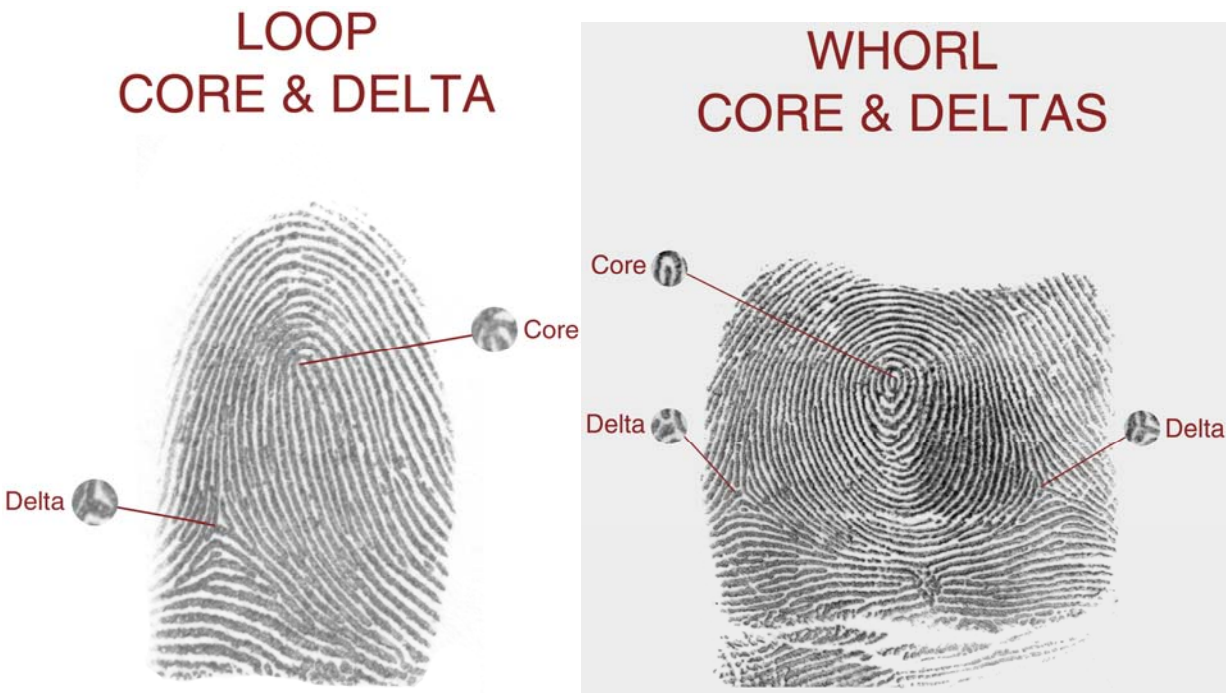


Figure 6 - Example Core and Delta placement

7.5.3.1 Core Information Type

The core information type shall be recorded in the first two bits of the upper byte of the number of cores. 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.

7.5.3.2 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.

7.5.3.3 Core Position

The X coordinate of the core shall be recorded in the lower fourteen bits of the first two bytes (fourteen bits). The Y coordinate shall be placed in the lower fourteen bits of the following two bytes. The coordinates shall be expressed in pixels at the resolution indicated in the record header.

7.5.3.4 Core Angle

The angle of the core shall be recorded in one byte in units of 1.40625 (360/256) degrees. The core angle is measured increasing counter-clockwise starting from the horizontal axis to the right. The value shall be a non-negative value between 0 and 255, inclusive. For example, an angle value of 16 represents 22.5 degrees. If the core information type is zero (see Section 7.5.3.1), then this field shall not be present.

7.5.3.5 Delta Information Type

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

7.5.3.6 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.

7.5.3.7 Delta Position

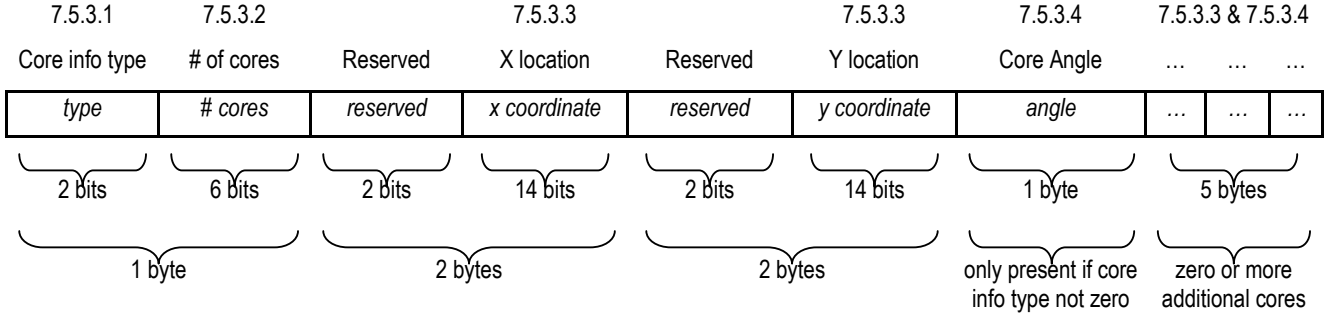
The X coordinate of the delta shall be recorded in the lower fourteen bits of the first two bytes (fourteen bits). The Y coordinate shall be placed in the lower fourteen bits of the following two bytes. The coordinates shall be expressed in pixels at the resolution indicated in the record header.

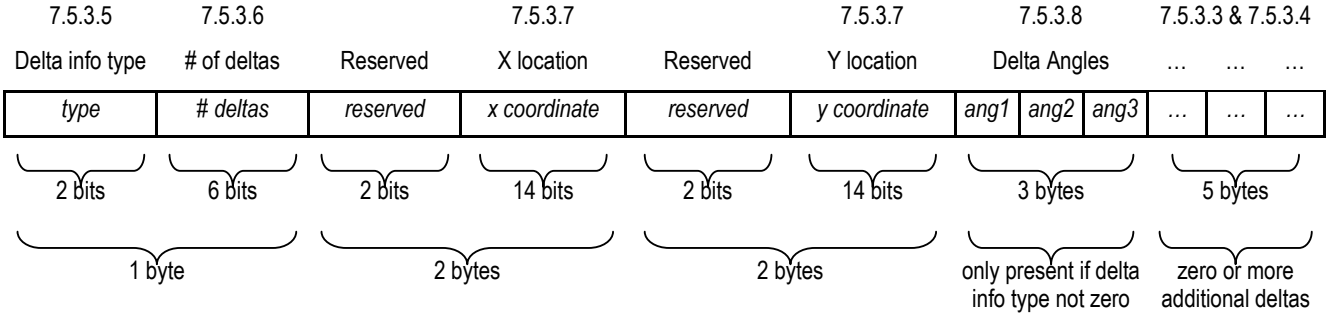
7.5.3.8 Delta Angles

The three angle attributes of the delta shall each be recorded in one byte in units of 1.40625 (360/256) degrees. The delta angle is measured increasing counter-clockwise starting from the horizontal axis to the right. The value shall be a non-negative value between 0 and 255, inclusive. For example, an angle value of 16 represents 22.5 degrees. If the delta information type is zero (see Section 7.5.3.5), then this field shall not be present.

7.5.3.9 Core and Delta Format Summary

The core and delta format shall be as follows:





7.5.4 Zonal Quality Data

If the extended data area type code is 0x0003, the extended data area contains zonal quality data. This format is provided to contain optional information about the quality of the fingerprint image within each cell in a grid defined on the original fingerprint image. Within each cell, the quality may depend on the presence and clarity of ridges, spatial distortions and other characteristics.

The zonal quality data shall be represented as follows. The first two bytes shall contain the horizontal and vertical cell sizes in pixels. These size bytes shall be followed by the quality indications for each cell, with one or more bits for each cell. The cell quality bits shall be packed into bytes, padded with zeroes on the right to complete the final byte. All cells are the same size, with the exception of the final cells in each row and in each

column. The final cell in each row and in each column may be less than the stated cell size, if the cell width and height are not factors of the image width and height respectively.

7.5.4.1 Cell Width and Height

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

7.5.4.2 Cell Data Length

The number of bytes containing the cell quality data shall be recorded in two bytes. The contents of this field shall be equal to the pixel width in the original image divided by the cell width, rounded up, multiplied by the pixel height of the original image divided by the cell height, rounded up, multiplied by the cell information depth, then divided by eight and rounded up.

$$CellDataLength(7.5.4.2) = ceil\left(\frac{CellInfoDepth\{7.5.4.3\}\, ceil\left(\frac{XSizeofScannedImage\{7.3.6\}}{CellWidth\{7.5.4.1a\}}\right) ceil\left(\frac{YSizeofScannedImage\{7.3.7\}}{CellHeight\{7.5.4.1b\}}\right)}{8}\right)$$

where the function ceil() indicates the smallest integer greater or equal to the inner quantity. This field is included for convenience in reading the data record.

7.5.4.3 Cell Quality Information Depth

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

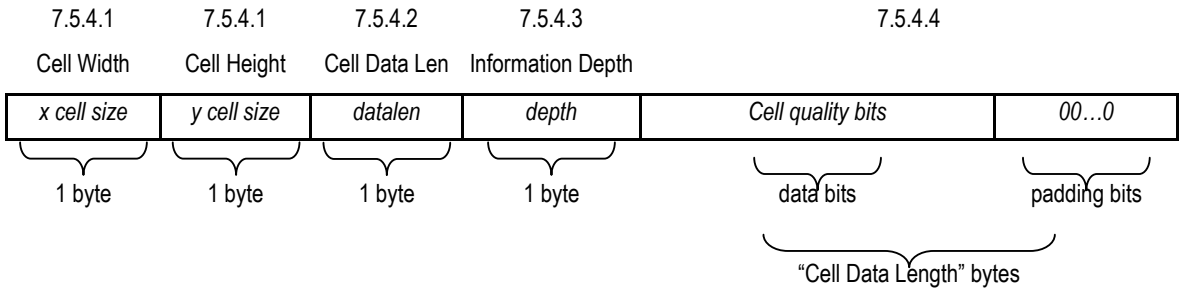
7.5.4.4 Cell Quality Data

The quality of the fingerprint image in each cell shall be represented by one or more bits, as indicated in 7.5.4.3. Quality data for cells shall be stored in usual "raster" order – left to right, then top to bottom. If the finger image within this cell is of good clarity and significant ridge data is present, the cell quality shall be represented by higher values (by the bit value '1' if the information depth is 1). If the cell does not contain significant ridge data, or the ridge pattern within the cell is blurred, broken or otherwise of poor quality, the cell quality shall be represented by lower values (the bit value '0' if the information depth is 1).

The cell quality shall be packed into bytes. The final byte in the cell quality data may be packed with bit values of zero ('0') on the right as required to complete the last byte.

7.5.4.4 Zonal Quality Data Format Summary

The zonal quality data format shall be as follows:



7.6 Minutiae Record Format Summary

Table 7 is a reference for the fields present in the Finger Minutia Record format. Optional extended data formats for ridge counts, core and delta data and zonal quality information are not represented here. For more specific information, please refer to the text and to the Record Format Diagrams in Annex A.

Table 7 - Minutiae Record Format Summary

	Field	Size	Valid Values	Notes
One per Record	Format Identifier	4 bytes	0x464D5200 ('F' 'M' 'R' 0x0)	"FMR " – finger minutiae record
	Version of this standard	4 bytes	n n n 0x0	" XX"
	Length of total record in bytes	4 bytes	24 - 4294967295	either 0x0018 to 0x0000FFFFFFFF
	Capture Equipment Certification	4 bits		
	Capture Device Type ID	12 bits		Vendor specified
	Image Size in X	2 bytes		in pixels
	Image Size in Y	2 bytes		in pixels
	X (horizontal) Resolution	2 bytes		in pixels per cm
	Y (vertical) Resolution	2 bytes		in pixels per cm
	Number of Finger Views	1 byte	0 to 255	
	Reserved byte	1 byte	00	0 for this version of the standard (reserved for future use)
One per View	Finger Position	1 byte	0 to 10	See Table 2
	View Number	4 bits	0 to 15	
	Impression Type	4 bits	0 to 3 or 8	See Table 3
	Finger Quality	1 byte	0 to 100	0 to 100
	Number of Minutiae	1 byte		
One per minutiae	X (minutia type in upper 2 bits)	2 byte		Expressed in image pixels
	Y (upper 2 bits reserved)	2 byte		Expressed in image pixels
	θ	1 byte	0 to 255	Resolution is 1.40625 degrees
	Quality	1 byte	0 to 100	1 to 100 (0 indicates "quality not reported")
One per view	Extended Data Block Length	2 bytes		0x0000 = no private area
0+ per view	Extended Data Area Type Code	2 bytes		only present if Extended Data Block Length ≠ 0
	Extended Data Area Length	2 bytes		only present if Extended Data Block Length ≠ 0
	Extended Data	In prev. field		only present if Extended Data Block Length ≠ 0
Each extended data area may contain vendor-specific data, or one or more of the following (in any order):				
0+ per view	Ridge count data: Ridge count extraction method	1 byte	0 to 2	
	Ridge count data – idx #1	1 byte	1 to # of minutiae	
	Ridge count data – idx #2	1 byte	1 to # of minutiae	
	Ridge count data – count	1 byte		
	additional ridge counts…			
0+ per view	Core and delta data: Core information type	2 bits	0 to 1	
	Number of cores	4 bits	0 to 15	
	X location	2 bytes		
	Y location	2 bytes		
	Angle (*if core info type ≠ 0*)	1 byte	0 to 255	
	Delta information type	2 bits	0 to 1	
	Number of deltas	4 bits	0 to 15	
	X location	2 bytes		
	Y location	2 bytes		
	Angles (*if delta info type ≠ 0*)	3 bytes	0 to 255	
0+ per view	Zonal quality data: Cell Width	1 byte	1 to 255	
	Cell Height	1 byte	1 to 255	
	Cell Data Length	2 bytes	1 to 65536	
	Cell Information Bit Depth	1 byte	1 to 255	
	Cell Quality Data	CellDataLen		

8 Finger Minutiae Card Format

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

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

8.1 Normal Size Finger Minutiae Format

With the normal size format, a minutia is encoded in 5 bytes (see Table 8):

- minutia type t (2 bits):
  00 = other,
  01 = ridge ending (encoded as valley skeleton bifurcation point), or ridge skeleton end point
  10 = ridge bifurcation (encoded as ridge skeleton bifurcation point)
  11 = reserved for future use

- coordinate x (14 bits), unit = 10^{-2} mm

- reserved (2 bits), default value: 00

- coordinate y (14 bits), unit = 10^{-2} mm

- angle θ (8 bits), unit = $2\pi/256$

Table 8 — Normal size finger minutiae format

type t	x-coordinate	reserved	y-coordinate	angle θ
2 bytes		2 bytes		1 byte

8.2 Compact Size Finger Minutiae Format

With the compact size format, only 3 bytes are used per minutia (see Table 9). This reduction of memory space is only possible at the cost of a reduction in resolution of coordinates and angle.

- coordinate x (8 bits), unit = 10^{-1} mm
- coordinate y (8 bits), unit = 10^{-1} mm
- minutia type t (2 bits): same coding as with the normal size format
- angle θ (6 bits), unit = $2\pi/64$

Table 9 — Compact size finger minutiae format

x-coordinate	y-coordinate	type t	angle θ
1 byte	1 byte	1 byte	

NOTE - The maximum value for the x and y coordinate is 25.5mm with the compact format.

8.3 Number of Minutiae, Minutiae Ordering Sequence and Truncation

8.3.1 General Aspects

The minutiae data of a finger consist of n minutia encoding shown in Table 8 (or alternatively Table 9). The number n depends on

- the minimum number of minutiae required according to the security level (see Annex C)
- 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 Biometric Information Template, if the default value is not used (see Annex C).

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

If the number of minutiae exceeds the maximum number processible by a card, truncation is necessary. The truncation is a 2 step process. At first, finger minutiae of poor quality are eliminated. If still too many minutiae are there, then truncation shall be made by peeling off minutiae from the convex hull of the minutiae set and before sorting into the order required by the card.

8.3.2 Biometric matching algorithm parameters

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

8.3.3 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 10 shall be used.

Table 10 – Data Object for Number of Minutiae

Tag	L	Value
´81´	2	min (1 byte, binary coding) || max (1 byte, binary coding)

If this DO is not present in the BIT, the default values apply (see Annex C).

8.3.4 Minutiae Order

For the indication of the ordering scheme for minutiae, the DO Minutiae order as shown in Table 11 shall be used.

Table 11 – Data Object for Minutiae Order

Tag	L	Value
´82´	1	see Table 12

Table 12 – 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, see note 1
			0	1	0			Cartesian y-x
			0	1	1			Angle, see note 2
			1	0	0			Polar, root = center of mass
x	x	x						000, other values are RFU

NOTES –

1. Ordered by ascending/descending x-coordinate, if equal by ascending/descending y-coordinate (first x, then y)

2. The angle represents the orientation of the minutia.

The following description defines the ordering procedure in detail to avoid misunderstandings or misinterpretations.

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.

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.

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.

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.

Angle

Sorting a minutiae list by angle is done as follows. As defined in a previous section the angle of a minutia begins with value 0 to the right horizontal axis and increases counter-clockwise. 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 subordering are defined, if the angle values in two or more minutiae are equal. Any possible ordering sequence of the minutiae with the same angle value is legal in this case.

Polar

Polar is an ordering sequence by ascending or descending polar coordinates. First of all, a virtual coordinate root is defined as the center of mass of all minutiae. The polar coordinates of every minutiae 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 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 relative angle value 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 and n is the number of minutiae.

9 CBEFF Format Owner and Format Types

Format owner and format type are encoded according to CBEFF. The format owner is ISO/IEC JTC 1/SC 37. The IBIA registered format owner id is ’0101’.

The format type denotes one of the finger minutiae formats according to this standard, see Table 13.

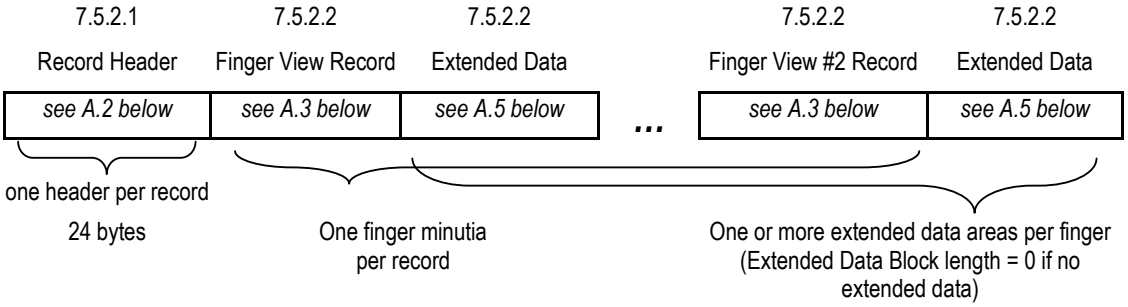
Table 13 — Format types

Format Type	Meaning
´0201´	Finger minutiae record format – no extended data, with - ridge endings (valley skeleton bifurcation points) - ridge bifurcations (ridge skeleton bifurcation points)
´0202´	Finger minutiae record format – extended data, with - ridge endings (valley skeleton bifurcation points) - ridge bifurcations (ridge skeleton bifurcation points)
´0203´	Finger minutiae card format - normal size, with - ridge endings (valley skeleton bifurcation points) - ridge bifurcations (ridge skeleton bifurcation points)
´0204´	Finger minutiae card format - normal size, with - ridge skeleton end points - ridge bifurcations (ridge skeleton bifurcation points)
´0205´	Finger minutiae card format - compact size, with - ridge endings (valley skeleton bifurcation points) - ridge bifurcations (ridge skeleton bifurcation points)
´0206´	Finger minutiae card format - compact size, with - ridge skeleton end points - ridge bifurcations (ridge skeleton bifurcation points)

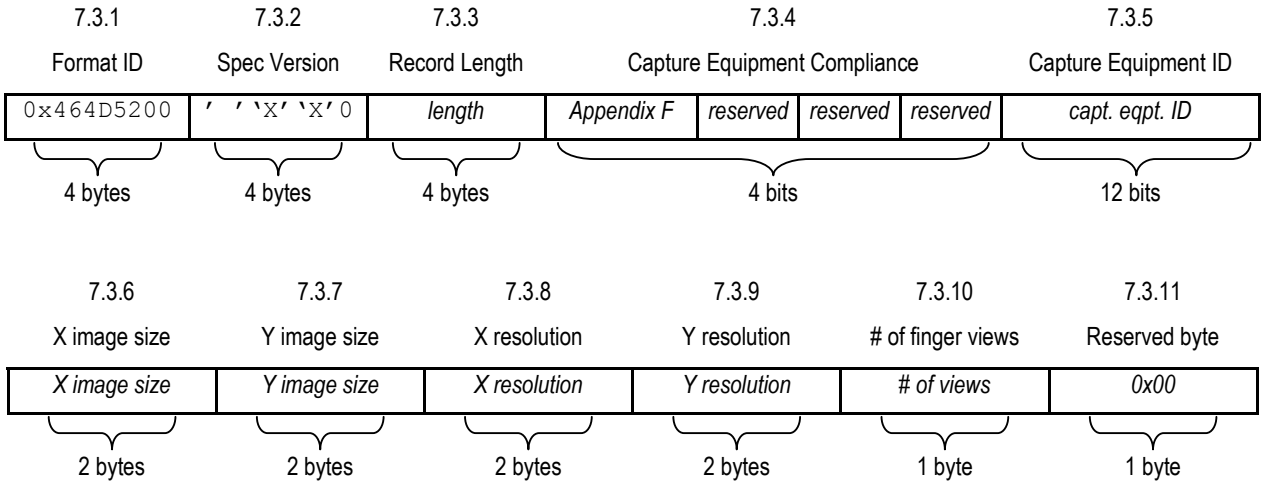
Annex A
(normative)

Record Format Diagrams

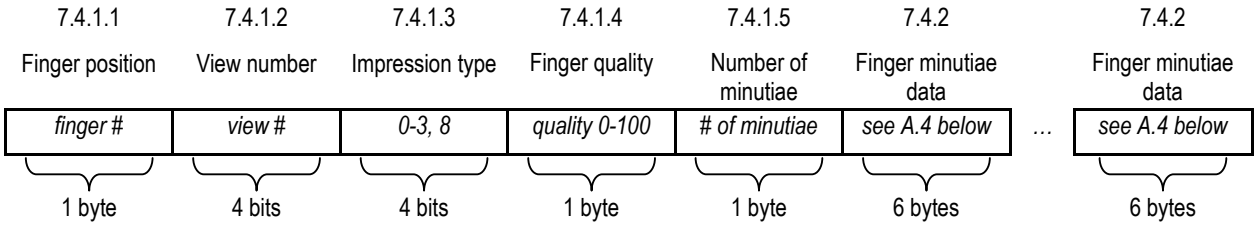
A.1 Overall Record Format



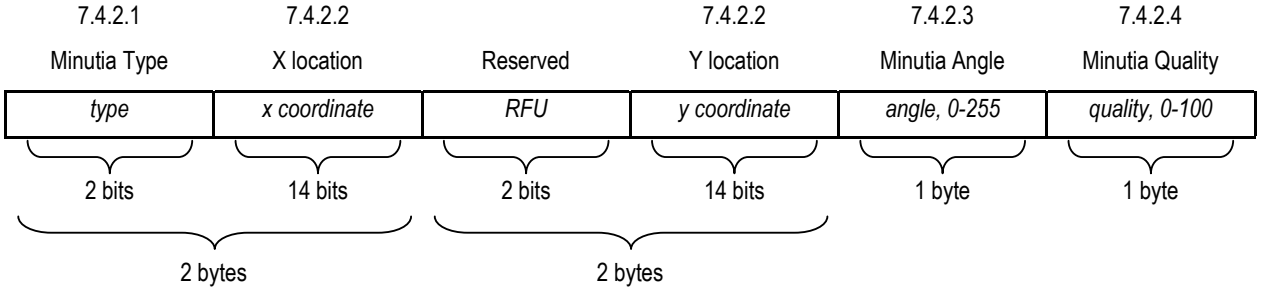
A.2 Record Header



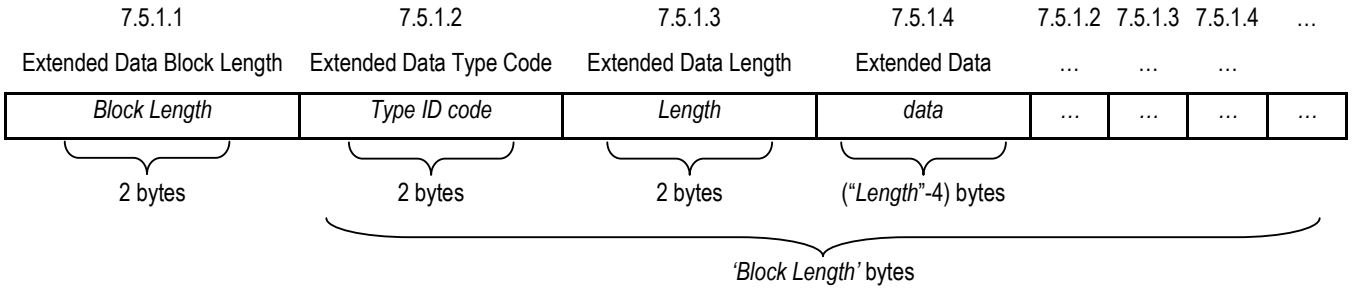
A.3 Single Finger View Minutiae Record



A.4 Finger Minutiae Data



A.5 Extended Data



Annex B
(informative)

Example Data Record

This example minutiae record demonstrates the format for a given set of data.

B.1 Data

Scanner ID = 0x00B5 (these values are determined by the IBIA - for the Vendor ID - and by the vendor)

Sensor Resolution: 500 dpi in both X and Y axes; 196.85 pixels per cm, Image was 512 by 512 pixels

Plain live-scan prints of the left and right index fingers

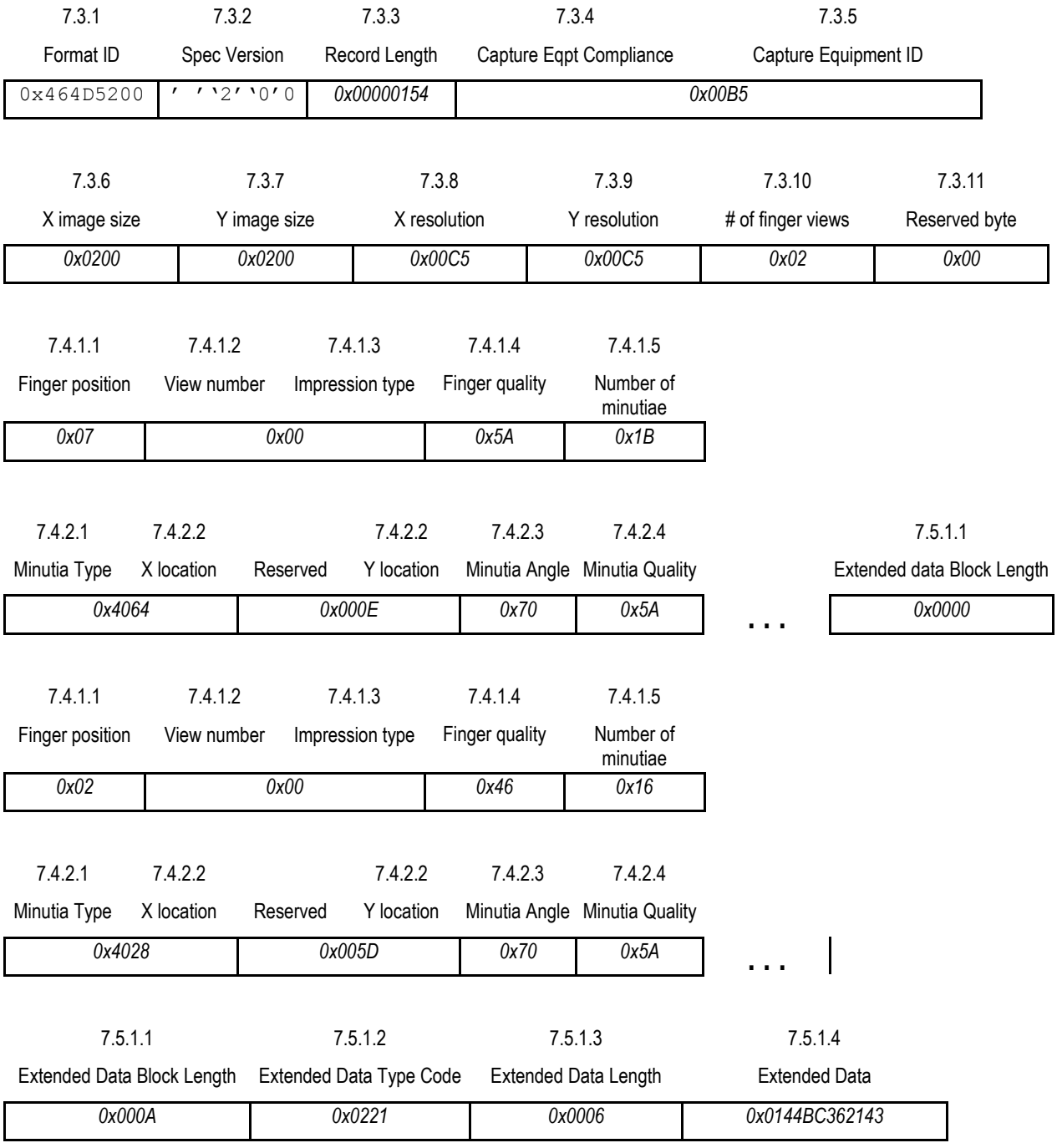
Left Index: Finger quality is 90% of the maximum possible; 27 minutia, listed in table below; no private feature data

Right Index: Finger quality is 70% of the maximum possible; 22 minutia, listed in table below. Private feature data area (Type 0x0221) consisting of six bytes: 0x01, 0x44, 0xBC, 0x36, 0x21, 0x43

Record length = 340 = 24 (record header) + 2 * 4 (finger headers) + 27 * 6 (minutia for 1st finger) + 22 * 6 (minutia for 2nd finger) + 2 (null private area for 1st finger) + 12 (private area for 2nd finger)

Minutia	Left Index Finger					Right Index Finger				
#	Type	X	Y	Angle	quality	Type	X	Y	Angle	quality
0	Ending	100	14	112	90	ending	40	93	0	90
1	Ending	164	17	85	80	bifurcation	116	100	0	80
2	Bifurcation	55	18	22	90	ending	82	95	12	70
3	Bifurcation	74	22	76	60	bifurcation	140	113	15	70
4	Ending	112	22	90	80	ending	122	135	18	80
5	Bifurcation	42	31	44	90	bifurcation	55	72	21	50
6	Bifurcation	147	35	51	90	ending	94	74	24	60
7	Ending	88	38	165	40	ending	155	62	42	80
8	Bifurcation	43	42	4	80	bifurcation	42	64	55	70
9	Ending	56	48	33	70	ending	155	85	59	80
10	Ending	132	49	72	90	bifurcation	96	192	62	80
11	Bifurcation	71	50	66	80	ending	114	86	85	80
12	Other	95	51	81	90	bifurcation	142	90	90	70
13	Ending	112	53	132	50	ending	57	137	100	90
14	Bifurcation	135	58	32	80	ending	131	75	110	80
15	Other	41	60	59	70	ending	45	113	120	80
16	Bifurcation	67	62	145	90	bifurcation	111	171	130	50
17	Ending	91	63	132	80	ending	95	62	150	60
18	Ending	112	65	33	60	bifurcation	61	114	200	80
19	Ending	53	71	45	90	bifurcation	143	72	250	80
20	Bifurcation	104	74	12	80	ending	63	104	300	70
21	Ending	75	79	21	90	bifurcation	125	73	350	40
22	Bifurcation	48	80	92	90					
23	Ending	130	89	45	80					
24	Bifurcation	63	95	126	80					
25	Ending	47	108	164	90					
26	Bifurcation	126	115	172	30					

B.2 Example Data Format Diagrams



B.3 Raw Data for the Resulting Minutiae Record

Record Header:

0x464D5200203220000000015400B50200020000C500C50200

1st Finger Header:

0x07005A1B

1st Finger Minutiae data:

0x4064000E505A	0x40A400113C50	0x80370012105A
0x804A0016363C	0x407000164050	0x802A001F1F5A
0x80930023245A	0x405800267528	0x802B002A0350
0x403800301746	0x40840031335A	0x804700322F50
0x005F00333A5A	0x407000355E32	0x8087003A1750
0x0029003C2A46	0x8043003E675A	0x405B003F5E50
0x40700041173C	0x40350047205A	0x8068004A0950
0x404B004F0F5A	0x80300050415A	0x408200592050
0x803F005F5A50	0x402F006C755A	0x807E00737A1E

1st Private Data Area:

0x0000

2nd Finger Header:

0x02004616

2nd Finger Minutiae data:

0x4028005D005A	0x807400640050	0x4052005F0946
0x808C00710B46	0x407A00870D50	0x803700480F32
0x405E004A113C	0x409B003E1E50	0x802A00402746
0x409B00552A50	0x806000C02C50	0x407200563C50
0x808E005A4046	0x40390089475A	0x4083004B4E50
0x402D00715550	0x806F00AB5C32	0x405F003E6B3C
0x803D00728E50	0x808F0048B250	0x403F0068D546
0x807D0049F928		

2nd Private Data Area:

0x000A022100060144BC362143

Annex C
(informative)

Handling of Finger Minutiae Card Formats

C.1 Enrollment

C.1.1 Number of minutiae

The number of minutiae is a security sensitive parameter and depending on the security policy of the application. Persons who do not meet the minimum required number for enrolment cannot be enrolled. The maximum number of minutiae for the reference data is implementation dependent.

The recommended minimum number of minutiae required for enrollment is 16 and for verification is 12. The strength of function (see note at the end of this clause) may have impact on these values.

The maximum number of minutiae to be sent to a card is implementation dependent and related to:

- transmission time
- memory resources
- execution time
- security aspects

The recommended maximum value for enrollment and verification is 60. It is up to the extraction device to limit the number of minutiae sent to the card to 60 or the indicated value (see CBEFF Annex G, Table G.1).

NOTE - In the Common Criteria, the following definitions are given:

Strength of Function (SOF) — A qualification of a Target of Evaluation (TOE) security function expressing the minimum efforts assumed to defeat its expected security behaviour by directly attacking its underlying security mechanisms.

SOF-basic — A level of TOE strength of function where analysis shows that the function provides adequate protection against casual breach of TOE security by attackers possessing a low attack potential.

SOF-medium — A level of TOE strength of function where analysis shows that the function provides adequate protection against straightforward or intentional breach of TOE security by attackers possessing a moderate attack potential.

SOF-high — A level of TOE strength of function where analysis shows that the function provides adequate protection against deliberately planned or organised breach of TOE security by attackers possessing a high attack potential.

C.1.2 Number of required finger presentations

The number of required finger presentations during an enrollment process is enrollment system dependent.

C.2 Matching

The verification data is subject to translation (in x- and y-direction), rotation (deviation of the orientation) and distortion. Matching also has to take into account components or factors like FAR/FRR.

C.2.1 Matching conditions

The result of the matching process is a score, which may denote the number of matching minutiae or any other appropriate value. In interoperability tests, it may be verified whether different implementations of the matching algorithm meet a required FAR/FRR e.g. in relation to the strength of function for the respective application.

If minutia types are taken into account in the matching process, the different types match according to Table 1.

C.2.2 Threshold Value

A verification decision result is positive (i.e. the user verification is successful), if the score S as matching result is greater or equal than the required threshold value T:

$S \geq T$

The threshold value depends on several factors or components such as

- Required False Acceptance Rate FAR
- Required False Rejection Rate FRR
- Matching conditions, see C.2.1
- The amount of minutiae enrolled
- The amount of minutiae presented
- Strength of function.

The treatment of the threshold value is dependent on the implemented matching strategy. In the following an example of the calculation of a threshold value is presented.

The threshold value T considered in this example is a dynamic value to be calculated for each verification process and depends on:

- Ar: amount of minutiae in the reference data
- Av: amount of minutiae in the verification data
- Avmin: minimum amount of minutiae required in the verification data
- Avmax: maximum amount of minutiae in the verification data relevant for threshold computation
- Tmin: minimum threshold value, which denotes the minimum amount of minutiae to be matched for positive verification
- Tmax: maximum threshold value, which denotes the maximum required amount of minutiae to be matched for positive verification.

T is computed as follows:

$T = Tmin + (Ac – Avmin) * (Tmax – Tmin)/(Avmax – Avmin)$

with

$Ac = qAr + (1 – q)Av,$

whereby Ac is the calculated amount of minutiae and the qualifier q the weight for Ar and Av

and

Avmin = min. amount of minutiae to be presented in a verification process

Avmax = max. amount of minutiae considered relevant in a verification process.

The values of Tmax, Tmin, Avmax, Avmin and q chosen for this example are shown in .

Table C.2 - Values for threshold computation (example)

Qualifier q	Tmin	Tmax	Avmin	Avmax
0.66	6	12	12	60

The values in Table C.2 together with the above formula have the following meaning:

- the amount of the reference minutiae have more significance than the amount of the verification minutiae (2/3 to 1/3)
- a score of 4 matching minutiae is generally rejected and leads to a negative verification result (S < T, Tmin required = 6)
- a score of 5 matching minutiae leads to positive verification (S ≥ T), if the respective person has a minimum of verification minutiae (12)
- a score of 12 matching minutiae leads in any case to a positive verification (Tmax required = 12).

NOTE: At court, some countries require 12 matching minutiae. However, the application area, the environment conditions and security requirements are different at court and for on-card-matching.

C.2.3 Retry Counter

For on-card matching, a retry counter (which is decremented by subsequent negative verifications and set to its initial value by positive verification) has to be implemented in order to limit the number of trials. The following aspects have impact on the initial value:

- experience of the user
- environmental conditions (e.g. construction of sensor embedding and finger placement)
- quality of verification data
- strength of function.

If the retry counter has reached the value 0, then the respective biometric verification method is blocked. Resetting the retry counter to its initial value is possible, if supported, e.g. by using the RESET RETRY COUNTER command (see ISO/IEC 7816-4) with a resetting code (8 digits).

The recommended initial value of the retry counter lies in the range of 5 and 15. The security policy of the application provider and the required strength of function have impact on the possible range and the value applied.

C.3 Security Aspects of Finger Minutiae Presentation to the Card

Fingerprints are left everywhere and therefore this kind of biometric data are considered to be public. An attacker may succeed in getting a good fingerprint of a person, derive from them the biometric verification data and present it to the stolen card of the respective person. To avoid this kind of attack and also replay attacks of data used in a previous verification process, a trusted path between card and service system is required. Such a trusted path is achieved by cryptographic means, e.g. using secure messaging according to ISO/IEC

7816-4. The specification of those secure messaging functions is usually application dependent and outside the scope of this standard.

Annex D
(normative)
Fingerprint Image Quality Specifications

The following pages are included as-is from the source document, the FBI EFTS (Electronic Fingerprint Transmission Specification).

D.1 SCOPE AND PURPOSE

These specifications apply to fingerprint scanner systems and printers that will supply fingerprint data to the Integrated Automated Fingerprint Identification System (IAFIS), and to printers and displays within the IAFIS. They provide objective criteria for insuring image quality.
Electronic images must be of sufficient quality to allow for: (1) conclusive fingerprint comparisons (identification or non-identification decision); (2) fingerprint classification; (3) automatic feature detection; and (4) overall Automated Fingerprint Identification System (AFIS) search reliability.
The fingerprint comparison process requires a high fidelity image without any banding, streaking or other visual defects. Finer detail such as pores and incipient ridges are needed since they can play an important role in the comparison. Additionally, the gray-scale dynamic range must be captured with sufficient depth to support image enhancement and restoration algorithms.
The image quality requirements have associated test procedures, which are described in the document *Test Procedures for Verifying IAFIS Scanner Image Quality Requirements*. These procedures will be used by the Government in acceptance testing to ensure compliance with the requirements, and in performance capability demonstrations as an indication of capability to perform. Equipment shall be tested to meet the requirements in normal operating modes, e.g., scanners shall not be tested at slower than normal operating speeds to meet modulation transfer function specifications. A vendor may recommend alternate testing methods.

D.2 FINGERPRINT SCANNERS

The following subsections describe the image quality performance characteristics required for a fingerprint scanner (live scan and card scan). These specifications require that the scanner shall capture fingerprints at a minimum resolution in both the detector row and detector column directions (also known as 'along-scan' and 'cross-scan' directions) of 500 pixels/inch, plus or minus 5 pixels per inch. The final output delivered image from the scanner system shall have a resolution of 500 pixels/inch, plus or minus 5 pixels per inch, and each pixel shall be gray level quantized to 8 bits. [Requirement described in the ANSI standard: *Data Format for the Interchange of Fingerprint Information*, ANSI/NIST-CSL 1-1993.]

D.2.1 Geometric Image Accuracy

The absolute value of the difference "D", between the actual distance "X" between any two points on a target and the distance "Y" between those same two points as measured on the output scanned image of that target, shall meet the following requirements for the value D:

D 0.0007, for 0 X 0.07
D 0.01X, for 0.07 X 1.50

where: D, X, Y are in inches and D = Y – X

The requirement corresponds to a positional accuracy of ± 1% for distances between 0.07 and 1.5 inches, and a constant ± 0.0007 inches (1/3 pixel) for distances less than or equal to 0.07 inches. The geometric image accuracy shall be measured using precision 1 cycle per millimeter Ronchi targets on white Mylar reflective base manufactured by Applied Image, Inc.[1]

[1] Applied Image, 1653 East Main Street, Rochester, NY 14526, Phone (716) 482-0300

D.2.2 Modulation Transfer Function

The measured modulation transfer function (MTF) of the scanner, in both the detector row and detector column directions, and over any region of the scanner's field of view, shall have modulation values which fall within the ranges given in the following MTF table, at the given spatial frequencies:

cyc/mm	MTF
1	.905 to 1.00
2	.797 to 1.00
3	.694 to 1.00
4	.598 to 1.00
5	.513 to 1.00
6	.437 to 1.00
8	.312 to 1.00
10	.200 to 1.00

The MTF shall be measured using test chart number M-13-60-1X manufactured by Sine Patterns, Inc.[2]. The single, representative sine wave modulation in each imaged sine wave frequency pattern is determined from the sample modulation values collected from within that pattern. The sample modulation values are computed from the maximum and minimum levels corresponding to the 'peak' and adjacent 'valley' in each sine wave period. These maximum and minimum levels represent the corresponding locally averaged image gray levels mapped through a calibration curve into target reflectance space, where the local average of gray levels is computed in a direction orthogonal to the sinusoidal variation direction. Sample image modulation is then defined as:

(maximum - minimum) / (maximum + minimum)

The calibration curve is constructed by performing a least squares linear regression curve fit between the image gray levels of the 14 density patches in the test target and the corresponding target reflectance values. The scanner MTF at each frequency is then defined as:

MTF = representative image modulation / target modulation

[Target modulations and target density patch values are supplied with the test target by the manufacturer.]

D.2.3 Signal-to-Noise Ratio

Both the ratio of signal to white noise standard deviation and the ratio of signal to black noise standard deviation of the digital scanner shall be greater than or equal to 125 using the following procedure:

1) A random 0.25 inch x 0.25 inch test field within the image area is chosen and the white reference target, Munsell[3] N9-white matte, is placed in the test field.

2) A white test population of 8-bit reflectance values from at least 1000 samples within the test field are collected. The average value and standard deviation are computed from this test population.

3) Steps 1 and 2 are repeated for the black reference target, Munsell N3 - black matte.

4) The signal to noise ratio (SNR) is computed as the difference between average white and average black values, alternately divided by the white noise standard deviation ('white SNR') and the black noise standard deviation ('black SNR').

Note: The scanner shall be set up such that the white reference target is below scanner saturation level, and the black reference target is above scanner dark current level. Also, care should be taken, via direct visual or visual display observation, to avoid areas of dust, pinholes, scratches, or other imperfections on the target when selecting the sub-area for the 1000 samples.

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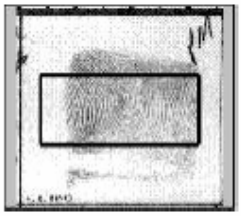
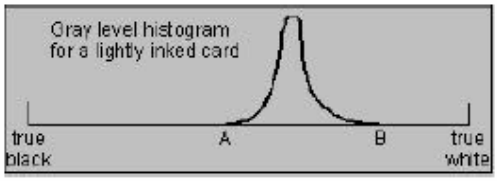
[2] Sine Patterns, 236 Henderson Drive, Penfield, NY 14526, Phone (716) 248-5338

[3] Munsell-Macbeth, P.O. Box 230, Newburgh, NY 12551, Phone (914) 565-7660

D.2.4 Gray-Scale Range of Image Data



At least 80% of the captured individual fingerprint images shall have a gray-scale dynamic range of at least 200 gray levels and at least 99% shall have a dynamic range of at least 128 gray levels. For this requirements section, 'dynamic range' is defined as the total number of gray levels that have signal content from the fingerprint image. Fingerprint card format lines, boxes, and text shall be excluded from the dynamic range computation and white surround in the immediate vicinity of a given fingerprint shall be included in the dynamic range computation (dashed box at right). Compliance with these dynamic range requirements shall be verified using a stratified sample of fingerprint cards assembled by the Government.



The intent is to avoid excessively low contrast images. Live-scan systems and card scanners at a booking station can control dynamic range by rolling the prints properly. However, with central site or file conversion systems, where a variety of card types and image qualities are encountered, adaptive processing may be necessary. The 8-bit quantization of the gray-scale values for very low contrast fingerprints needs to more optimally represent the reduced gray-scale range of such fingerprints. In the example histogram accompanying this section, the gray-scale values divide up the range from A to B. The parameters A and B are stored with the image to provide an audit trail.

D.2.5 Gray-scale Linearity

Using the 14 gray patches in the Sine Patterns, Inc. test target M-13-60-1X as the scanner input (independent variable), with their manufacture-supplied reflectance values, none of the corresponding 14 scanner output gray levels (dependent variable) shall deviate by more than 7.65 gray levels from a linear, least squares regression line fitted between the two variables. The output sample values within an area of at least 0.25 x 0.25 inches shall be utilized to compute the average output gray level for each patch.

D.2.6 Output Gray Level Uniformity

Output gray level uniformity shall be determined by scanning both a white reference target, Munsell N9 - white matte, and a black reference target, Munsell N3 - black matte. The scanner shall be set up such that the white reference target is below scanner saturation level, and the black reference target is above scanner dark current level in the respective tests. Using the white target as the scanner input, the following three requirements shall be met:

(1) The outputs of any two adjacent rows or columns of length 9 pixels or greater shall not have mean gray levels that differ by more than 2.5 gray levels.

(2) For all pixels within a 0.25 inch x 0.25 inch area ('quarter inch area') located in any region of the total scanner field of view, no individual pixel's gray level shall vary from the mean gray level by more than 22.0 gray levels.

(3) For any two non-contiguous quarter inch areas located anywhere in the total scanner field of view, the mean gray levels of the two quarter inch areas shall not differ by more than 12.0 gray levels.

And, using the black target as the scanner input, the following three requirements shall be met:

(1) The outputs of any two adjacent rows or columns of length 9 pixels or greater shall not have mean gray levels that differ by more than 1.0 gray levels.

(2) For all pixels within a 0.25 inch x 0.25 inch area ('quarter inch area') located in any region of the total scanner field of view, no individual pixel's gray level shall vary from the mean gray level by more than 8.0 gray levels.

(3) For any two non-contiguous quarter inch areas located anywhere in the total scanner field of view, the mean gray levels of the two quarter inch areas shall not differ by more than 3.0 gray levels.

D.3 LATENT PRINT SCANNERS

The following subsections describe the image quality performance characteristics required for a latent print scanner operating in a 1000 pixels/inch mode. These specifications require that the scanner shall capture fingerprints at a minimum resolution in both the detector row and detector column directions (also known as 'along-scan' and 'cross-scan' directions) of 1000 pixels/inch. The final output delivered image from the scanner system (at the 1000 ppi setting) shall have a resolution of 1000 pixels/inch, plus or minus 10 pixels per inch, and each pixel shall be gray level quantized to a minimum of 8 bits. The complete latent print specification consists of all requirements given in this Section, plus all non-conflicting requirements given in Section 2.0 Fingerprint Scanners.

D.3.1 Geometric Image Accuracy

The absolute value of the difference "D", between the actual distance "X" between any two points on a target and the distance "Y" between those same two points as measured on the output scanned image of that target, shall meet the following requirements for the value D:

D 0.0005, for 0 X 0.07

D 0.0071X, for 0.07 X 1.50

where: D, X, Y are in inches and D = Y – X

The requirement corresponds to a positional accuracy of ± .71% for distances between 0.07 and 1.5 inches, and a constant ± 0.0005 inches (½ pixel) for distances less than or equal to 0.07 inches. The geometric image accuracy shall be measured using precision 1 cycle per millimeter Ronchi targets on white Mylar reflective base manufactured by Applied Image, Inc.[4]

D.3.2 Modulation Transfer Function

The measured modulation transfer function (MTF) of the scanner, in both the detector row and detector column directions, and over any region of the scanner's field of view, shall have modulation values which fall within the ranges given in the following MTF table, at the given spatial frequencies:

cyc/mm	MTF
1	0.925 to 1.00
2	0.856 to 1.00
3	0.791 to 1.00
4	0.732 to 1.00
5	0.677 to 1.00
6	0.626 to 1.00
8	0.536 to 1.00
10	0.458 to 1.00
12	0.392 to 1.00
14	0.336 to 1.00
16	0.287 to 1.00
18	0.246 to 1.00
20	0.210 to 1.00

The MTF shall be measured using test chart number M-13-60-1X manufactured by Sine Patterns, Inc.[5]. The single, representative sine wave modulation in each imaged sine wave frequency pattern is determined from the sample modulation values collected from within that pattern. The sample modulation values are computed from the maximum and minimum levels corresponding to the 'peak' and adjacent 'valley' in each sine wave period. These maximum and minimum levels represent the corresponding locally averaged image gray levels mapped through a calibration curve into target reflectance space, where the local average of gray levels is

[4] Applied Image, 1653 East Main Street, Rochester, NY 14526, Phone (716) 482-0300

[5] Sine Patterns, 236 Henderson Drive, Penfield, NY 14526, Phone (716) 248-5338

computed in a direction orthogonal to the sinusoidal variation direction. Sample image modulation is then defined as:

(maximum - minimum) / (maximum + minimum)

The calibration curve is constructed by performing a least squares linear regression curve fit between the image gray levels of the 14 density patches in the test target and the corresponding target reflectance values. The scanner MTF at each frequency is then defined as:

MTF = representative image modulation / target modulation

[Target modulations and target density patch values are supplied with the test target by the manufacturer.]

D.4 IAFIS DISPLAY SPECIFICATIONS

Two types of displays are required. One is for the ten-print examiner and document processing. The other is for the latent examiner.

D.4.1 Ten-print / Document Processing Display

The ten-print/document processing display shall meet the following performance levels:

Parameter	Value	Comments
Colors	256	8 bits/pixel
Number of addressable pixels	1280 x 1024	
Pixel size	0.28 mm (max)	width at 50% amplitude at center of display
Active display area	14" x 10.5" (min)	Landscape mode
Display refresh rate	at least 72 Hz noninterlaced	Minimizes flicker
Video bandwidth	at least 100 MHz	
Luminance	33 fL (min)	of white area
Video pulse rise & fall time	3 nanosec. (max)	ensures no visible smearing
Geometric pixel location error	±1.5% (max)	No point varies more then 1.5% from its correct position
Operator controls	brightness, contrast	on front panel
Brightness Uniformity	±15% of mean deviation (max)	over entire display at low, medium and high brightness

D.4.2 Latent Print Comparison Display

The other display is for use by the FBI's latent fingerprint examiners. Because this display will be used to support latent fingerprint comparisons, the resolution and brightness (luminance) requirements are higher. The display shall be a monochrome cathode ray tube display, which shall meet the following performance levels:

Parameter	Value	Comments
Colors	8 bits/pixel @ CRT video input	
Number of addressable pixels	1600 x 1200	
Pixel size	0.19 mm (max)	width at 50% amplitude at center of display
Active display area	14" x 10.5" (min)	Landscape mode
Display refresh rate	at least 72 Hz noninterlaced	Minimizes flicker
Video bandwidth	at least 100 MHz	
Luminance	50 fL (min)	of white area
Video pulse rise & fall time	3 nanosec. (max)	ensures no visible smearing
Geometric pixel location error	±1.5% (max)	No point varies more then 1.5% from its correct position
Operator controls	brightness, contrast	on front panel
Brightness Uniformity	±15% of mean deviation (max)	over entire display at low, medium and high brightness

The ambient lighting in the work area is expected to be a combination of natural and fluorescent lighting.

D.5 PRINTER SPECIFICATIONS

The fingerprint examiners in the IAFIS environment will depend upon softcopy images to make comparisons and will require hardcopy images in certain instances. Some contributors will print cards from live scan or card scan devices for submission to the FBI. In all such cases the images will be mapped from their digital form to high resolution printing devices. The printed images must be of sufficient quality to support all phases of identification, including conclusive fingerprint comparisons (identification or non-identification decision).
Two classes of printing devices are required. The first is intended to support fingerprint card reproduction. These printers will be used within the IAFIS environment and by submitters who choose to print and mail their live scan results. The printers should provide high throughput, low-cost-per-copy, non-fading output. This monochrome printer shall perform at the following minimum levels:

Gray levels	16
Paper size	8" x 8" (min)
Resolution	500 dots/inch (min.), where each pixel is capable of producing 16 gray levels

A second class of printer is required to support the investigative fingerprint comparison function. Continuous tone monochrome output is required. This printer shall perform at the following minimum levels:

Gray levels	8-bit continuous-tone gray-scale
Paper	Production of output paper print shall not require liquid processing
Paper size	8" x 11"
Resolution	Resolution At least 500 pixels per inch, where each pixel is capable of producing 256 gray levels from an 8 bits/pixel input

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