INTERNATIONAL STANDARD

ISO/IEC 39794-4

First edition
2019-12

Information technology — Extensible biometric data interchange formats —

Part 4:
Finger image data

Reference number
ISO/IEC 39794-4:2019(E)

ISO copyright office
CP 401 • Ch. de Blandonnet 8
CH-1214 Vernier, Geneva
Phone: +41 22 749 01 11
Fax: +41 22 749 09 47
Email: copyright@iso.org
Website: www.iso.org

Published in Switzerland

Contents

Page

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.

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

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents) or the IEC list of patent declarations received (see http://patents.iec.ch).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see www.iso.org/iso/foreword.html.

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

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

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

The purchase of this ISO/IEC document carries a copyright licence for the purchaser to use ISO/IEC copyright in the schemas in the annexes to this document for the purpose of developing, implementing, installing and using software based on those schemas, subject to ISO/IEC licensing conditions set out in the schemas.

Introduction

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

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

This third generation of finger image data interchange formats complements ISO/IEC 19794-4 (both the 2005 and 2011 editions). The first generation of biometric data interchange formats, which has been adopted, e.g. by ICAO for the biometric data stored in machine readable travel documents, is expected to be retained in the standards catalogue as long as needed.

This document is intended for those applications requiring the exchange of raw or processed fingerprint and other friction ridge images (for example, palm images) that may not necessarily be limited in the amount of resources available for data storage or transmitting time. It can be used for the exchange of scanned fingerprints containing detailed image pixel information.

Use of the captured or processed image allows interoperability among biometric systems relying on minutiae-based, pattern-based or other algorithms. Thus, data from the captured finger image offers the developer more freedom in choosing or combining comparison algorithms. For example, an enrolment image may be stored on a contactless chip located on an identification document. This will allow future verification of the holder of the document with systems that rely on either minutiae-based or pattern-based algorithms. Establishment of an image-based representation of fingerprint information will not rely on pre-established definitions of minutiae, patterns or other types. It will provide implementers with the flexibility to accommodate images captured from dissimilar devices, varying image sizes, spatial sampling rates and different greyscale depths. Use of the finger image will allow each vendor to implement their own algorithms to determine whether two fingerprint records are from the same finger.

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

Information technology — Extensible biometric data interchange formats —

Part 4: Finger image data

1 Scope

This document specifies:

— generic extensible data interchange formats for the representation of friction ridge image data: a tagged binary data format based on an extensible specification in ASN.1 and a textual data format based on an XML schema definition that are both capable of holding the same information;

— examples of data record contents;

— application specific requirements, recommendations, and best practices in data acquisition; and

— conformance test assertions and conformance test procedures applicable to this document.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

ISO/IEC 8824-1, *Information technology — Abstract Syntax Notation One (ASN.1): Specification of basic notation — Part 1*

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

ISO/IEC 14495-1, *Information technology — Lossless and near-lossless compression of continuous-tone still images: Baseline*

ISO/IEC 15444 (all parts), *Information technology — JPEG 2000 image coding system*

ISO/IEC 15948, *Information technology — Computer graphics and image processing — Portable Network Graphics (PNG): Functional specification*

ISO/IEC 39794-1, *Information technology — Extensible biometric data interchange formats — Part 1: Framework*

W3C Recommendation, *XML Schema Part 1: Structures* (Second Edition), 28 October 2004

W3C Recommendation, *XML Schema Part 2: Datatypes* (Second Edition), 28 October 2004

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardisation at the following addresses:

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

— ISO Online Browsing Platform available at http://www.iso.org/obp.

3.1
spatial sampling rate
number of pixels per unit distance used by a sensor or scanning device to initially capture an image

3.2
coding model
procedure used to convert input data into symbols to be coded

3.3
coding process
general term for referring to an encoding process, a decoding process, or both

3.4
column
samples per line in an image

3.5
compressed data
either compressed image data or table specification data or both

3.6
compressed image data
coded representation of an image

Note 1 to entry: As specified in Annex F.

3.7
compression
reduction in the number of bits used to represent source image data

3.8
decoder
embodiment of a decoding process

3.9
decoding process
process which takes as its input compressed image data and outputs a continuous-tone image

3.10
dequantization
inverse procedure to quantization by which the decoder recovers a representation of the DWT coefficients

3.11
reconstructed image
<data>continuous-tone image which is the output of the decoder

Note 1 to entry: As defined in Annex F.

3.12
source image
<data>continuous-tone image used as input to any encoder

Note 1 to entry: As defined in Annex F.

3.13
digital image
<data>two-dimensional array of data

3.14
downsampling
procedure by which the spatial resolution of an image is reduced

3.15
DWT
discrete wavelet transform
linear transformation, implemented by a multirate filter bank, that maps a digital input signal to a collection of output subbands

3.16
encoder
embodiment of an encoding process

3.17
encoding process
process which takes as its input a continuous-tone image and outputs compressed image data

3.18
entropy-coded data segment
independently decodable sequence of entropy encoded bytes of compressed image data

3.19
entropy decoder
embodiment of an entropy decoding procedure

3.20
entropy decoding
lossless procedure which recovers the sequence of symbols from the sequence of bits produced by the entropy coder

3.21
entropy encoder
embodiment of an entropy encoding procedure

3.22
entropy encoding
lossless procedure which converts a sequence of input symbols into a sequence of bits such that the average number of bits per symbol approaches the entropy of the input symbols

3.23
fingerprint image
representation of an area of friction skin on the fleshy surface of a finger located horizontally between the two edges of the fingernail and vertically between the first joint and the tip of a finger

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

3.24
Huffman decoder
embodiment of a Huffman decoding procedure

3.25
Huffman decoding
entropy decoding procedure which recovers the symbol from each variable length code produced by the Huffman encoder

3.26
Huffman encoder
embodiment of a Huffman encoding procedure

3.27
Huffman encoding
entropy encoding procedure which assigns a variable length code to each input symbol

3.28
Huffman table
set of variable length codes required in a Huffman encoder and Huffman decoder

3.29
image data
either source image data or reconstructed image data

3.30
image spatial sampling rate
number of pixels per unit distance in the image

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

3.31
interchange format
representation of compressed image data for exchange between application environments

3.32
lossless
descriptive term for encoding and decoding processes and procedures in which the output of the decoding procedure(s) is identical to the input to the encoding procedure(s)

3.33
marker
two-byte code in which the first byte is FE_{Hex} and the second byte is a value between 1 and FE_{Hex}

3.34
marker segment
marker and associated set of parameters

3.35
palm
friction ridge skin on the side and underside of the hand

3.36
parameter
fixed length integers 8, 16, or 32 bits in length, used in the compressed data format

3.37
plain fingerprint image
image captured from a finger placed on a platen without any rolling movement

3.38
procedure
set of steps which accomplishes one of the tasks which comprise an encoding or decoding process

3.39
progressive
<coding>separation of data segments into blocks that can be transmitted successively to allow the compressed image data to be decoded at successively higher levels of resolution

3.40
quantization table
set of quantization values (i.e., bin widths) used to quantize DWT coefficients within the subbands

3.41
quantize
act of performing the quantization procedure for a DWT coefficient

3.42
restart interval
number of coefficients processed as an independent sequence within an image

3.43
restart marker
marker that separates two restart intervals in an image

3.44
rolled fingerprint image
image captured that is located between the two edges of the fingernail

Note 1 to entry: This type of image is typically acquired using a rolling motion from one edge of the fingernail to the other.

3.45
run length
number of consecutive symbols of the same value

3.46
SWT
symmetric wavelet transform
linear transform implemented by applying a DWT to a periodized symmetric extension of the input signal

3.47
sample
one element in the two-dimensional array which comprises a finger image

3.48
table specification data
coded representation from which the tables, used in the encoder and decoder, are generated

3.49
upsampling
procedure by which the spatial resolution of an image is increased

4 Abbreviated terms

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

ppcm	pixels per centimetre
ppi	pixels per inch
CTF	contrast transfer function
JPEG	joint photographic experts group
MTF	modulation transfer function
PGM	portable gray map

PNG portable network graphics

TIR total internal reflection

WSQ wavelet scalar quantization

5 Conformance

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

— its data structure, data values and the relationships between its data elements as specified throughout Clauses 6, 7, 8, and Annex A, and

— the relationship between its data values and the input biometric data from which the biometric data record was generated as specified throughout Clauses 6, 7, 8, and Annex A.

A system that produces biometric data records conforms to this document if all biometric data records that it outputs conform to this document (as defined above) as claimed in the implementation conformance statement (ICS) associated with that system. A system does not need to be capable of producing biometric data records that cover all possible aspects of this document, but only those that are claimed to be supported by the system in the ICS.

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

6 Modality specific information

6.1 Capture recommendations

6.1.1 Fingerprint image

This document is designed to accommodate both plain (flat) or rolled fingerprint images. Biometric systems perform better if the volar pad of the finger is centred both horizontally and vertically in the image capture area. Therefore, when capturing a fingerprint image, the centre of the fingerprint image should be located in the approximate centre of the image capture area.

For multiple finger verification and/or identification purposes, there exist fingerprint capture devices that will acquire images of multiple fingers during a single capture cycle. These devices are capable of capturing the plain impressions from two, three or four adjacent fingers of either hand during a single scanning. The plain impressions from the two thumbs or two index fingers can also be captured at one time. Therefore, with three placements of the fingers on a device's scanning surface all ten fingers from an individual would be acquired in three scans – right four fingers, left four fingers, and two thumbs. For these multi-finger captures, half of the captured fingers should be located to the left of the image centre and the other half of the fingers to the right of the image centre.

6.1.2 Palm image

This document is also designed to accommodate images from the palm of the hand or from the side of the hand opposite the thumb also known as the "writer's palm". Most comparison subsystems perform better if the flat or fleshy part of the palm or writer's palm is centred both horizontally and vertically in the image capture area. Therefore, when capturing a palmprint image, the centre of the palm or writer's palm image area should be located in the approximate centre of the image capture area. The palm itself may be captured as one entity, or various pieces of it can be captured as single images such as the thenar (fleshy part behind the thumb), hypothenar (fleshy area opposite the thumb), or interdigital (area of the palm directly beneath the four fingers).

6.2 Image coordinate system considerations

The recorded image data shall appear to be the result of a scanning of an impression of a friction ridge image. For the purpose of describing the position of each pixel within an image to be exchanged, a pair of reference axes shall be used. The origin of the axes, pixel location (0,0), shall be located at the upper left-hand corner of each image. The x-coordinate (horizontal) position shall increase positively from the origin to the right side of the image. The y-coordinate (vertical) position shall increase positively from the origin to the bottom of the image.

To assure that friction ridge images are interoperable with existing fingerprint images in legacy datasets, care shall be taken to assure that the orientation of the fingerprint is correct. Figure 1 shows how this shall be achieved.

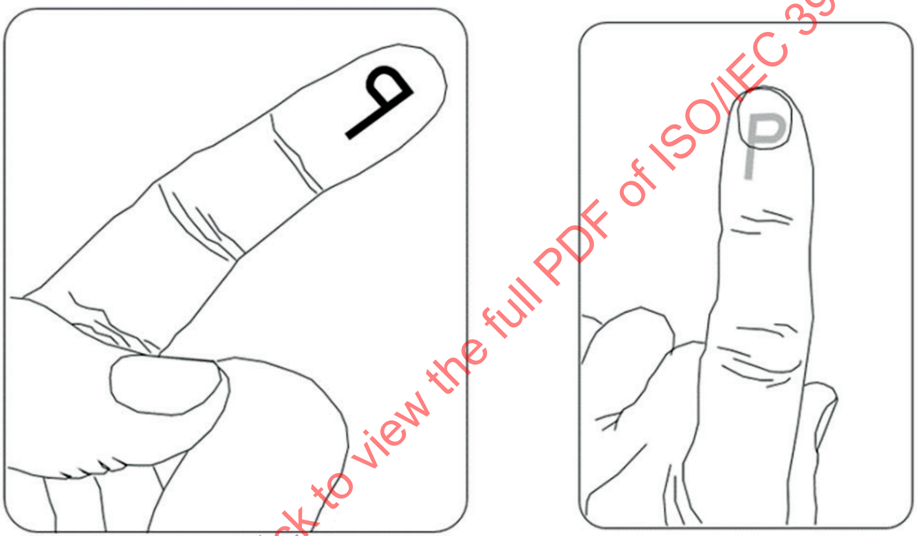

Figure 1 — Illustration of fingerprint orientation

6.3 Image representation requirements

6.3.1 General

Image representation requirements are dependent on various factors including the application, the available amount of raw pixel information to retain or exchange, and targeted performance metrics. Because of these factors, the images represented will have characteristics based on the aspects described in 6.3.2 through 6.3.5.

6.3.2 Colorspace

Finger images shall be represented as greyscale image data.

6.3.3 Pixel aspect ratio

The finger image shall be represented using square pixels, in which the horizontal and vertical dimensions of the pixels are equal. Any difference between these two dimensions should be within 1 %, i.e. the ratio of horizontal to vertical pixel dimensions should be between 0,99 and 1,01.

6.3.4 Bit-depth

The greyscale precision of the pixel data shall be specified in terms of the bit-depth or the number of bits used to represent the greyscale value of a pixel. A bit-depth of 8 provides 256 levels of grey. For greyscale data, the minimum value that can be assigned to a "black" pixel shall be zero. The maximum value that can be assigned to a "white" pixel shall be the greyscale value with all of its bits of precision set to "1". However, the “blackest" pixel in an image may have a value greater than "0" and the "whitest" pixel may have a value less than its maximum value.

6.3.5 Image spatial sampling rate

The spatial sampling rate of the image data formatted and recorded for interchange establishes the number of pixels for a given distance over the fingerprint object. A finger image may be represented with a certain number of pixels per cm (ppcm) or pixels per inch (ppi). A finger image with a sampling rate of 197 ppcm is practically equivalent to a finger image with a sampling rate of 500 ppi. For example, if a spatial sampling rate of 500 ppi is established for a fingerprint sensor with a width of 0.635 cm (corresponding to a quarter inch), there will be 125 pixels across the width of the image.

7 Abstract data elements

7.1 Purpose and overall structure

This clause describes the contents of data elements defined in this document. The description is independent of the encoding of the data elements.

The full naming conventions for ASN.1 module components and component types definitions, naming conventions for XML schema elements and element types definitions also ASN.1 and XML schema definition extensions applied per the ISO/IEC 39794 series are specified in ISO/IEC 39794-1.

The tagged binary encoding as well as the XML encoding is given in Clause 8 and Annex A.

The structure of the abstract data elements is described in Figure 2.

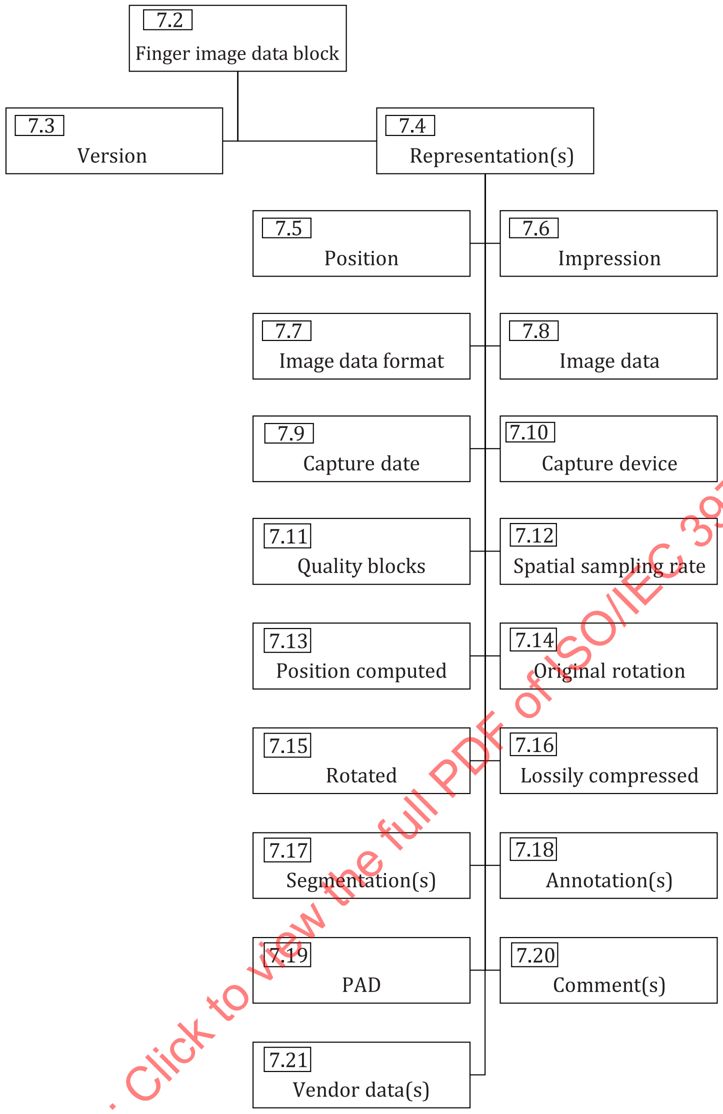

Figure 2 — Fingerprint image data block

NOTE Figure 2 is not automatically generated and can only be viewed as an overview of the structure.

7.2 Finger image data block

Abstract values: See Figure 2 – Fingerprint image data block.

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

7.3 Version block

Abstract values: See ISO/IEC 39794-1.

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

7.4 Representation blocks

Abstract values: See Figure 2 – Fingerprint image data block.

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

7.5 Position

Abstract values: See Annex A. As the number of positions is long and duplicative, it is best to understand the possible positions by examining the schema directly.

Contents: This data element establishes which friction ridge region is encoded in the image data. For example, a right index finger image is described with a position of "rightIndexFinger" in an ASN.1 encoding. Note that the position encodings are specified to improve interoperability with existing standards, notably ANSI/NIST ITL standards[3].

7.6 Impression

Abstract values: See Table 1.

Contents: This data element establishes how the friction ridge interacted with the capture system at the time of capture. Note that the impression encodings are specified to improve interoperability with existing standards, notably ANSI/NIST ITL standards[3].

Table 1 — Description for finger impression values

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

Table 1 *(continued)*

Abstract value	Description
unknownImpression	Impression information was not captured or has been lost.
otherImpression	Impression information is known, but does not correspond to any specified values.

7.7 Image data format

7.7.1 Supported data format

Abstract values: See Table 2.

Contents: Finger images shall be encoded using uncompressed or compressed formats. The format used to encode the finger image data shall match the format specified in this data element. Table 2 lists the supported data formats and associated parameters that may be used.

Table 2 — Image data format

Abstract value	Image data format	Normative reference	Allowed spatial sampling	Maximum compression ratio
pgm	None	None	All	None
wsq	WSQ	IAFIS_IC-0110, Annex F	197 ppcm	15:1
Jpeg2000Lossy	JPEG 2000 (lossy)	ISO/IEC 15444	394 ppcm	15:1
Jpeg2000Lossless	JPEG 2000 (lossless)	ISO/IEC 14495-1	197 ppcm or 394 ppcm	None
png	PNG	ISO/IEC 15948	All	None

7.7.2 PGM encoding definition

A finger image may be encoded in the Netpbm portable grayscale binary image format. The format definition is [15]:

1) a "magic number" = "P5" for identifying the file type followed by:

2) any whitespace (blanks, TABs, CRs, LFs);

3) a width formatted as ASCII characters in decimal;

4) any whitespace (blanks, TABs, CRs, LFs);

5) a height in ASCII decimal;

6) any whitespace (blanks, TABs, CRs, LFs);

7) the maximum grayscale value (Maxval), again in ASCII decimal: the Maxval shall be less than 65536, and more than zero;

8) a single whitespace character (usually a newline);

9) a raster of height rows, in order from top to bottom. Each row consists of width grayscale values, in order from left to right. Each grayscale value is a number from 0 through Maxval, with 0 being black and Maxval being white. Each grayscale value is represented in pure binary by either 1 or 2 bytes. If the Maxval is less than 256, it is 1 byte. Otherwise, it is 2 bytes. The most significant byte is first.

7.8 Image data

Contents: This data element contains the encoded friction ridge image data.

NOTE The finger image data does not necessarily represent a finger. In general, any position specified in 7.5 may be collected and would be encoded into the finger image data element.

7.9 Capture date/time block

See ISO/IEC 39794-1.

7.10 Capture device block

7.10.1 Model identifier block

See ISO/IEC 39794-1.

7.10.2 Capture device technology identifier

Abstract Values: See Table 3.

Contents: This data element establishes the class of capture device technology used to acquire the captured biometric sample. Note that the technology encodings are specified to improve interoperability with existing standards, notably ANSI/NIST ITL standards[3].

Table 3 — Description for finger image capture device technology identifier

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

Table 3 *(continued)*

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

7.10.3 Certification identifier blocks

Abstract Values: See ISO/IEC 39794-1 and Table 4.

Contents: This data element establishes the certification scheme as specified in Annex D. The certification authority is ISO/IEC JTC1/SC 37 with the registered biometric organization identifier 257 (0101_{Hex}). The Certification identifier structure conforms to ISO/IEC 39794-1.

Table 4 — Certification scheme identifiers for certification schemes specified in Annex D

Certification scheme identifier	Annex
1	Annex D.1 — Image quality specification for AFIS systems.
2	Annex D.2 — Image quality specification for personal verification.
3	Annex D.3 — Requirements and test procedures for optical fingerprint scanners.
4 to 65535	Reserved by SC 37 for future use.

7.11 Quality blocks

See ISO/IEC 39794-1.

7.12 Spatial sampling rate block

Abstract values: See Annex A. As it consists of two elements, it is best to understand the possible positions by examining the schema directly.

Contents: This data element establishes the resolution of the friction ridge image. It consists of two elements, the unit of samples or pixels per unit distance and the unit of measure for which the number of samples are related (either inch or cm). If this element is not present, the image's spatial sampling rate is established at 500 pixels per inch (ppi), or equivalently 197 pixels per centimetre (ppcm).

7.13 Position computed by capture device

Abstract values: True or False.

Contents: This Boolean data element establishes whether the capture device determined the friction ridge position automatically. If false, then the position encoded was established by the user or operator at the time of capture.

7.14 Original rotation

Abstract values: an angle from 0 to 359.

Contents: This data element establishes the original rotation of the finger image. The finger image is modelled as a rough ellipse, and the major axis of that ellipse is vertical when the rotation is 0. The rotation of the fingerprint is measured counter clockwise with increasing rotation angles.

7.15 Image rotated to vertical

Abstract values: True or False.

Contents: This Boolean data element establishes whether the represented finger image has been rotated to make its major axis vertical.

7.16 Image has been lossily compressed

Abstract values: True or False.

Contents: This Boolean data element establishes whether the finger image is or has been lossily compressed. It is useful to provide this information for images that may have been previously compressed with a lossy compression algorithm (WSQ, JPEG 2000 Lossy).

7.17 Segmentation blocks

Abstract values: See Annex A. As it consists of multiple internal data elements, it is best to understand the possible positions by examining the schema directly.

Contents: This data elements contains the segmentation algorithm identifier block and one or more segment blocks.

The segment block data element contains n-sided polygon coordinates that enclose segments of the friction ridge image data.

For example, a right four slap position may be acquired by a fingerprint capture device, and the slap image can be processed by fingerprint segmentation software. The software may provide bounding boxes that enclose the fingerprint regions. A bounding box can be described by 2 vertices: a top-left vertex coordinate and a bottom-right vertex coordinate. Alternatively, the segment could be defined by 4 points that specify a tetragon that encloses a single fingerprint region. The x-y values of the coordinate are relative to the image coordinates of the origin image.

The order of the vertex coordinates (when >2) shall be in their consecutive order around the perimeter of the polygon, either clockwise or counter clockwise. No two vertices may occupy the same location. The polygon side defined by the last coordinate and the first coordinate shall complete the polygon. The polygon shall be a simple, plane figure with no sides crossing and no interior holes.

As there are finger positions that encompass multiple finger regions, a single finger image can have multiple segmentation blocks from different segmentation algorithm providers, which encapsulate multiple finger region segment blocks, each described by both a set of coordinates and a position, with optional information about orientation, quality, and segment confidence. The confidence value is a measure of estimated correctness regarding the accuracy of the enclosing coordinates.

7.18 Annotation blocks

Abstract Values: See Table 5.

Contents: This data element contains the annotations that describe reasons why appropriate position (see 7.5) friction ridges are not captured as expected. For example, a capture subject might be missing the right index finger, and the capture device captured a right four finger slap image. The segmentation software performs much better when it knows that the right index finger is missing. Furthermore, there are applications use cases that drive different reasons. The generic reasons that are supported by this document are specified in Table 5.

Table 5 — Annotation reasons

Abstract value	Description
amputated	The friction ridge region has been amputated, or is anatomically missing.
unableToPrint	The friction ridge region is unable to be captured for undescribed reasons.
bandaged	The friction ridge region has a bandage on it rendering it not capturable.
physicallyChallenged	Physical ailments, like extreme arthritis, prevent the capture of the friction ridge region.
diseased	The friction ridge region suffers from the effects of a disease, rendering it not capturable.
unknown	Annotation information was not captured or has been lost.
other	Annotation information is known, but does not correspond to any specified values.

7.19 PAD data block

See ISO/IEC 39794-1.

7.20 Comment blocks

Abstract values: Any string value (see Annex A for details).

Contents: This data element contains comment data associated with friction ridge image data.

7.21 Vendor specific data blocks

Abstract values: See Annex A. As it consists of multiple internal data elements, it is best to understand the possible positions by examining the schema directly.

Contents: This data element contains the vendor data type identifier block along with vendor specific proprietary data associated with the friction ridge. The former specifies the biometric organization (vendor) and data type identifier assigned by biometric organization for possible data interpretation.

As this is an interoperable data interchange format, this data element shall not be used to contain data that can be provided with other elements of this document.

8 Encoding

8.1 Tagged binary encoding

The ASN.1 types (as defined in Clause A.1) which encode the abstract elements of Clause 7 shall conform to ISO/IEC 8824-1 and to ISO/IEC 39794-1.

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

The ASN.1 module in Clause A.1 can be retrieved from http://standards.iso.org/iso-iec/39794/-4/ed-1/en.

8.2 XML encoding

The XSD types as defined in Clause A.2 which encode the abstract elements of Clause 7 shall conform to the W3C Recommendations, *XML Schema Parts 1 and 2* and to ISO/IEC 39794-1.

An XML document encoding friction ridge image data shall obey the given XSD.

The XSD in Clause A.2 is available at http://standards.iso.org/iso-iec/39794/-4/ed-1/en.

9 Registered BDB format identifiers

The registrations listed in Table 6 have been made in accordance with ISO/IEC 19785-1[13] to identify the finger image data interchange formats defined in document. The format owner is ISO/IEC JTC 1/SC 37 with the registered biometric organization identifier 257 (0101_{Hex}).

Table 6 — BDB format identifiers

BDB format identifier	Short name	Full object identifier
40 (0028_{Hex})	g3-binary-finger-image	{ iso(1) registration-authority(1) cbeff(19785) biometric-organization(0) jtc1-sc37(257) bdbs(0) g3-binary-finger-image(40) }
41 (0029_{Hex})	g3-xml-finger-image	{ iso(1) registration-authority(1) cbeff(19785) biometric-organization(0) jtc1-sc37(257) bdbs(0) g3-xml-finger-image(41) }

Annex A
(normative)

Formal specifications

A.1 ASN.1 module for tagged binary encoding

```
ISO-IEC-39794-4-ed-1-v1 {iso(1) standard(0) iso-iec-39794(39794) part-4(4) ed-1(1) v1(1)
iso-iec-39794-4(0)}

-- Use of ISO/IEC copyright in this Schema is licensed for the purpose of
-- developing, implementing, and using software based on this Schema, subject
-- to the following conditions:
--
-- * Software developed from this Schema must retain the Copyright Notice,
--   this list of conditions and the disclaimer below ("Disclaimer").
--
-- * Neither the name or logo of ISO or of IEC, nor the names of specific
--   contributors, may be used to endorse or promote software derived from
--   this Schema without specific prior written permission.
--
-- * The software developer shall attribute the Schema to ISO/IEC and
--   identify the ISO/IEC standard from which it is taken. Such attribution
--   (e.g., "This software makes use of the Schema from ISO/IEC 39794-4
--   within modifications permitted in the relevant ISO/IEC standard.
--   Please reproduce this note if possible."), may be placed in the
--   software itself or any other reasonable location.
--
-- The Disclaimer is:
-- THE SCHEMA ON WHICH THIS SOFTWARE IS BASED IS PROVIDED BY THE COPYRIGHT
-- HOLDERS AND CONTRIBUTORS "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES,
-- INCLUDING, BUT NOT LIMITED TO, THE IMPLIED WARRANTIES OF MERCHANTABILITY
-- AND FITNESS FOR A PARTICULAR PURPOSE ARE DISCLAIMED. IN NO EVENT SHALL
-- THE COPYRIGHT OWNER OR CONTRIBUTORS BE LIABLE FOR ANY DIRECT, INDIRECT,
-- INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT
-- NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE,
-- DATA, OR PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY
-- THEORY OF LIABILITY, WHETHER IN CONTRACT, STRICT LIABILITY, OR TORT
-- (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY WAY OUT OF THE USE OF
-- THE CODE COMPONENTS, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH DAMAGE.

DEFINITIONS IMPLICIT TAGS ::= BEGIN

   IMPORTS
      QualityBlocks,
      ScoreOrError,
      RegistryIdBlock,
      CertificationIdBlocks,
      CaptureDateTimeBlock,
      PADDataBlock,
      VersionBlock,
      CoordinateCartesian2DUnsignedShortBlock,
      ExtendedDataBlock
   FROM ISO-IEC-39794-1-ed-1-v1;

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

```
        leftMiddleFinger(8),
        leftRingFinger(9),
        leftLittleFinger(10),
        rightFourFingers(13),
        leftFourFingers(14),
        bothThumbFingers(15),
        rightExtraDigitFinger(16),
        leftExtraDigitFinger(17),
        unknownFrictionRidge(18),
        entireJointImage(19),
        unknownPalm(20),
        rightFullPalm(21),
        rightWritersPalm(22),
        rightLowerPalm(23),
        rightUpperPalm(24),
        rightOtherPalm(25),
        rightInterdigital(26),
        rightThenar(27),
        rightHypothenar(28),
        leftFullPalm(29),
        leftWritersPalm(30),
        leftLowerPalm(31),
        leftUpperPalm(32),
        leftOtherPalm(33),
        leftInterdigital(34),
        leftThenar(35),
        leftHypothenar(36),
        rightGrasp(37),
        leftGrasp(38),
        rightIndexMiddleFingers(40),
        rightMiddleRingFingers(41),
        rightRingLittleFingers(42),
        leftIndexMiddleFingers(43),
        leftMiddleRingFingers(44),
        leftRingLittleFingers(45),
        rightIndexLeftIndexFingers(46),
        rightIndexMiddleRingFingers(47),
        rightMiddleRingLittleFingers(48),
        leftIndexMiddleRingFingers(49),
        leftMiddleRingLittleFingers(50),
        rightFourFingertips(51),
        leftFourFingertips(52),
        rightFingertips(53),
        leftFingertips(54),
        leftMiddleIndexRightIndexMiddleFingers(55),
        unknownSole(60),
        rightSole(61),
        leftSole(62),
        unknownToe(63),
        rightBigToe(64),
        rightSecondToe(65),
        rightMiddleToe(66),
        rightFourthToe(67),
        rightLittleToe(68),
        leftBigToe(69),
        leftSecondToe(70),
        leftMiddleToe(71),
        leftFourthToe(72),
        leftLittleToe(73),
        rightFrontBallFoot(74),
        rightBackHeelFoot(75),
        leftFrontBallFoot(76),
        leftBackHeelFoot(77),
        rightMiddleFoot(78),
        leftMiddleFoot(79),
        rightCarpalDelta(81),
        leftCarpalDelta(82),
        rightFullWithWriterPalm(83),
        leftFullWithWriterPalm(84),
        rightBracelet(85),
        leftBracelet(86),
```

```
   otherPosition(999)
}

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

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

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

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

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

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

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

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

```
ImageDataFormatCode ::= ENUMERATED {
   pgm(0),
   wsq(1),
   jpeg2000Lossy(2),
   jpeg2000Lossless(3),
   png(4)
}

ImageDataFormatExtensionBlock ::= SEQUENCE {
   ...
}

ImageDataFormat ::= CHOICE {
   code [0] ImageDataFormatCode,
   extensionBlock [1] ImageDataFormatExtensionBlock
}

CoordinateBlock ::= CoordinateCartesian2DUnsignedShortBlock

CoordinatesBlock ::= SEQUENCE (SIZE(2..MAX)) OF CoordinateBlock

SegmentBlock ::= SEQUENCE {
   position [0] Position,
   enclosingCoordinatesBlock [1] CoordinatesBlock,
   orientation [2] INTEGER (0..255) OPTIONAL,
   qualityBlocks [3] QualityBlocks OPTIONAL,
   confidence [4] ScoreOrError OPTIONAL,
   ...
}

SegmentBlocks ::= SEQUENCE OF SegmentBlock

SegmentationBlock ::= SEQUENCE {
   algorithmIdBlock [0] RegistryIdBlock,
   segmentBlocks [1] SegmentBlocks,
   ...
}

AnnotationReasonCode ::= ENUMERATED {
   unknown(0),
   other(1),
   amputated(2),
   unableToPrint(3),
   bandaged(4),
   physicallyChallenged(5),
   diseased(6)
}

AnnotationReasonExtensionBlock ::= SEQUENCE {
   fallback [0] AnnotationReasonCode,
   ...
}

AnnotationReason ::= CHOICE {
   code [0] AnnotationReasonCode,
   extensionBlock [1] AnnotationReasonExtensionBlock
}

AnnotationBlock ::= SEQUENCE {
   position [0] Position,
   reason [1] AnnotationReason,
   ...
}

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

SpatialSamplingRateBlock ::= SEQUENCE {
   samplesPerUnit [0] INTEGER (0..65535),
```



```
      unitDimension [1] UnitDimensionCode
   }

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

   FingerRotation ::= INTEGER (0..359)

   SegmentationBlocks ::= SEQUENCE OF SegmentationBlock

   AnnotationBlocks ::= SEQUENCE OF AnnotationBlock

   CommentBlock ::= VisibleString

   CommentBlocks ::= SEQUENCE OF CommentBlock

   VendorSpecificDataBlock ::= ExtendedDataBlock

   VendorSpecificDataBlocks ::= SEQUENCE OF VendorSpecificDataBlock

   RepresentationBlock ::= SEQUENCE {
      position [0] Position,
      impression [1] Impression,
      imageDataFormat [2] ImageDataFormat,
      imageData [3] OCTET STRING,
      captureDateTimeBlock [4] CaptureDateTimeBlock OPTIONAL,
      captureDeviceBlock [5] CaptureDeviceBlock OPTIONAL,
      qualityBlocks [6] QualityBlocks OPTIONAL,
      spatialSamplingRateBlock [7] SpatialSamplingRateBlock OPTIONAL,
      positionComputedByCaptureSystem [8] BOOLEAN OPTIONAL,
      originalRotation [9] FingerRotation OPTIONAL,
      imageRotatedToVertical [10] BOOLEAN OPTIONAL,
      imageHasBeenLossilyCompressed [11] BOOLEAN OPTIONAL,
      segmentationBlocks [12] SegmentationBlocks OPTIONAL,
      annotationBlocks [13] AnnotationBlocks OPTIONAL,
      pADDataBlock [14] PADDataBlock OPTIONAL,
      commentBlocks [15] CommentBlocks OPTIONAL,
      vendorSpecificDataBlocks [16] VendorSpecificDataBlocks OPTIONAL,
      ...
   }

   RepresentationBlocks ::= SEQUENCE OF RepresentationBlock

   FingerImageDataBlock ::= [APPLICATION 4] SEQUENCE {
      versionBlock [0] VersionBlock,
      representationBlocks [1] RepresentationBlocks,
      ...
   }

END
```

A.2 XML schema definition for XML encoding

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

* Software developed from this Schema must retain the Copyright Notice, this list of
conditions and the disclaimer below ("Disclaimer").

* Neither the name or logo of ISO or of IEC, nor the names of specific contributors, may
be used to endorse or promote software derived from this Schema without specific prior
written permission.

* The software developer shall attribute the Schema to ISO/IEC and identify the ISO/IEC
standard from which it is taken. Such attribution (e.g., "This software makes use of the
Schema from ISO/IEC 39794-4 within modifications permitted in the relevant ISO/IEC
standard. Please reproduce this note if possible."), may be placed in the software itself
or any other reasonable location.

The Disclaimer is:
THE SCHEMA ON WHICH THIS SOFTWARE IS BASED IS PROVIDED BY THE COPYRIGHT HOLDERS AND
CONTRIBUTORS "AS IS" AND ANY EXPRESS OR IMPLIED WARRANTIES, INCLUDING, BUT NOT LIMITED TO,
THE IMPLIED WARRANTIES OF MERCHANTABILITY AND FITNESS FOR A PARTICULAR PURPOSE ARE
DISCLAIMED. IN NO EVENT SHALL THE COPYRIGHT OWNER OR CONTRIBUTORS BE LIABLE FOR ANY
DIRECT, INDIRECT, INCIDENTAL, SPECIAL, EXEMPLARY, OR CONSEQUENTIAL DAMAGES (INCLUDING, BUT
NOT LIMITED TO, PROCUREMENT OF SUBSTITUTE GOODS OR SERVICES; LOSS OF USE, DATA, OR
PROFITS; OR BUSINESS INTERRUPTION) HOWEVER CAUSED AND ON ANY THEORY OF LIABILITY, WHETHER
IN CONTRACT, STRICT LIABILITY, OR TORT (INCLUDING NEGLIGENCE OR OTHERWISE) ARISING IN ANY
WAY OUT OF THE USE OF THE CODE COMPONENTS, EVEN IF ADVISED OF THE POSSIBILITY OF SUCH
DAMAGE.-->

<xs:schema
   xmlns:xs="http://www.w3.org/2001/XMLSchema"
   xmlns:vc="http://www.w3.org/2007/XMLSchema-versioning"
   xmlns:cmn="http://standards.iso.org/iso-iec/39794/-1"
   xmlns="http://standards.iso.org/iso-iec/39794/-4"
   vc:minVersion="1.0"
   targetNamespace="http://standards.iso.org/iso-iec/39794/-4"
   elementFormDefault="qualified"
   attributeFormDefault="unqualified">

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

  <xs:complexType name="PositionCodeType">
   <xs:choice>
      <xs:element name="unknownPosition" type="xs:int" fixed="0" />
      <xs:element name="rightThumbFinger" type="xs:int" fixed="1" />
      <xs:element name="rightIndexFinger" type="xs:int" fixed="2" />
      <xs:element name="rightMiddleFinger" type="xs:int" fixed="3" />
      <xs:element name="rightRingFinger" type="xs:int" fixed="4" />
      <xs:element name="rightLittleFinger" type="xs:int" fixed="5" />
      <xs:element name="leftThumbFinger" type="xs:int" fixed="6" />
      <xs:element name="leftIndexFinger" type="xs:int" fixed="7" />
      <xs:element name="leftMiddleFinger" type="xs:int" fixed="8" />
      <xs:element name="leftRingFinger" type="xs:int" fixed="9" />
      <xs:element name="leftLittleFinger" type="xs:int" fixed="10" />
      <xs:element name="rightFourFingers" type="xs:int" fixed="13" />
      <xs:element name="leftFourFingers" type="xs:int" fixed="14" />
      <xs:element name="bothThumbFingers" type="xs:int" fixed="15" />
      <xs:element name="rightExtraDigitFinger" type="xs:int" fixed="16" />
      <xs:element name="leftExtraDigitFinger" type="xs:int" fixed="17" />
      <xs:element name="unknownFrictionRidge" type="xs:int" fixed="18" />
      <xs:element name="entireJointImage" type="xs:int" fixed="19" />
      <xs:element name="unknownPalm" type="xs:int" fixed="20" />
      <xs:element name="rightFullPalm" type="xs:int" fixed="21" />
      <xs:element name="rightWritersPalm" type="xs:int" fixed="22" />
      <xs:element name="rightLowerPalm" type="xs:int" fixed="23" />
      <xs:element name="rightUpperPalm" type="xs:int" fixed="24" />
      <xs:element name="rightOtherPalm" type="xs:int" fixed="25" />
```



```
      <xs:element name="rightInterdigital" type="xs:int" fixed="26" />
      <xs:element name="rightThenar" type="xs:int" fixed="27" />
      <xs:element name="rightHypothenar" type="xs:int" fixed="28" />
      <xs:element name="leftFullPalm" type="xs:int" fixed="29" />
      <xs:element name="leftWritersPalm" type="xs:int" fixed="30" />
      <xs:element name="leftLowerPalm" type="xs:int" fixed="31" />
      <xs:element name="leftUpperPalm" type="xs:int" fixed="32" />
      <xs:element name="leftOtherPalm" type="xs:int" fixed="33" />
      <xs:element name="leftInterdigital" type="xs:int" fixed="34" />
      <xs:element name="leftThenar" type="xs:int" fixed="35" />
      <xs:element name="leftHypothenar" type="xs:int" fixed="36" />
      <xs:element name="rightGrasp" type="xs:int" fixed="37" />
      <xs:element name="leftGrasp" type="xs:int" fixed="38" />
      <xs:element name="rightIndexMiddleFingers" type="xs:int" fixed="40" />
      <xs:element name="rightMiddleRingFingers" type="xs:int" fixed="41" />
      <xs:element name="rightRingLittleFingers" type="xs:int" fixed="42" />
      <xs:element name="leftIndexMiddleFingers" type="xs:int" fixed="43" />
      <xs:element name="leftMiddleRingFingers" type="xs:int" fixed="44" />
      <xs:element name="leftRingLittleFingers" type="xs:int" fixed="45" />
      <xs:element name="rightIndexLeftIndexFingers" type="xs:int" fixed="46" />
      <xs:element name="rightIndexMiddleRingFingers" type="xs:int" fixed="47" />
      <xs:element name="rightMiddleRingLittleFingers" type="xs:int" fixed="48" />
      <xs:element name="leftIndexMiddleRingFingers" type="xs:int" fixed="49" />
      <xs:element name="leftMiddleRingLittleFingers" type="xs:int" fixed="50" />
      <xs:element name="rightFourFingertips" type="xs:int" fixed="51" />
      <xs:element name="leftFourFingertips" type="xs:int" fixed="52" />
      <xs:element name="rightFingertips" type="xs:int" fixed="53" />
      <xs:element name="leftFingertips" type="xs:int" fixed="54" />
      <xs:element name="leftMiddleIndexRightIndexMiddleFingers" type="xs:int" fixed="55"
/>
      <xs:element name="unknownSole" type="xs:int" fixed="60" />
      <xs:element name="rightSole" type="xs:int" fixed="61" />
      <xs:element name="leftSole" type="xs:int" fixed="62" />
      <xs:element name="unknownToe" type="xs:int" fixed="63" />
      <xs:element name="rightBigToe" type="xs:int" fixed="64" />
      <xs:element name="rightSecondToe" type="xs:int" fixed="65" />
      <xs:element name="rightMiddleToe" type="xs:int" fixed="66" />
      <xs:element name="rightFourthToe" type="xs:int" fixed="67" />
      <xs:element name="rightLittleToe" type="xs:int" fixed="68" />
      <xs:element name="leftBigToe" type="xs:int" fixed="69" />
      <xs:element name="leftSecondToe" type="xs:int" fixed="70" />
      <xs:element name="leftMiddleToe" type="xs:int" fixed="71" />
      <xs:element name="leftFourthToe" type="xs:int" fixed="72" />
      <xs:element name="leftLittleToe" type="xs:int" fixed="73" />
      <xs:element name="rightFrontBallFoot" type="xs:int" fixed="74" />
      <xs:element name="rightBackHeelFoot" type="xs:int" fixed="75" />
      <xs:element name="leftFrontBallFoot" type="xs:int" fixed="76" />
      <xs:element name="leftBackHeelFoot" type="xs:int" fixed="77" />
      <xs:element name="rightMiddleFoot" type="xs:int" fixed="78" />
      <xs:element name="leftMiddleFoot" type="xs:int" fixed="79" />
      <xs:element name="rightCarpalDelta" type="xs:int" fixed="81" />
      <xs:element name="leftCarpalDelta" type="xs:int" fixed="82" />
      <xs:element name="rightFullWithWriterPalm" type="xs:int" fixed="83" />
      <xs:element name="leftFullWithWriterPalm" type="xs:int" fixed="84" />
      <xs:element name="rightBracelet" type="xs:int" fixed="85"  />
      <xs:element name="leftBracelet" type="xs:int" fixed="86"  />
      <xs:element name="otherPosition" type="xs:int" fixed="999"  />
   </xs:choice>
  </xs:complexType>

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

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



```
   </xs:choice>
  </xs:complexType>

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

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

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

  <xs:complexType name="CaptureDeviceTechnologyIdCodeType">
   <xs:choice>
      <xs:element name="unknownCaptureDeviceTechnology" type="xs:int" fixed="0" />
      <xs:element name="otherCaptureDeviceTechnology" type="xs:int" fixed="1" />
      <xs:element name="scannedInkOnPaper" type="xs:int" fixed="2" />
      <xs:element name="opticalTIRBrightField" type="xs:int" fixed="3" />
      <xs:element name="opticalTIRDarkField" type="xs:int" fixed="4" />
      <xs:element name="opticalImage" type="xs:int" fixed="5" />
      <xs:element name="opticalLowFrequency3DMapped" type="xs:int" fixed="6" />
      <xs:element name="opticalHighFrequency3DMapped" type="xs:int" fixed="7" />
      <xs:element name="capacitive" type="xs:int" fixed="9" />
      <xs:element name="capacitiveRF" type="xs:int" fixed="10" />
      <xs:element name="electroLuminescence" type="xs:int" fixed="11" />
      <xs:element name="reflectedUltrasonic" type="xs:int" fixed="12" />
      <xs:element name="impediographicUltrasonic" type="xs:int" fixed="13" />
      <xs:element name="thermal" type="xs:int" fixed="14" />
      <xs:element name="directPressure" type="xs:int" fixed="15" />
      <xs:element name="indirectPressure" type="xs:int" fixed="16" />
      <xs:element name="liveTape" type="xs:int" fixed="17" />
      <xs:element name="latentImpression" type="xs:int" fixed="18" />
      <xs:element name="latentPhoto" type="xs:int" fixed="19" />
      <xs:element name="latentMolded" type="xs:int" fixed="20" />
      <xs:element name="latentTracing" type="xs:int" fixed="21" />
      <xs:element name="latentLift" type="xs:int" fixed="22" />
   </xs:choice>
  </xs:complexType>

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

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



```
   </xs:choice>
  </xs:complexType>

  <xs:complexType name="ImageDataFormatCodeType">
   <xs:choice>
      <xs:element name="pgm" type="xs:int" fixed="0" />
      <xs:element name="wsq" type="xs:int" fixed="1" />
      <xs:element name="jpeg2000Lossy" type="xs:int" fixed="2" />
      <xs:element name="jpeg2000Lossless" type="xs:int" fixed="3" />
      <xs:element name="png" type="xs:int" fixed="4" />
   </xs:choice>
  </xs:complexType>

  <xs:complexType name="ImageDataFormatExtensionBlockType">
    <xs:sequence>
      <xs:any namespace="##other" processContents="lax"/>
    </xs:sequence>
  </xs:complexType>

  <xs:complexType name="ImageDataFormatType">
   <xs:choice>
      <xs:element name="code" type="ImageDataFormatCodeType" />
      <xs:element name="extensionBlock" type="ImageDataFormatExtensionBlockType" />
   </xs:choice>
  </xs:complexType>

  <xs:complexType name = "CoordinateBlockType" >
   <xs:complexContent>
      <xs:extension base="cmn:CoordinateCartesian2DUnsignedShortBlockType"/>
   </xs:complexContent>
  </xs:complexType>

  <xs:complexType name="CoordinatesBlockType">
    <xs:sequence>
      <xs:element name="coordinateBlock" type="CoordinateBlockType" minOccurs="2"
maxOccurs="unbounded" />
    </xs:sequence>
  </xs:complexType>

  <xs:complexType name="SegmentBlockType">
    <xs:sequence>
      <xs:element name="position" type="PositionType" />
      <xs:element name="enclosingCoordinatesBlock" type="CoordinatesBlockType" />
      <xs:element name="orientation" type="xs:unsignedByte" minOccurs="0" />
      <xs:element name="qualityBlocks" type="cmn:QualityBlocksType" minOccurs="0" />
      <xs:element name="confidence" type="cmn:ScoreOrErrorType" minOccurs="0" />
      <xs:any minOccurs="0" namespace="##other" processContents="lax" />
    </xs:sequence>
  </xs:complexType>

  <xs:complexType name="SegmentBlocksType">
    <xs:sequence>
      <xs:element name="segmentBlock" type="SegmentBlockType" maxOccurs="unbounded" />
    </xs:sequence>
  </xs:complexType>

  <xs:complexType name="SegmentationBlockType">
    <xs:sequence>
      <xs:element name="algorithmIdBlock" type="cmn:RegistryIdBlockType" />
      <xs:element name="segmentBlocks" type="SegmentBlocksType" />
      <xs:any minOccurs="0" namespace="##other" processContents="lax" />
    </xs:sequence>
  </xs:complexType>

  <xs:complexType name="AnnotationReasonCodeType">
   <xs:choice>
      <xs:element name="unknown" type="xs:int" fixed="0" />
      <xs:element name="other" type="xs:int" fixed="1" />
      <xs:element name="amputated" type="xs:int" fixed="2" />
      <xs:element name="unableToPrint" type="xs:int" fixed="3" />
      <xs:element name="bandaged" type="xs:int" fixed="4" />
```



```
      <xs:element name="physicallyChallenged" type="xs:int" fixed="5" />
      <xs:element name="diseased" type="xs:int" fixed="6" />
   </xs:choice>
  </xs:complexType>

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

  <xs:complexType name="AnnotationReasonType">
   <xs:choice>
      <xs:element name="code" type="AnnotationReasonCodeType" />
      <xs:element name="extensionBlock" type="AnnotationReasonExtensionBlockType" />
   </xs:choice>
  </xs:complexType>

  <xs:complexType name="AnnotationBlockType">
    <xs:sequence>
      <xs:element name="position" type="PositionType" />
      <xs:element name="reason" type="AnnotationReasonType" />
      <xs:any minOccurs="0" namespace="##other" processContents="lax" />
    </xs:sequence>
  </xs:complexType>

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

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

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

  <xs:simpleType name="FingerRotationType">
    <xs:restriction base="xs:unsignedInt">
      <xs:maxInclusive value="359"/>
    </xs:restriction>
  </xs:simpleType>

  <xs:complexType name="SegmentationBlocksType">
    <xs:sequence>
      <xs:element name="segmentationBlock" type="SegmentationBlockType"
maxOccurs="unbounded" />
    </xs:sequence>
  </xs:complexType>

  <xs:complexType name="AnnotationBlocksType">
    <xs:sequence>
      <xs:element name="annotationBlock" type="AnnotationBlockType" maxOccurs="unbounded"
/>
    </xs:sequence>
  </xs:complexType>
```



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

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

  <xs:complexType name = "VendorSpecificDataBlockType" >
    <xs:complexContent>
      <xs:extension base="cmn:ExtendedDataBlockType"/>
    </xs:complexContent>
  </xs:complexType>

  <xs:complexType name="VendorSpecificDataBlocksType">
    <xs:sequence>
      <xs:element name="vendorSpecificDataBlock" type="VendorSpecificDataBlockType"
maxOccurs="unbounded"/>
    </xs:sequence>
  </xs:complexType>

  <xs:complexType name="RepresentationBlockType">
    <xs:sequence>
      <xs:element name="position" type="PositionType" />
      <xs:element name="impression" type="ImpressionType" />
      <xs:element name="imageDataFormat" type="ImageDataFormatType" />
      <xs:element name="imageData" type="xs:base64Binary" />

      <xs:element name="captureDateTimeBlock" type="cmn:CaptureDateTimeBlockType"
minOccurs="0" />
      <xs:element name="captureDeviceBlock" type="CaptureDeviceBlockType" minOccurs="0" />
      <xs:element name="qualityBlocks" type="cmn:QualityBlocksType" minOccurs="0" />

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

      <xs:element name="positionComputedByCaptureSystem" type="xs:boolean" minOccurs="0"
/>
      <xs:element name="originalRotation" type="FingerRotationType" minOccurs="0" />
      <xs:element name="imageRotatedToVertical"  type="xs:boolean" minOccurs="0" />
      <xs:element name="imageHasBeenLossilyCompressed"  type="xs:boolean" minOccurs="0" />

      <xs:element name="segmentationBlocks" type="SegmentationBlocksType" minOccurs="0" />
      <xs:element name="annotationBlocks" type="AnnotationBlocksType" minOccurs="0" />
      <xs:element name="pADDataBlock" type="cmn:PADDataBlockType" minOccurs="0" />
      <xs:element name="commentBlocks" type="CommentBlocksType" minOccurs="0" />
      <xs:element name="vendorSpecificDataBlocks" type="VendorSpecificDataBlocksType"
minOccurs="0" />

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

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

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

  <xs:complexType name="FingerImageDataBlockType">
    <xs:sequence>
      <xs:element name="versionBlock" type="cmn:VersionBlockType" />
      <xs:element name="representationBlocks" type="RepresentationBlocksType" />
      <xs:any minOccurs="0" namespace="##other" processContents="lax" />
    </xs:sequence>
  </xs:complexType>
```

```
  <xs:element name="fingerImageData" type="FingerImageDataBlockType" />
</xs:schema>
```


Annex B
(informative)

Encoding examples

B.1 Sample ASN.1 encoding for finger image data

An example encoding can be retrieved from http://standards.iso.org/iso-iec/39794/-4/ed-1/en.

B.2 Sample XML encoding for finger image data


```
<?xml version="1.0" encoding="UTF-8"?>
<fir:fingerImageData xmlns:cmn="http://standards.iso.org/iso-iec/39794/-1"
xmlns:fir="http://standards.iso.org/iso-iec/39794/-4">
  <fir:versionBlock>
    <cmn:generation>3</cmn:generation>
    <cmn:year>2019</cmn:year>
  </fir:versionBlock>
  <fir:representationBlocks>
    <fir:representationBlock>
      <fir:position>
        <fir:code>
          <fir:rightIndexFinger/>
        </fir:code>
      </fir:position>
      <fir:impression>
        <fir:code>
          <fir:rolledContact/>
        </fir:code>
      </fir:impression>
      <fir:imageDataFormat>
        <fir:code>
          <fir:png/>
        </fir:code>
      </fir:imageDataFormat>
      <fir:imageData>

iVBORw0KGgoAAAANSUhEUgAAABgAAAAYCAAAAADFHGIkAAAACXBIWXMAACcQAAAn
EAGUaVEZAAACY0lEQVQozwFYAqf9Af+nrBYPLA4aNJnWz/wGFxLw5OsGTDtL/AQo
GA38Ij4e6CEN+fscDTnJ/H8kIADmx/ABLf2MHw6QxPzpCefquAsgJgAAruPOCxbo
BHVC7tRqFgdJPRsu4Awxzul3+icEBPI17QH/WtYI6vqIXOOE2RkU5Bjk3gsVB2Uw
GQAEV+IHZzwloCADDAbJZB+97/aKKiEArM6yBMRXM1uyUhD/9jlvNBgl878SAOpV
BQjmBAGtEhulzd7jemThxGcj/7oYpnYUGAgAKjcB/2oBDugEm+F6wQr/N6S1fv3x
AWB43SkABBgmIwuIF1LHBO49hBRkFRviQ3Iq5ew39QEkC7cZu28A+9z/4Y71FwoH
SSufnyX/3RMESXbGsRsj1YFdccoDXyUYJqM2Hwj4AYflAezQmBY4Px5l8gUiaN87
6TgM9BLyjE8A4wFu+yftb73L3/slcvXIwLf1ChN/VdjcjgsE6y5LEZrY5SeVozwP
B97yEIxbAGTEAwYDBBx4s7IE6mZWQ/EXxxsNJG9Xt5b6CEHjTgH/XfkIZR8eCyPx
fhWg9mpOhNcDDRZDPJQCLNDtGj3aMDIs0f2DBjZOlusNaGx/4hGhBCDmZEab2x0N
hnLgBFFXfPcAGDqxWgogNgQRm/Wu3gVvKJvX7X1XUuwXLH9wz/0KO1oB/7KeEw5/
DInk3aD8MRAMNJ2E0uI7MluwAY3X8wuO/MT35178U/cxKnJ19vMjUBO00QTnDxN5
+uEKBE38cxFDUQ89DxGREux4BvAECyxU88QEA0L1lQcRYfq7H/RcEoHIBh5tYSQC
NTRwx9QAAAAASUVORK5CYII=

</fir:imageData>
      <fir:captureDateTimeBlock>
        <cmn:year>2018</cmn:year>
        <cmn:month>12</cmn:month>
        <cmn:day>30</cmn:day>
        <cmn:hour>13</cmn:hour>
      </fir:captureDateTimeBlock>
      <fir:captureDeviceBlock>
        <fir:modelIdBlock>
```

```
    <cmn:organization>200</cmn:organization>
    <cmn:id>33</cmn:id>
  </fir:modelIdBlock>
  <fir:technologyId>
    <fir:code>
      <fir:opticalTIRBrightField/>
    </fir:code>
  </fir:technologyId>
  <fir:certificationIdBlocks>
    <cmn:certificationIdBlock>
      <cmn:organization>31</cmn:organization>
      <cmn:id>31</cmn:id>
    </cmn:certificationIdBlock>
  </fir:certificationIdBlocks>
</fir:captureDeviceBlock>
<fir:qualityBlocks>
  <cmn:qualityBlock>
    <cmn:algorithmIdBlock>
      <cmn:organization>11</cmn:organization>
      <cmn:id>11</cmn:id>
    </cmn:algorithmIdBlock>
    <cmn:scoreOrError>
      <cmn:score>44</cmn:score>
    </cmn:scoreOrError>
  </cmn:qualityBlock>
  <cmn:qualityBlock>
    <cmn:algorithmIdBlock>
      <cmn:organization>257</cmn:organization>
      <cmn:id>1</cmn:id>
    </cmn:algorithmIdBlock>
    <cmn:scoreOrError>
      <cmn:error>
        <cmn:code>
          <cmn:failureToAssess/>
        </cmn:code>
      </cmn:error>
    </cmn:scoreOrError>
  </cmn:qualityBlock>
</fir:qualityBlocks>
<fir:spatialSamplingRateBlock>
  <fir:samplesPerUnit>100</fir:samplesPerUnit>
  <fir:unitDimension>
    <fir:cm/>
  </fir:unitDimension>
</fir:spatialSamplingRateBlock>
<fir:positionComputedByCaptureSystem>0</fir:positionComputedByCaptureSystem>
<fir:originalRotation>35</fir:originalRotation>
<fir:imageRotatedToVertical>1</fir:imageRotatedToVertical>
<fir:imageHasBeenLossilyCompressed>0</fir:imageHasBeenLossilyCompressed>
<fir:segmentationBlocks>
  <fir:segmentationBlock>
    <fir:algorithmIdBlock>
      <cmn:organization>259</cmn:organization>
      <cmn:id>1</cmn:id>
    </fir:algorithmIdBlock>
    <fir:segmentBlocks>
      <fir:segmentBlock>
        <fir:position>
          <fir:code>
            <fir:rightIndexFinger/>
          </fir:code>
        </fir:position>
        <fir:enclosingCoordinatesBlock>
          <fir:coordinateBlock>
            <cmn:x>0</cmn:x>
            <cmn:y>0</cmn:y>
          </fir:coordinateBlock>
          <fir:coordinateBlock>
            <cmn:x>23</cmn:x>
            <cmn:y>23</cmn:y>
          </fir:coordinateBlock>
```

```
              </fir:enclosingCoordinatesBlock>
              <fir:confidence>
                <cmn:score>100</cmn:score>
              </fir:confidence>
            </fir:segmentBlock>
          </fir:segmentBlocks>
        </fir:segmentationBlock>
      </fir:segmentationBlocks>
      <fir:annotationBlocks>
        <fir:annotationBlock>
          <fir:position>
            <fir:code>
              <fir:rightIndexFinger/>
            </fir:code>
          </fir:position>
          <fir:reason>
            <fir:code>
              <fir:physicallyChallenged/>
            </fir:code>
          </fir:reason>
        </fir:annotationBlock>
      </fir:annotationBlocks>
      <fir:pADDataBlock>
        <cmn:decision>
          <cmn:code>
            <cmn:attack/>
          </cmn:code>
        </cmn:decision>
        <cmn:scoreBlocks>
          <cmn:scoreBlock>
            <cmn:mechanismIdBlock>
              <cmn:organization>26</cmn:organization>
              <cmn:id>27</cmn:id>
            </cmn:mechanismIdBlock>
            <cmn:scoreOrError>
              <cmn:score>72</cmn:score>
            </cmn:scoreOrError>
          </cmn:scoreBlock>
        </cmn:scoreBlocks>
        <cmn:captureContext>
          <cmn:code>
            <cmn:verification/>
          </cmn:code>
        </cmn:captureContext>
        <cmn:supervisionLevel>
          <cmn:code>
            <cmn:unknown/>
          </cmn:code>
        </cmn:supervisionLevel>
        <cmn:riskLevel>37</cmn:riskLevel>
        <cmn:criteriaCategory>
          <cmn:code>
            <cmn:unknown/>
          </cmn:code>
        </cmn:criteriaCategory>
        <cmn:parameter>

C2bBNZAEX7ouiQ==

</cmn:parameter>
        <cmn:challenges>
          <cmn:challenge>

d5a11PMXNlV0kw==

</cmn:challenge>
        </cmn:challenges>
      </fir:pADDataBlock>
      <fir:commentBlocks>
        <fir:commentBlock>ISO/IEC 39794-4 BDB encoding example</fir:commentBlock>
        <fir:commentBlock>Small finger image</fir:commentBlock>
```

```
      </fir:commentBlocks>
      <fir:vendorSpecificDataBlocks>
        <fir:vendorSpecificDataBlock>
          <cmn:dataTypeIdBlock>
            <cmn:organization>11</cmn:organization>
            <cmn:id>1</cmn:id>
          </cmn:dataTypeIdBlock>
          <cmn:data>

PYzbL37NIXC/Ew==

</cmn:data>
        </fir:vendorSpecificDataBlock>
        <fir:vendorSpecificDataBlock>
          <cmn:dataTypeIdBlock>
            <cmn:organization>11</cmn:organization>
            <cmn:id>2</cmn:id>
          </cmn:dataTypeIdBlock>
          <cmn:data>

FThbfqHEACNGaQ==

</cmn:data>
        </fir:vendorSpecificDataBlock>
      </fir:vendorSpecificDataBlocks>
    </fir:representationBlock>
  </fir:representationBlocks>
</fir:fingerImageData>
```


Annex C
(normative)

Conformance testing methodology

C.1 Overview

To provide sufficient information about the IUT for the testing laboratory to properly conduct a conformance test and for an appropriate declaration of conformity to be made, the supplier of the IUT shall provide the information in Table C.1 and also complete the columns "IUT support" and "Supported range" in Table C.2 that applies to tested finger image extensible BDB format(s). All tables shall be provided to the testing laboratory prior to, or at the same time as, the IUT is provided to the testing laboratory.

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

Supplier name and address	
Contact point for queries about the ICS	
Implementation name	
Implementation version	
Any other information necessary for full identification of the implementation	
Registered BDB format identifier of the format that conformance is claimed to	
Are any mandatory requirements of the standard not fully supported (Yes or No)	
Date of statement	

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

Most Level 1 and Level 2 requirements are specified in the schemas of Annex A and shall not be repeated in tabular form. As specified in ISO/IEC 39794-1, this document specifies a table of optional elements that the IUT claims to support and which a testing laboratory can attest to.

ITU-T maintains a list of tools that can be used to work with xml documents and schemas[16].

W3C maintains a list of tools that can be used to work with xml documents and schemas[17].

Table C.2 — IUT optional element claimed support

Provision identifier	Reference in data format specification	Provision summary	Level	Status	Format type applicability		IUT support	Support-ed range	Test result
					Tagged binary encoding	XML encoding			
P1	Annex A	A finger-image data block may contain unknown extensions.	1 and 2	O	Y	Y			
P2	Annex A	A representation block may contain a capture date/time block.	1 and 2	O	Y	Y			
P3	Annex A	A representation block may contain a capture device block.	1 and 2	O	Y	Y			
P4	Annex A	A capture device block may contain certification identifier blocks.	1 and 2	O	Y	Y			
P5	Annex A	A capture device block may contain unknown extensions.	1 and 2	O	Y	Y			
P6	Annex A	A representation block may contain quality blocks.	1 and 2	O	Y	Y			
P7	ISO/IEC 39794-1	A quality block may contain unknown extensions.	1 and 2	O	Y	Y			
P8	Annex A	A representation block may contain a spatial sampling rate block.	1 and 2	O	Y	Y			
P9	Annex A	A representation block may contain a position-computed-by-capture-system field.	1 and 2	O	Y	Y			
P10	Annex A	A representation block may contain an original rotation field.	1 and 2	O	Y	Y			
P11	Annex A	A representation block may contain an image-rotated-to-vertical field.	1 and 2	O	Y	Y			
P12	Annex A	A representation block may contain an im-age-has-been-lossily-compressed field.	1 and 2	O	Y	Y			
P13	Annex A	A representation block may contain segmenta-tion blocks.	1 and 2	O	Y	Y			
P14	Annex A	A representation block may contain annotation blocks.	1 and 2	O	Y	Y			
P15	Annex A	An annotation block may contain unknown extensions.	1 and 2	O	Y	Y			

Table C.2 *(continued)*

Provision identifier	Reference in data format specification	Provision summary	Level	Status	Format type applicability		IUT support	Support-ed range	Test result
					Tagged binary encoding	XML encoding			
P16	Annex A	A representation block may contain a PAD data block.	1 and 2	O	Y	Y			
P17	ISO/IEC 39794-1	A PAD data block may contain a PAD decision.	1 and 2	O	Y	Y			
P18	ISO/IEC 39794-1	A PAD data block may contain PAD score blocks.	1 and 2	O	Y	Y			
P19	ISO/IEC 39794-1	A PAD data block may contain PAD extended data blocks.	1 and 2	O	Y	Y			
P20	ISO/IEC 39794-1	A PAD data block may contain a context-of-capture field.	1 and 2	O	Y	Y			
P21	ISO/IEC 39794-1	A PAD data block may contain a level-of-supervision/ surveillance field.	1 and 2	O	Y	Y			
P22	ISO/IEC 39794-1	A PAD data block may contain a risk level field.	1 and 2	O	Y	Y			
P23	ISO/IEC 39794-1	A PAD data block may contain a category-of-criteria field.	1 and 2	O	Y	Y			
P24	ISO/IEC 39794-1	A PAD data block may contain a PAD parameters field.	1 and 2	O	Y	Y			
P25	ISO/IEC 39794-1	A PAD data block may contain PAD challenges.	1 and 2	O	Y	Y			
P26	ISO/IEC 39794-1	A PAD data block may contain a PAD capture date/time field.	1 and 2	O	Y	Y			
P27	Annex A	A representation block may contain comment blocks.	1 and 2	O	Y	Y			
P28	Annex A	A representation block may contain vendor specific data blocks.	1 and 2	O	Y	Y			
P29	Annex A	A representation block may contain unknown extensions.	1 and 2	O	Y	Y			
P30	Annex A	A segment block may contain an orientation field.	1 and 2	O	Y	Y			
P31	Annex A	A segment block may contain quality blocks.	1 and 2	O	Y	Y			
P32	ISO/IEC 39794-1	A quality block within a segment block may contain unknown extensions.	1 and 2	O	Y	Y			

Table C.2 *(continued)*

Provision identifier	Reference in data format specification	Provision summary	Level	Status	Format type applicability		IUT support	Support-ed range	Test result
					Tagged binary encoding	XML encoding			
P33	Annex A	A segment block may contain a confidence field.	1 and 2	O	Y	Y			
P34	Annex A	A segment block may contain unknown exten-sions.	1 and 2	O	Y	Y			
P35	Annex A	A segmentation block may contain unknown extensions.	1 and 2	O	Y	Y			

IUT support notes

To be filled in by the supplier of the IUT on the copy of this table provided to the testing laboratory and to be included in the copy of this table that forms part of the test report.

Test result notes

To be filled in by the testing laboratory, if necessary, during the execution of the conformance test and to be included in the copy of this table that forms part of the test report.

C.2 Conformance test assertions

Table C.3 details the Level 2 conformance tests that a testing organization should perform on an IUT. These Level 2 tests are necessary as the schema validation does not perform these checks. All other Level 1 and Level 2 conformance requirements are tested by schema validation.

Table C.3 — Level 2 conformance tests

Test identifier	Provision identifier	Conformance test assertion
T-1	7.3	VersionBlock.generation == 3
T-2	7.7	Encoding algorithm matches encoding of friction ridge data
T-3	7.17	All coordinates have a unique X,Y position (there are no duplicate coordinates in a segment)

Annex D
(normative)

Capture device certifications

D.1 Image quality specification for AFIS systems

D.1.1 General

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

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

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

The image quality requirements for fingerprint scanners are covered in D.1.2 and D.1.3. The compliance test procedures for these requirements are out of scope of this Annex. An example for a test specification that allows testing of conformance with this image quality specification is available[9].

D.1.2 Fingerprint scanner

D.1.2.1 Overview

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

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

A scanner intended to scan standard 8,0 by 8,0 inch tenprint cards, shall be capable of capturing an area of at least 5,0 by 8,0 inches, which captures all 14 print blocks, either each print block as a separate

1) The term "fingerprint" in this annex can also include palmprint, whole hand print or a print from other parts of the human body.

image or all print blocks together as a single image. In terms of individual print blocks, Table D.1 gives the preferred capture sizes applicable to both card scan and live scan systems, with the exception that, when scanning fingerprint cards, the card form dimensions take precedence.

Table D.1 — Preferred capture sizes

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

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

D.1.2.2 Linearity

D.1.2.2.1 Requirement

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

D.1.2.2.2 Background

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

D.1.2.3 Geometric accuracy

D.1.2.3.1 Requirement (across-bar)

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

For 500-ppi scanner:

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

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

for 1000-ppi scanner:

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

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

where

D = |Y-X|;

X = actual target distance;

Y = measured image distance.

D, X, Y are in inches.

D.1.2.3.2 Requirement (along-bar)

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

D.1.2.3.3 Background

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

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

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

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

D.1.2.4 Spatial frequency response

D.1.2.4.1 Requirements

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

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

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

Table D.2 — MTF requirement using sine wave target

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

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

Table D.3 — CTF requirement using bar target (nominal test frequencies)

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

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

It is not required that the bar target contain the exact frequencies listed in Table D.3; however, the target does need to cover the listed frequency range and contain bar patterns close to each of the listed frequencies. Formulae (D.1) and (D.2) are used to obtain the specification CTF modulation values when using bar targets that contain frequencies not listed in Table D.3.

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

$$CTF = 3{,}04105E^{-4} * f^2 - 7{,}99095E^{-2} * f + 1{,}02774 \tag{D.1}$$

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

$$CTF = -1{,}85487E^{-5} * f^3 + 1{,}41666E^{-3} * f^2 - 5{,}73701E^{-2} * f + 1{,}01341 \tag{D.2}$$

D.1.2.4.2 Background

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

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

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

MTF = peak image modulation/target modulation

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

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

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

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

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

D.1.2.5 Signal-to-noise ratio

D.1.2.5.1 Requirement

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

D.1.2.5.2 Background

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

D.1.2.6 Grey-level uniformity

D.1.2.6.1 Requirement — Adjacent row, column uniformity

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

D.1.2.6.2 Requirement — Pixel-to-pixel uniformity

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

D.1.2.6.3 Requirement — Small area uniformity

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

D.1.2.6.4 Background

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

D.1.2.7 Finger image quality

The scanner shall provide high quality finger images; the quality will be assessed with respect to the requirements in D.1.2.7.1.

D.1.2.7.1 Requirement — Fingerprint grey range

At least 80,0 % of the captured individual finger images shall have a grey-level dynamic range of at least 200 grey-levels, and at least 99,0 % shall have a dynamic range of at least 128 grey-levels.

D.1.2.7.2 Background

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

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

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

D.1.2.7.3 Requirement — Finger artefacts and anomalies

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

D.1.2.7.4 Background

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

— jitter noise effects,

— sharp truncations in average grey-level between adjacent print blocks,

— gaps in the grey-level histograms, *i.e.*, zero pixels in intermediate grey-levels, or clipping to less than 256 possible grey-levels,

— imaging detector butt joints,

— noise streaks,

— card bleed-through, and

— grey-level saturation.

D.1.2.7.5 Requirement — Fingerprint sharpness and detail rendition

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

D.1.2.7.6 Background

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

D.1.3 Identification flats

D.1.3.1 Overview

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

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

The identification flats scanner shall meet all the requirements stated in D.1.2 as well as the requirements in D.1.3.2.

D.1.3.2 Requirement — Capture protocol

The system shall provide a simple capture protocol.

D.1.3.3 Background

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

D.1.3.4 Requirement — Verifiable finger sequence data

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

D.1.3.5 Background

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

D.2 Image quality specification for personal verification

D.2.1 General

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

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

D.2.2 Requirements

The compliance test procedures are out of scope of this Annex. An example for a test specification that allows testing of conformance with this image quality specification is available[9].

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

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

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

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

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

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

Table D.4 — Basic requirements

Parameter	Requirement
Capture size	≥12,8 mm wide by ≥16,5 mm high
True optical or native spatial sampling rate (Nyquist frequency)	≥500 ppi in sensor detector row and column directions
Spatial sampling rate scale	490 ppi to 510 ppi in sensor detector row and column directions
Image type	Capability to output monochrome image at 8 bits per pixel, 256 grey-levels (prior to any compression)

D.2.2.1 Geometric accuracy

D.2.2.1.1 Requirement #1 (across-bar)

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

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

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

where

D is |Y-X|;

X is actual target distance;

Y is measured image distance.

D, X, Y are in inches.

D.2.2.1.2 Requirement #2 (along-bar)

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

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

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

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

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

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

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

D.2.2.1.3 Background

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

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

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

D.2.2.2 Spatial frequency response (SFR)

D.2.2.2.1 Requirements

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

The CTF or MTF shall meet or exceed the minimum modulation values defined in Formula (D.3) (for CTF) or Formula (D.4) (for MTF), over the frequency range of 1,0 to 10,0 cy/mm, in both the detector row and detector column directions, and over any region of the total capture area. Table D.5 gives the minimum CTF and MTF modulation values at nominal test frequencies. None of the CTF or MTF modulation values in the 1,0 to 10,0 cy/mm range shall exceed 1,12, and the target image shall not exhibit any significant amount of aliasing in that range.

$$CTF = -5{,}71711E^{-5} * f^4 + 1{,}438781 * f^3 - 8{,}94631E^{-3} * f^2 - 8{,}05399E^{-2} * f + 1{,}00838 \quad \text{(D.3)}$$

$$MTF = -2{,}80874E^{-4} * f^3 + 1{,}06255E^{-2} * f^2 - 1{,}67473E^{-1} * f + 1{,}02829 \quad \text{(D.4)}$$

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

Table D.5 — CTF and MTF requirements at nominal test frequencies

Frequency (f) in cy/mm at object plane	Minimum CTF modulation when using bar target	Minimum MTF modulation when using sine wave or edge target
1,0	0,920	0,871
2,0	0,822	0,734
3.0	0,720	0,614
4,0	0,620	0,510
5,0	0,526	0,421
6,0	0,440	0,345
7,0	0,362	0,280
8,0	0,293	0,225
9,0	0,232	0,177
10,0	0,174	0,135

D.2.2.2.2 Background

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

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

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

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

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

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

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

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

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

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

Edge target – The computation of MTF from an imaged edge target follows the relevant ISO standard[11]. The target edge is oriented at an angle of 5,2 degrees, alternately with respect to the sensor row and column directions. If the device has a nonlinear response, then the nonlinearity needs to be measured and taken into account in the computations. The computed output modulation values are normalised to 1,0 at zero frequency (by dividing by the area of the line spread function), resulting in an acceptable measure of the device MTF. If the spatial frequency response of the target edge is known, then a further division by that response function is performed to obtain a more exact measure of the device MTF. The edge target shall contain at least two fiducial marks from which the image scale in the across-the-edge direction can be measured, in pixels per inch.

D.2.2.3 Grey-level uniformity

D.2.2.3.1 Requirement #1 — Adjacent row, column uniformity

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

D.2.2.3.2 Requirement #2 — Pixel to pixel uniformity

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

D.2.2.3.3 Requirement #3 — Small area uniformity

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

D.2.2.3.4 Requirement #4 — Noise

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

D.2.2.3.5 Background

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

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

D.2.2.4 Fingerprint image quality

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

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

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

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

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

D.2.2.4.1 Requirement #1 — Fingerprint grey range

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

D.2.2.4.2 Background

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

D.2.2.4.3 Requirement #2 — Fingerprint artefacts and anomalies

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

D.2.2.4.4 Background

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

— jitter noise effects,

— localized offsets of fingerprint segments,

— sensor segmentation/butt joints,

— noise streaks, erratic pixel response,

— grey-level saturation, and

— poor reproducibility.

D.2.2.4.5 Requirement #3 — Fingerprint sharpness and detail rendition

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

D.2.2.4.6 Background

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

D.3 Requirements and test procedures for optical fingerprint scanners

D.3.1 General

This annex details requirements and testing procedures for high quality optical fingerprint scanners. A grey-level for the purposes of D.3 is a particular value contained within the range of a grayscale image.

D.3.2 Testing prerequisites

D.3.2.1 Requirements on the testing laboratory

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

— suitable software for data evaluation (D.3.2.3),

— spreadsheet software, and

— suitable test targets (D.3.2.4).

The personal of the test laboratory should have fundamental knowledge on the test of optical systems/instruments, especially on the test of fingerprint scanners.

D.3.2.2 Requirements on the test object

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

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

D.3.2.3 Requirements on the evaluation software

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

- The software shall have the digital finger image as input.
- It shall define a square window width of about 60 % of finger image width.
- It shall locate the left/right and bottom/top edges of the fingerprint.
- It shall define a set of overlapping windows covering the entire fingerprint area.
- It shall exclude very dense and very low structure areas within the fingerprint from further evaluation.
- It shall compute the 2D power spectrum of each window using a 2D FFT.
- It shall be normalised by total energy and window size.
- It shall apply a Human Visual System (HVS) filter (inclusion of such a filter makes the final quality values more closely correspond to human observer assessments of relative quality).
- It shall use an initial image quality value per window, i.e. the 2D normalised, filtered power spectrum values at non-zero frequencies are summed, resulting in a single quality number for the given sub image.
- It shall identify the window with the highest image quality.

It shall convert the image quality to the dc normalised image quality, that means it shall scale the finger image to the range [0,100], where 0 is the worst quality, 100 is the best quality. The software shall work as follows:

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

D.3.2.4 Demands on the test targets

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

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

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

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

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

D.3.3 Requirements and test procedures

D.3.3.1 Investigation of the greyscale linearity

D.3.3.1.1 Requirements

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

D.3.3.1.2 Background

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

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

D.3.3.1.3 Used targets

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

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

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

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

D.3.3.1.4 Test procedure

D.3.3.1.4.1 Test step 1

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

D.3.3.1.4.2 Test step 2

The adjacent verage grey value of each target image shall be determined with suitable software. The reflectivity and the resulting grey value of each target shall be determined as pair of values.

D.3.3.1.4.3 Test step 3

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

D.3.3.1.5 Requirement compliance

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

D.3.3.2 Investigation of the spatial sampling rate and geometrical accuracy

D.3.3.2.1 Requirements

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

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

— for 500 ppi scanners: $D \leq 0{,}0007$, for $0{,}00 < X \leq 0{,}07$ and $D \leq 0{,}01X$, for $0{,}07 \leq X \leq 1{,}50$;

— for 1000 ppi scanners: $D \leq 0{,}0005$, for $0{,}00 < X \leq 0{,}07$ and $D \leq 0{,}0071X$, for $0{,}07 \leq X \leq 1{,}50$;

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

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

D.3.3.2.2 Background

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

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

D.3.3.2.3 Used targets

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

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

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

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

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

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

D.3.3.2.4 Test procedure

D.3.3.2.4.1 Test step 1

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

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

D.3.3.2.4.2 Test step 2

The pixels coordinates of the edges of the stripe field in the recorded image are determined. These data and the picture dimensions are necessary for the evaluation by suitable software (see D.3.2.3). This software determines within the specified measurement field the distance between neighbouring stripes, the average distance between six stripes and the coordinates of the central line of each stripe. As a unit, pixels shall be used.

D.3.3.2.4.3 Test step 3

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

D.3.3.2.5 Requirement compliance

The values listed in D.3.3.3.1 shall be completely met.

D.3.3.3 Investigation of the contrast transfer function

D.3.3.3.1 Requirements

The spatial frequency response shall be measured using a binary grid target (Ronchi-Grating), denoted as contrast transfer function (CTF) measurement. When measuring the bar CTF, it shall meet or exceed the minimum modulation values defined by Formula (D.5) or (D.6), in both the detector row and detector column directions, and over any region of the scanner's field of view. CTF values computed from Formula (D.5) or (D.6) for nominal test frequencies are given in Table D.6. None of the CTF modulation values measured at specification spatial frequencies shall exceed 1,05. The output bar target image shall not exhibit any significant amount of aliasing.

Table D.6 — Minimum and maximum modulation

Frequency [cy/mm]	Minimum modulation for 500 ppi scanners	Minimum modulation for 1000 ppi scanners	Maximum modulation
1,0	0,948	0,957	1,05
2,0	0,869	0,904	1,05
3,0	0,791	0,854	1,05

Table D.6 *(continued)*

Frequency [cy/mm]	Minimum modulation for 500 ppi scanners	Minimum modulation for 1000 ppi scanners	Maximum modulation
4,0	0,713	0,805	1,05
5,0	0,636	0,760	1,05
6,0	0,559	0,716	1,05
7,0	0,483	0,675	1,05
8,0	0,408	0,636	1,05
9,0	0,333	0,598	1,05
10,0	0,259	0,563	1,05
12,0	—	0,497	1,05
14,0	—	0,437	1,05
16,0	—	0,382	1,05
18,0	—	0,332	1,05
20,0	—	0,284	1,05

It is not required that the bar target contain the exact frequencies listed in the previous table, however, the target does need to cover the listed frequency range and contain bar patterns close to each of the listed frequencies. Formulae (D.5) and (D.6) are used to obtain the minimum acceptable CTF modulation values when using bar targets that contain frequencies not listed in Table D.6.

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

$$CTF = 3{,}04105E^{-4} * f^2 - 7{,}99095E^{-2} * f + 1{,}02774 \quad (D.5)$$

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

$$CTF = -1{,}85487E^{-5} * f^3 + 1{,}41666E^{-3} * f^2 - 5{,}73701E^{-2} * f + 1{,}01341 \quad (D.6)$$

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

D.3.3.3.2 Background

A multiple parallel bar target refers to a Ronchi target, which consists of an equal-width bar and space square wave pattern with high contrast ratio and sharp edge definition. These targets shall have all spatial frequencies in the range mentioned in D.3.3.3.1. All these gratings shall be placed on one single target. Additionally, on this target there shall be large black and white structures to determine a CTF at a frequency of about 0 cy/mm. The spatial frequency of these structures shall be smaller than 3 % of the Nyquist frequency. For all scanners these structures shall have a width of at least 1,7 mm. Each of the test field with the frequencies listed above shall have an adequate number and length of the gratings as listed in Table D.7.

Table D.7 — Dimensions of the target structures

Spatial frequency R [mm^{-1}]	Min. number of stripes	Width of the stripes [mm]	Min. length of the stripes [mm]	R/R Nyquist (at 500 ppi)	R/R Nyquist (at 1000 ppi)
0,3	1	>1,700	2,50	3 %	1,5 %
1	4	0,500	2,50	10 %	5 %
2	5	0,250	1,25	20 %	10 %
3	5	0,167	0,85	30 %	15 %

Table D.7 *(continued)*

Spatial frequency R [mm⁻¹]	Min. number of stripes	Width of the stripes [mm]	Min. length of the stripes [mm]	R/R Nyquist (at 500 ppi)	R/R Nyquist (at 1000 ppi)
4	5	0,125	0,63	40 %	20 %
5	10	0,100	0,50	50 %	25 %
6	10	0,083	0,42	60 %	30 %
7	10	0,071	0,36	70 %	35 %
8	10	0,063	0,32	80 %	40 %
9	10	0,056	0,28	90 %	45 %
10	10	0,050	0,25	100 %	50 %
12	10	0,042	0,25	—	60 %
14	10	0,036	0,25	—	70 %
16	10	0,032	0,25	—	80 %
18	10	0,028	0,25	—	90 %
20	10	0,025	0,25	—	100 %

D.3.3.3.3 Used targets

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

The target can consist of directly reflecting structures, such as chromium stripes on a glass substrate. The target shall be structured as mentioned in D.3.3.3.2. The light passing the glass substrate shall be coupled out by a prism which shall be placed on top of the target (see D.3.2.4).

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

When determining the CTF, the laboratory shall consider that the target has a certain frequency response (mainly caused by the manufacturing process). Thus the CTF of all used targets shall be tested by a microscope before using them for this investigation.

If the target covers at least 25 % of the recording surface of the fingerprint scanner, it shall be placed only once in the centre of the recording surface. Otherwise it shall be placed twice on the recording surface, left and right of the centre. Thus, the corresponding number of images shall be recorded.

D.3.3.3.3.2 Test targets for optical fingerprint scanner working on the principle of frustrated total internal reflection in the dark field

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

When determining the CTF, the laboratory shall consider that the target has a certain frequency response (mainly caused by the manufacturing process). Thus the CTF of all used targets shall be investigated by a microscope before using them for this test.

If the target covers at least 25 % of the recording surface of the fingerprint scanner, it shall be placed only once in the centre of the recording surface. Otherwise it shall be placed twice on the recording surface, left and right of the centre. Thus, the corresponding number of images shall be recorded.

D.3.3.3.4 Test procedure

D.3.3.3.4.1 Test step 1

The targets shall be placed on the recording surface (see D.3.2.4). The alignment of the targets with respect to the pixel rows of the image shall be better than 0,5 inch. From each target two images shall be recorded, one with the stripes aligned in vertical direction, a second with the stripes aligned in horizontal direction.

D.3.3.3.4.2 Test step 2

Adjacent within the recorded images the coordinates of the edges of a rectangular surrounding all gratings are determined. With these coordinates, the file size and the dimension of the test targets, the CTF of all single test gratings will be calculated.

D.3.3.3.4.3 Test step 3

The determined CTF values shall be corrected by using the real/measured modulation of the target (see D.3.2.4). In addition, the target modulation realizes no perfect “black” and “white”. Thus, the modulation shall be corrected by using the “black” and “white” values determined from the large structures as mentioned in D.3.3.1.2; all CTF values have to be divided by this modulation.

D.3.3.3.5 Requirement compliance

The values listed in D.3.3.3.1 shall be completely met. The CTF values for horizontal and vertical direction shall correspond to these values. The acquired images are not allowed to show significant aliasing effects.

D.3.3.4 Investigation of the signal-to-noise ratio and the grey–level uniformity

D.3.3.4.1 Requirements

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

The grey-level uniformity is defined for the three following cases:

— Adjacent row, column uniformity: At least 99 % of the average grey-levels between every two adjacent quarter-inch long rows and 99 % between every two adjacent quarter-inch long columns, within each imaged area, shall not differ by more than 1,0 grey-levels when scanning a uniform low reflectance target, and shall not differ by more than 2,0 grey-levels when scanning a uniform high reflectance target.

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

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

D.3.3.4.2 Background

The signal is defined as the difference between the average output grey-levels obtained from scans of a uniform low reflectance and a uniform high reflectance target, measuring the average values for independent 0,25 inch * 0,25 inch areas within each scanned area. The noise is defined as the standard deviation of the grey-levels in each measurement area. Therefore, for each high reflectance, low reflectance image pair, there are two SNR values, one using the high reflectance standard deviation and one using the low reflectance standard deviation. The scanner shall be set up such that the average image grey-level of the high reflectance target is below 255 or high clipping level, whichever is lower, and the average image grey-level of the low reflectance target is above 0 or low clipping level, whichever is higher. Note that in this method of measuring SNR, no attempt is made to isolate different sources of noise or separately measure different types of noise; the computed noise represents all noise types and sources taken together. The grey-level uniformity is calculated from the same images as described in D.3.3.4.1.

D.3.3.4.3 Used targets

D.3.3.4.3.1 Test targets for optical fingerprint scanner working on the principle of frustrated total internal reflection in the bright field

For the measurements of the signal-to-noise ratio and the grey-level uniformity the utilization of high reflecting targets, which are applied on the recording surface of the scanner, is precluded. For this test homogenous absorbing targets with a constant optical density shall be placed in the beam path of the scanner. The resulting image shall be an equable bright or dark image, whose average grey value shall be four grey values above the minimum grey value of the scanner or respectively four grey values below the maximum grey value of the scanner. If the targets are placed within the optical beam path of the scanner, they shall be realized as thin filters to avoid a beam displacement which would lead to inhomogeneity and enhanced noise.

D.3.3.4.3.2 Test targets for optical fingerprint scanner working on the principle of frustrated total internal reflection in the dark field

The target shall consist of diffuse bright and dark reflecting material. The targets shall be homogeneous to fulfil together with the scanner the listed requirements. For the test, e.g. the Munsell test, normal recommendations are: N3 (dark, 7 % reflection), N9 (bright, 79 % reflection). When using the target its substrate can be wetted by the used immersion liquid. Its optical properties are normally not influenced by this, but the test can only be performed once with one target and shall be performed as fast as possible.

D.3.3.4.4 Test procedure

D.3.3.4.4.1 Test step 1

For optical fingerprint scanners working on the principle of disturbed total reflection in the bright field: The filters shall be inserted in the optical beam path of the scanner (opened housing of the scanner) or the exposure time of the scanner shall be accordingly adjusted. For each filter inserted in the beam path or each setting of the exposure time an image of the free image capture area shall be recorded, resulting at least in one bright and one dark image.

For optical fingerprint scanners working on the principle of disturbed total reflection in the dark field: The targets shall be placed with immersion liquid as interface medium on the recording surface. From each of the two targets one image shall be recorded, resulting in one bright and one dark image.

D.3.3.4.4.2 Test step 2

For determining the SNR the acquired pictures is divided into test fields of the size 0,25 inch * 0,25 inch and the mean grey value, the number of false pixels, and the standard deviation of the grey values of all rows and columns of this test field are determined. With these values the SNR and the grey-level uniformity are calculated. The SNR will be calculated for all test fields distributed all over the image. For each pixel the difference to the average grey value of the test field will be calculated. To determine the SNR in the bright and the dark field the quotient of these values with the standard deviation of the grey values of each test field in the bright and the dark field are calculated.

For determining the grey-level uniformity the acquired pictures are again divided into test fields of the size 0,25 inch * 0,25 inch and the mean grey value, the number of false pixels, and the standard deviation of the grey values of all rows and columns of this test field are determined.

D.3.3.4.5 Requirement compliance

The values listed D.3.3.4.1 have to be completely fulfilled.

D.3.3.5 Investigation of the grey scale range of finger images

D.3.3.5.1 Requirements

A fingerprint scanner operating at 500 ppi or 1000 ppi, shall perform the following sets of live scans:

For a standard roll and plain finger live scanner: capture a complete set of fingerprints from each of 10 subjects; i.e., 10 rolls (all 5 fingers from each hand), 2 plain thumb impressions, and 2 plain 4-finger impressions.

For a palm scanner component of a live scan system: capture left and right palms from each of 10 subjects.

For an identification flats live scanner: capture left and right 4-finger plain impressions and dual thumb plain impressions from each of 10 subjects.

Within the histogram of each image all grey values with at least 5 Pixels in this image are counted. The histogram shall show no break and no other artefact. At least 80 % of the captured individual finger images shall have a greyscale dynamic range of at least 200 grey-levels, and at least 99 % shall have a dynamic range of at least 128 grey-levels.

D.3.3.5.2 Background

This test shows the scanner performance in normal operation mode.

D.3.3.5.3 Used targets

No targets are used in this test case.

D.3.3.5.4 Test procedure

D.3.3.5.4.1 Test step 1

The test persons shall place their finger one after another on the image capture area of the fingerprint scanner. From each finger a single image is recorded. If the scanner can record four finger images, such an image of each hand is recorded.

D.3.3.5.4.2 Test step 2

The histograms of all images are evaluated according to the previously listed requirements.

D.3.3.5.5 Requirement compliance

The values listed in D.3.3.5.1 shall be completely met.

Annex E
(informative)

Conditions for capturing fingerprint image data

E.1 Purpose

This annex recommends techniques designed to enable the best possible fingerprint images to be captured from a scanner. It is intended for users of fingerprint image capture systems, as well as fingerprint image capturing system designers and biometric authentication system designers. Descriptions in the document are targeted at the capture of high-quality plain fingerprint images, but do not mandate anything about fingerprinting methods. Rolled finger impressions, such as those taken for law enforcement applications, are not the focus of this annex, as the capture of such prints is generally supervised by a trained operator to ensure correct placement and pressure. The term “confirmation” used in this document means making a final acceptance/rejection decision according to a visual inspection of a captured image. Specific decision criteria are not defined here, but some guidelines to make decisions are provided. System designers and system providers are recommended to adopt these guidelines as needed. Procedures to be executed when fingerprints image cannot be captured are beyond the scope of this document as are the techniques for the compression and encoding of captured images.

E.2 Recommendations for 2D contact fingerprint image capture devices

E.2.1 Image quality specifications

It is recommended to use fingerprint image capture devices that meet one or more of the certification specifications found in Table 4. Capture devices need to be re-calibrated periodically. The method by which this is done is device specific and beyond the scope of this document. The frequency with which a device should be re-calibrated depends on both the vendor/device and the application for which it is being used and will normally be defined as part of the standard operating procedures for the system.

E.2.2 Recommended finger positioning

Consistent finger positioning on the sensor surface makes it possible to acquire a larger effective image area from the same part of a finger every time. In other words, overlapped areas between images to be compared become larger, which is expected to improve the accuracy of verification.

The core of a fingerprint is defined as the topmost point on the innermost recurving ridgeline of a fingerprint. If the core is located at the centre of the captured image it will generally result in a larger overlapping area for verification purposes (see Figure E.1). For this purpose, it may be beneficial to employ a display monitor where the finger positioning can be checked, or to use devices with a function that automatically detects the finger position and provides appropriate feedback to the user. This will also prevent a device from capturing only a side of a fingertip.

Note that for some types of pattern classes the core is not located at the centre of the finger. In such cases, it may not be practical to use the core alignment method described above.

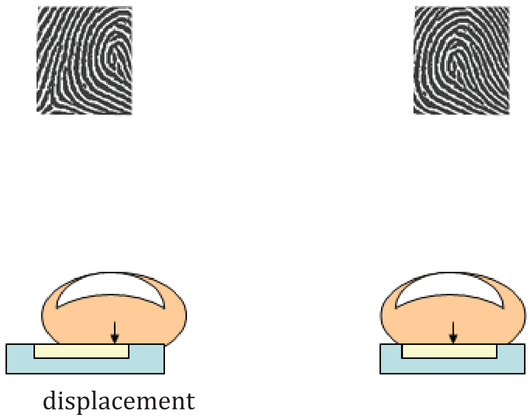

Figure E.1 — Centred finger

If directions of fingertips on the sensor surface are always the same, the overlapping area between two verification images will be consistent (see Figure E.2).

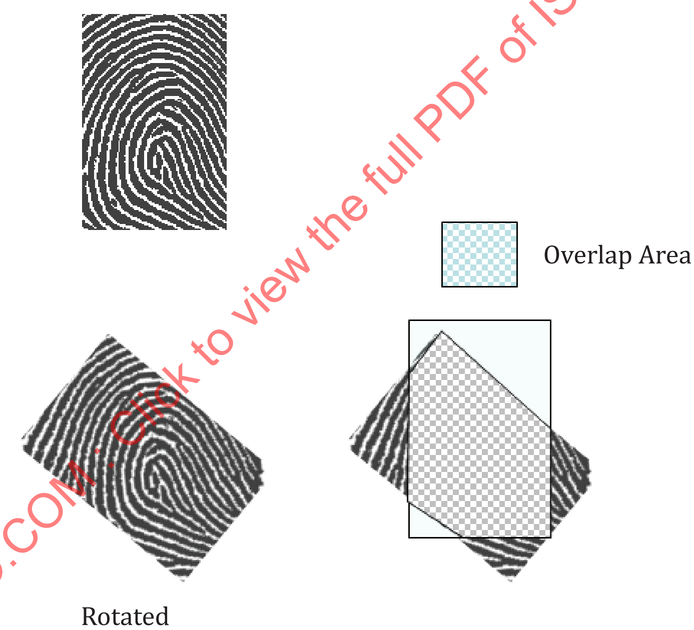

Figure E.2 — Rotation and its overlap area

Guidance (either visual or audible) for placing the finger in the same orientation each time should be provided, or the physical design of the device should be such as to encourage correct placement (see Figure E.3).

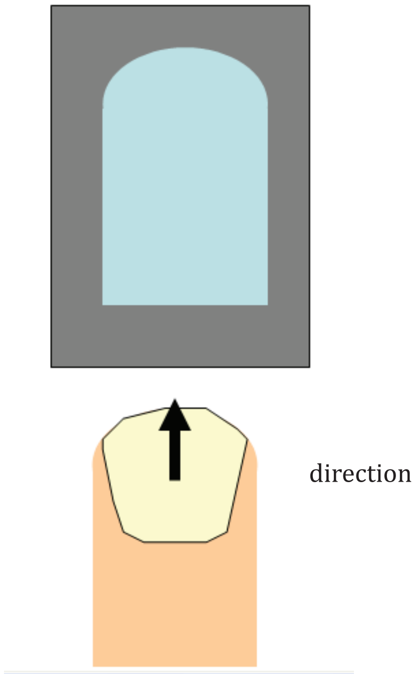

Figure E.3 — Fingertip direction

If a finger is placed at an angle to the sensor rather than placed flat on it, the side of the fingerprint will be captured and in general the utility of the sample will be reduced (see Figure E.4).

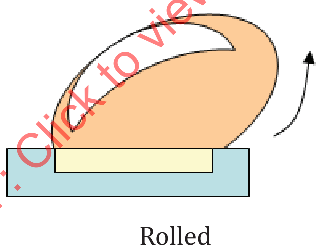

Figure E.4 — Angled finger

Decreasing such rolling motion is also necessary to improve the accuracy. Note that simultaneous capture of multiple fingers has an advantage of reducing the rolling motion (see Figure E.5).

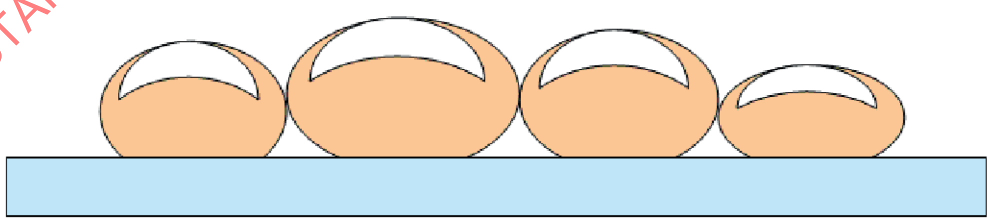

Figure E.5 — Multiple-finger slap

Automatic core-detection performance more or less depends on detection algorithm performance. On the other hand, while user cooperation will be required, slap fingerprints (simultaneous capture of four fingers) and the first joint position control may enable significant improvement once the users become familiar with the method.

E.2.3 Illumination, lighting, and activation

Optical fingerprint sensors illuminate the finger when capturing it. However, ambient light may adversely affect the capture. For example a ceiling light may enter the sensor. This can be alleviated by providing a roof or other means to block the ambient light or using light with a wavelength range different from that of the ambient light. In the case where visible light is used to illuminate the sensor, turning this light on can be used as a cue to commence the capture process.

E.2.4 Cleanness of platen and latent prints

Before image capture device calibration, the capture platen shall be free of residual fingerprints. It is preferable to check whether any residual fingerprint may affect the subsequent capture. Excessive build-up of dirt or residual fingerprints on the platen can adversely affect the quality of the captured image. The sensor should be cleaned in accordance with manufacturer's guidelines and agreed standard operating procedures for the application.

E.2.5 Moisturizing

Quality of a captured image may be degraded when the finger skin is very dry. If dry skin is thought to be resulting in low image quality for an individual, it may help to moisturise the finger, for example, by breathing on it, touching a sweaty part of the skin, wiping it with a wet paper, or applying gel or cream to it.

Note that if the finger is over-moisturized, the moisture may be captured on an image or leave a mark on the sensor surface. In that case, the sensor surface shall be dried by wiping off the moisture or by other means.

E.2.6 Drying

When a finger is very moist, it shall be wiped with a dry paper or air-dried. If excessively moist skin is thought to be resulting in low image quality for an individual, it may help to dry the finger.

E.2.7 Missing

There may be some cases where a fingerprint cannot be captured due to a missing finger or some other reasons. Appropriate policies need to be in place for handling such cases, depending on whether the situation is temporary (broken bone, injury, etc.) or permanent (amputation, physically-challenged, etc.).

E.2.8 Finger selection and order of capture

It is preferable to provide screen display and/or audio guidance to provide instructions on finger selection and order, whether to capture the left hand only, right hand only, or both, and in the case of both hands, which hand to capture first. When more than one finger is to be captured, or a choice of finger is supported, the target finger(s) should be clearly indicated to the user, for example, via diagrams or illustrations.

Alternative input rules shall be determined in advance in case there are fingers that cannot be captured. When the index finger is unavailable, for example, a rule of using the middle finger, thumb, or ring finger as an alternative, and the selection order of the alternative fingers should be determined. When capturing multiple fingers, switched fingers can be confirmed by using the verification function among each finger.

E.2.9 Assessing fingerprint image quality

Performance of any biometric system is highly dependent on the quality of data captured by the sensor.

Many fingerprint capture devices now include automated image quality assessment software to provide feedback to users, often in real time. Algorithms related to fingerprint image quality are described in ISO/IEC 29794-4[14] and serve as a reference implementation for quality value calculations adopted by device providers.

Another method is to capture several images from one finger and perform a cross-comparison between them to see if the comparison scores obtained are above the threshold that has been set for the system. If they are, then the quality is sufficient for the intended application.

An extension of this approach is to plot the scores from all of the cross-comparisons (see Figure E.6); the image with the highest average score is assumed to have the highest image quality.

A benefit of assessing image quality at enrolment is that it can highlight problems where the subject's fingerprint characteristics are not of adequate quality for the intended application, thereby enabling appropriate countermeasures to be put in place (e.g., use a different finger, postpone the enrolment or consider using a different modality).

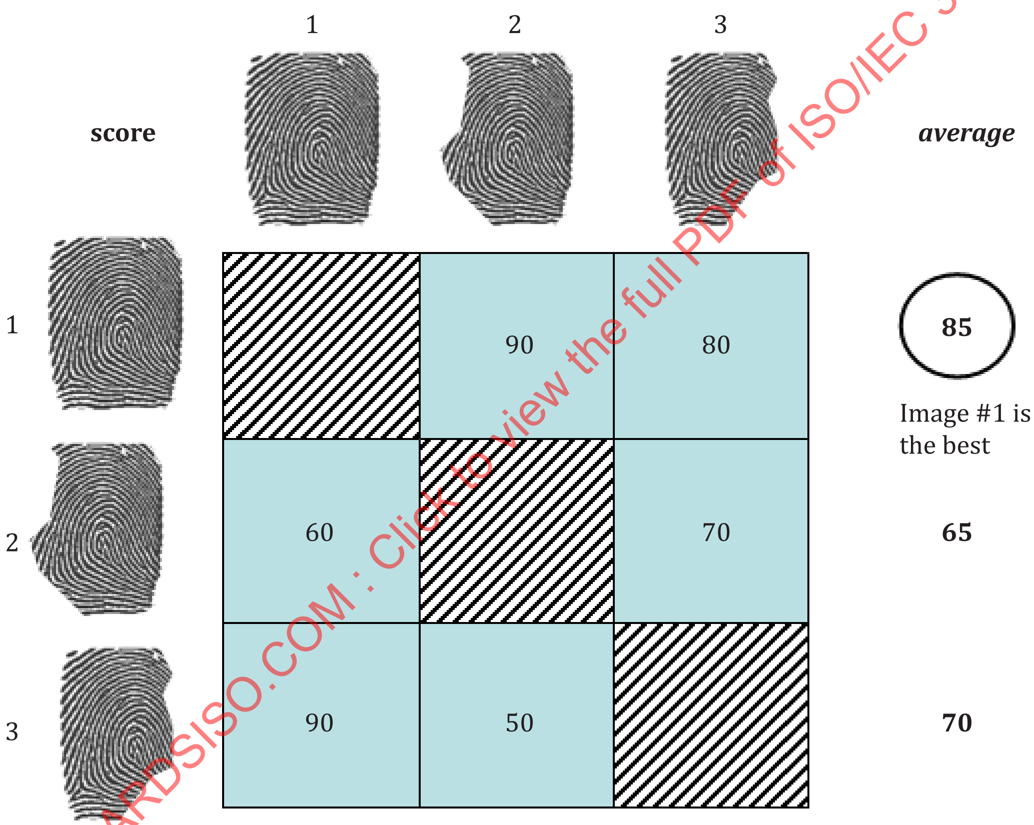

Figure E.6 — Selecting best image by using comparison trial average score

E.2.10 Existing data treatment

If an image of the finger was captured in the past, identification of the finger is possible by performing a comparison process. It may also be possible to find out that an image of a finger believed to not have been captured in the past is registered with a different ID.

E.2.11 Image capture factors

Height from the floor or the desktop to the scanner surface, as well as the angle of the scanner surface to the floor or the desktop, affects the quality of captured images. Other factors that affect quality are the number of fingers to be captured simultaneously (1, 2, 4, etc.) and whether both right and left hands are captured simultaneously or not.

Where enrolment is undertaken at multiple locations, it is highly desirable that comparable devices are used, not only in terms of image quality criteria (i.e. device certification such as D.1, D.2, and D.3), but also platen size and capture processes. Controlling environmental variables such as the height and angle of the capture device will also help to ensure consistent capture quality.

Consideration shall also be given to the capture of fingerprints from those who are especially tall or short, as well as those with certain medical conditions or disabilities. The use of a portable or handheld sensor may make it easier to capture good quality fingerprint images from such subjects.

Positional relation between the sensor surface and the body also affects the quality of captured images. Usually, people tend to extend their hands with the thumb side up and the little finger side down. For this reason, a finger will be rolled (with the finger bone as an axis) when placing the finger on the sensor horizontal surface. This is not such an issue when capturing four fingers simultaneously, but when selecting the location for the capture device proper consideration should be given to these and other usability factors.

E.2.12 Operation

In some applications, and especially those where there is no operator supervision, the provision of clear instructions to users, perhaps by means of a monitor display or audio guidance, is desirable. Such guidance messages may include the following:

— Capture should start automatically.

— If a device rejects a captured image and requires another capture, recapturing process should be specifically notified to the user.

— If the capture does not succeed even after a defined number of attempts, the device should indicate that the user needs to take other measures.

E.2.13 Example configurations

E.2.13.1 One finger in a standing position

Image capture of one finger in a standing position is illustrated in Figure E.7.

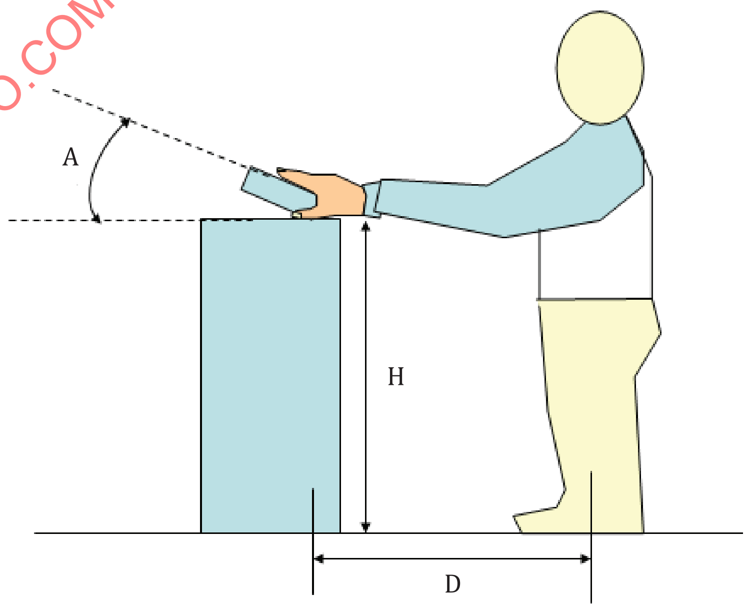

Figure E.7 — Standing position

Parameters such as height from the floor(H), angle(A), relative position between the body and the device(D), and other necessary item should be described in the design specification.

E.2.13.2 Four fingers in a sitting position

Image capture of four fingers in a sitting position is illustrated in Figure E.8. Same as in the case of one finger.

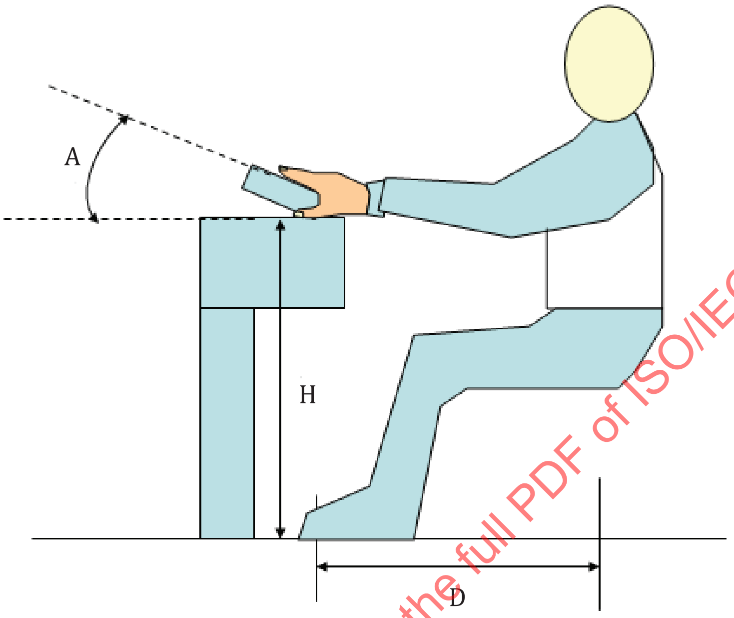

Figure E.8 — Sitting position

E.2.14 Indications to biometric operational personnel

More than one decision threshold is applied to comparison scores in some systems, for example, in those which return a decision of “unknown” in addition to “comparison” and “non-comparison”. When a comparison score is not sufficient due to image quality, it may be possible to reduce doubt about the verification result by presenting the quality value of the captured image to the operator if present.

E.2.15 Confirmation

The following may become possible by operators of the capturing system making a final decision when the automatic judgment is not sufficient:

— to check if the user correctly understands the capture procedure, or

— to visually check images based on highly-detailed information other than minutiae, for example whether the effective area is small or not.

E.3 Guidelines for image data

E.3.1 Image quality metrics

Algorithms related to fingerprint image quality described in ISO/IEC 29794-4[14] serve as references for quality value calculation algorithms that are adopted in system specifications by providers.

There have been attempts to detect the centre of the pattern of a fingerprint image area. System providers can consider introducing this function to the system specifications.

There have been attempts to calculate image quality using the reliability of minutiae detection. System providers can consider introducing this function to the system specifications.

E.3.2 Human interface (displaying capturing/captured image)

When capture subjects are cooperative, it may be better to make the captured images visible to them. When there is a concern about fingerprint image being peeped from a security perspective, presentation of a captured image may be avoided. In this case, an illustration can be presented instead.

E.3.3 Pre-processing

Some devices are provided with a function to capture higher-quality images by automatically altering sensor parameters to deal with fingerprint characteristic changes due to aging or to adapt to more variations of skin conditions. However, the capture process may take longer in order to implement parameter changes. Raw data captured by a sensor may be processed and enhanced to improve visualization. However, detailed greyscale information can be lost due to the enhancement.

E.4 Fingerprint image capture software

Capture software is expected to have the following features:

— indication of the start of capture which is that time that begins at the point when the subject places their hand on the platen;

— instruction of the capture sequence;

— selection of high-quality images according to automatic quality judgment;

— retry instruction after failed capture;

— software for automatic quality judgment function (vendors, product names, versions, etc.) should be specified;

— software for feature extraction should be specified;

— software for verification should be specified;

— comparison for trial at a registration function; and

— selection of best quality image using a trial comparison function.

E.5 Law enforcement finger size recommendations

Table E.1 provides guidance and recommendations for the capture size of single fingers and the combination of the index, middle, ring and little fingers from each hand. The values shown are aimed at the law enforcement application.

Table E.1 — Guidance for finger sizes

Finger position	Finger code	Max image area (cm^2)	Width		Length	
			(mm)	(in)	(mm)	(in)
Unknown	0	15,47	40,6	1,6	38,1	1,5
Right thumb	1	15,47	40,6	1,6	38,1	1,5
Right index finger	2	15,47	40,6	1,6	38,1	1,5
Right middle finger	3	15,47	40,6	1,6	38,1	1,5
Right ring finger	4	15,47	40,6	1,6	38,1	1,5
Right little finger	5	15,47	40,6	1,6	38,1	1,5

Table E.1 *(continued)*

Finger position	Finger code	Max image area (cm^2)	Width		Length	
			(mm)	(in)	(mm)	(in)
Left thumb	6	15,47	40,6	1,6	38,1	1,5
Left index finger	7	15,47	40,6	1,6	38,1	1,5
Left middle finger	8	15,47	40,6	1,6	38,1	1,5
Left ring finger	9	15,47	40,6	1,6	38,1	1,5
Left little finger	10	15,47	40,6	1,6	38,1	1,5
Plain right four fingers	13	61,95	81,3	3,2	76,2	3,0
Plain left four fingers	14	61,95	81,3	3,2	76,2	3,0
Plain thumbs (2)	15	61,95	81,3	3,2	76,2	3,0

E.6 Possible references

It is recommended to check reference literatures for the following issues:

— recommended selection of fingers and order based on statistical experimental results;

— minimum image size for good comparison performance; and

— significance of statistical logging and checking quality values (to be used for consideration of revising capture sequence, standards, software, threshold and others).

Annex F
(normative)

WSQ greyscale finger image compression specification

F.1 Requirements and guidelines

F.1.1 General

Annex F is applicable to continuous-tone greyscale digital finger images. Annex F:

— specifies a class of encoders for converting source finger image data to compressed image data;

— specifies a decoder process for converting compressed image data to reconstructed finger image data;

— specifies coded representations for compressed image data.

F.1.2 General

F.1.2.1 Wavelet scalar quantization (WSQ) compression

The WSQ class of encoders involves a decomposition of the finger image into a number of subbands, each of which represents information in a particular frequency band. The subband decomposition is achieved by a *discrete wavelet transformation* (DWT) of the finger image.

Each of the subbands is then *quantized* using values from a *quantization table*. No default values for quantization tables are given in Annex F.

The quantized coefficients are then passed to a *Huffman encoding* procedure which compresses the data. *Huffman table* specifications shall be provided to the encoder.

Figure F.1 shows the main procedures for WSQ encoding and decoding. The same tables specified for an encoder to use to compress a particular image shall be provided to a decoder to reconstruct that image.

F.1.2.2 Structure of compressed data

Compressed image data is described by a uniform structure and a set of parameters. The various parts of the compressed image data are identified by special two-byte codes called *markers*. Some markers are followed by particular sequences of parameters such as table specifications and headers. Others are used without parameters for functions such as marking the start-of-image and end-of-image. When a marker is associated with a particular sequence of parameters, the marker and its parameters comprise a *marker segment*.

The data created by the *entropy encoder* are also segmented, and one particular marker – the *restart marker* – is used to isolate *entropy-coded data segments*. The encoder outputs the restart markers, intermixed with the entropy-coded data, between certain subband boundaries. Restart markers can be identified without having to decode the compressed data to find them. Because they can be independently decoded, entropy-coded data segments provide for progressive transmission, and isolation of data corruption.

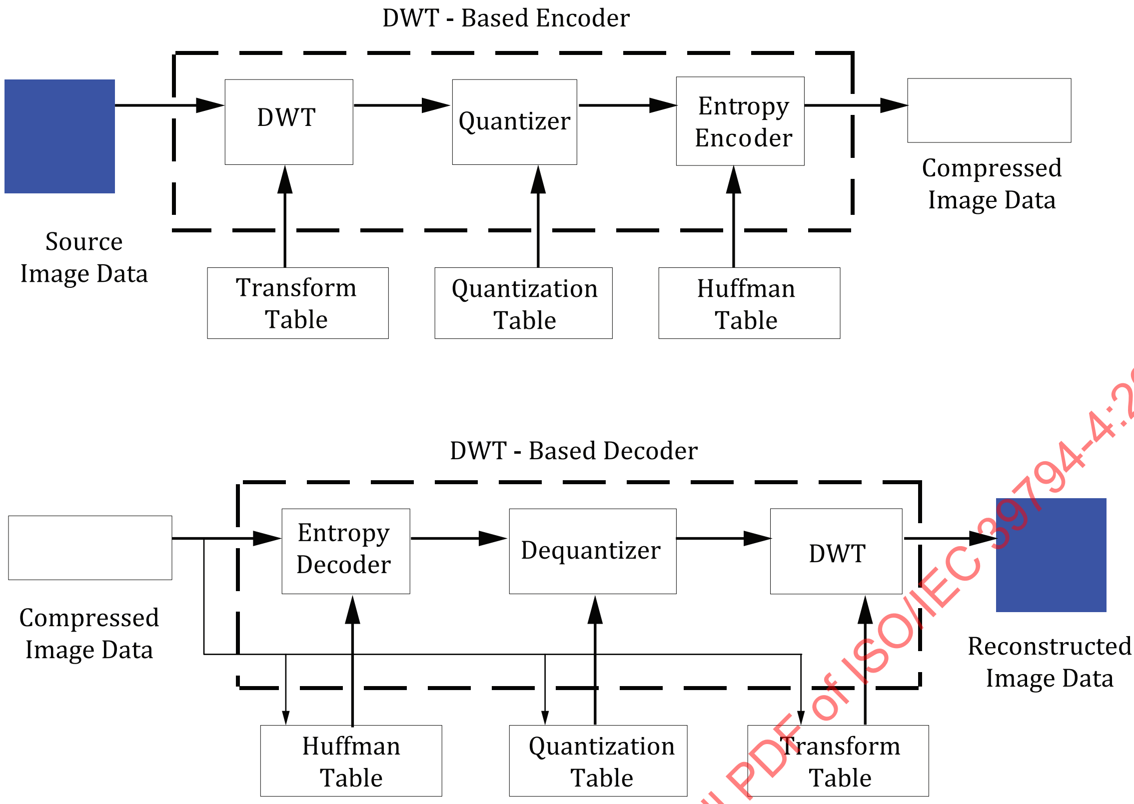

Figure F.1 — DWT-based encoder and decoder simplified diagram

F.1.2.3 Interchange format

In addition to certain required marker segments and the entropy-coded segments, the interchange format shall include the marker segments for all filter coefficient, quantization, and entropy-coding tables needed by the decoding process. This guarantees that a compressed image can cross the boundary between identification systems, regardless of how each environment internally associates tables with compressed image data.

F.1.2.4 Abbreviated format for compressed image data

The abbreviated format for compressed image data is identical to the interchange format, except that it does not include all tables required for decoding (it may include some of them). This format is intended for use within applications where alternative mechanisms are available for supplying some or all of the table-specification data needed for decoding.

F.1.2.5 Abbreviated format for table-specification data

This format contains only table-specification data. It is a means by which the application may install in the decoder the tables required to subsequently reconstruct one or more finger images.

F.1.3 Requirements

F.1.3.1 Interchange format requirements

The interchange format is the coded representation of compressed image data for exchange between application environments.

The interchange format requirements are that any compressed image data represented in interchange format shall comply with the syntax and codes assignments for the decoding process, as specified in F.3.

F.1.3.2 Encoder requirements

An encoder process converts source finger images to compressed image data. An encoder is an embodiment of the encoding process specified in F.2. To comply with Annex F, an encoder shall satisfy at least one of the following two requirements:

— convert source finger image data to compressed image data which complies with the interchange format syntax specified in F.3 with proper accuracy, and

— convert source finger image data to compressed image data which complies with the abbreviated format syntax for compressed image data specified in F.3 with proper accuracy.

F.1.3.3 Decoder requirements

A decoding process converts compressed image data to reconstructed image data. A decoder is an embodiment of the decoding process specified in F.2. To comply with Annex F, a decoder shall satisfy all three of the following requirements:

— convert to reconstructed finger image data any compressed image data with parameters that comply with the interchange format syntax specified in F.3 with proper accuracy;

— accept and properly store any table-specification data which complies with the abbreviated format syntax for table-specification data specified in F.3; and

— convert to reconstructed fingerprint data any compressed image data which complies with the abbreviated format syntax for compressed image data specified in F.3 with proper accuracy, provided that the table-specification data required for decoding the compressed image data has previously been installed into the decoder.

F.2 Mathematical definitions

F.2.1 Source finger image

Source finger images shall be captured with 8 bits of precision per pixel. Before the encoding process computes the discrete wavelet transform (DWT) for the image, the samples, $I(m,n)$, shall be transformed into $I'(m,n)$ as follows:

$$I'(m,n)=\frac{[I(m,n)-M]}{R} \qquad \begin{array}{l} 0 \le m \le Y-1 \\ 0 \le n \le X-1 \end{array}$$

The image width (X) and height (Y) parameters are defined in F.3.2.2. The decoding process shall apply an inverse transformation to restore the samples to their original scale. The midpoint and rescale parameters, M and R, are specified by the encoder and transmitted in the compressed image data.

F.2.2 Subband coding of finger images

F.2.2.1 Two-channel subband coder (in one dimension)

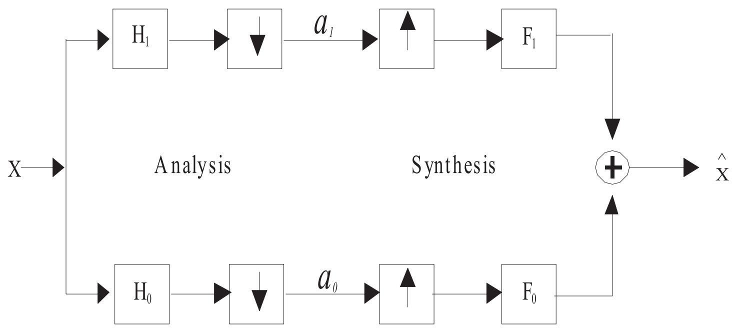

Figure F.2 — Two-channel subband coder

A two-channel subband encoder is a digital filter bank of the type shown in Figure F.2. It should be regarded as a pair of systems, the analysis bank and the synthesis bank. The subband coder provides zero distortion, $\hat{x}(n)=x(n)$.

The boxes H_i and F_i denote linear time-invariant digital filters[10], while ↓ and ↑ denote 2:1 down- and up-sampling operations:

$$(x*h)(k)=\sum_n x(n)h(k-n),$$

$$(\downarrow y)(k)=y(2k),$$

$$(\uparrow a)(k)=\begin{cases} a(k/2), & k \text{ even} \\ 0, & k \text{ odd} \end{cases}$$

The transform defined by the analysis bank, $x\rightarrow\{a_0,a_1\}$ will be referred to as a one-dimensional DWT, and the transform given by the synthesis bank as the inverse DWT.

F.2.2.2 Linear phase wavelet filters

This document utilizes two distinct classes of linear phase finite impulse response (FIR) filters. h_0 denotes the lowpass filter and h_1 the highpass filter in a filter bank. The first class will contain pairs of odd-length, symmetric filters (i.e., filters whose impulse responses are symmetric about their middle sample). These are called "Type I" linear phase FIR filters[10], or whole-sample symmetric (WSS) filters. The second class will contain pairs of even-length filters, one symmetric (the lowpass filter) and one antisymmetric (the highpass filter). These are called, respectively, "Type II" and "Type IV" filters[10]; since such filters are symmetric about the point halfway between their middle two samples, they are also referred to as half-sample symmetric/antisymmetric (HSS/HSA or HS-type) filters.

The compressed data format described in F.3 provides only for the transmission of impulse response coefficients from the right halves of the analysis filters; the synthesis filters are completely determined by the following anti-aliasing relations:

$f_0(n) = (-1)^n h_1(n-1)$ and

$f_1(n) = (-1)^{n-1} h_0(n-1)$.

For a WSS analysis bank, the lowpass filter, h_0, shall be symmetric about 0, i.e., h_0 runs from $h_0(-r_0)$ to $h_0(r_0)$. Using the syntax of Clause F.3.2.4.1, the length of h_0 is L0 = 2 r_0 + l. The transform table specified in Clause F.3.2.4.1 contains the impulse response coefficients from the right half of h_0:

$H0_1 = h_0(0), H0_2 = h_0(1), \ldots, H0_{last} = h_0(t_0)$

The left half of h_0 is given by the symmetry relation $h_0(-n) = h_0(n)$. The highpass filter, h_1, in a WSS analysis bank shall be symmetric about −1. The transmitted coefficients are:

$H1_1 = h_1(-1), H1_2 = h_1(0), \ldots, H1_{last} = h_1(r_1 - 1)$,

where L1 = $2r_1 + 1$; the left half of h_1 is given by the symmetry relation $h_1(-1-n) = h_1(n-1)$.

For an HS-type analysis bank, both filters shall be centered at −1/2, and thus run from $h_i(-r_i)$ to $h_i(r_i-1)$, where the length of h_i is Li = $2r_i$. The transmitted values are: (i = 0,1):

$Hi_1 = h_i(0), Hi_2 = h_i(1), \ldots, Hi_{last} = h_i(r_i - 1)$.

The lowpass filter, h_0, is symmetric (HSS), so the left half of h_0 is given by the symmetry relation $h_0(-l-n) = h_0(n)$. The highpass filter, h_1, is antisymmetric (HSA), so the left half of h_1 is given by the symmetry relation $h_1(-1-n) = -h_1(n)$.

F.2.2.3 Constraints on filter length

Encoders and decoders shall be capable of forming (or inverting) the subband decomposition specified in Figure F.6 using filters of lengths up to and including the maximum values:

L_{max} = 31 for WS-type filters,

L_{max} = 32 for HS-type filters.

F.2.2.4 Symmetric boundary conditions for the DWT

The generic input, $x(n)$, to Figure F.2 will, in practice, be a row or column vector from an image or from one of its DWT subbands. To describe precisely how a finite-length signal is transformed by the system depicted in Figure F.2, the following conventions are used for indexing and extrapolating x. All WSQ decoders shall be capable of decoding a compressed signal encoded in accordance with these conventions. x is assumed to run from $x(0)$ to $x(N_0-1)$, where N_0 is the (generic) length of x.

For transformation by WSS filters, x is extended to a whole-sample symmetric signal, $y = E_s^{(1,1)}x$, of length $N = 2N_0 - 2$, and periodized. For HS-type filters, x is extended to a half-sample symmetric signal, $y = E_s^{(2,2)}x$, of length $N = 2N_0$, and periodized. In each case, the filters are extended with zeros to length N and applied by N-periodic circular convolution; see Figure F.3.

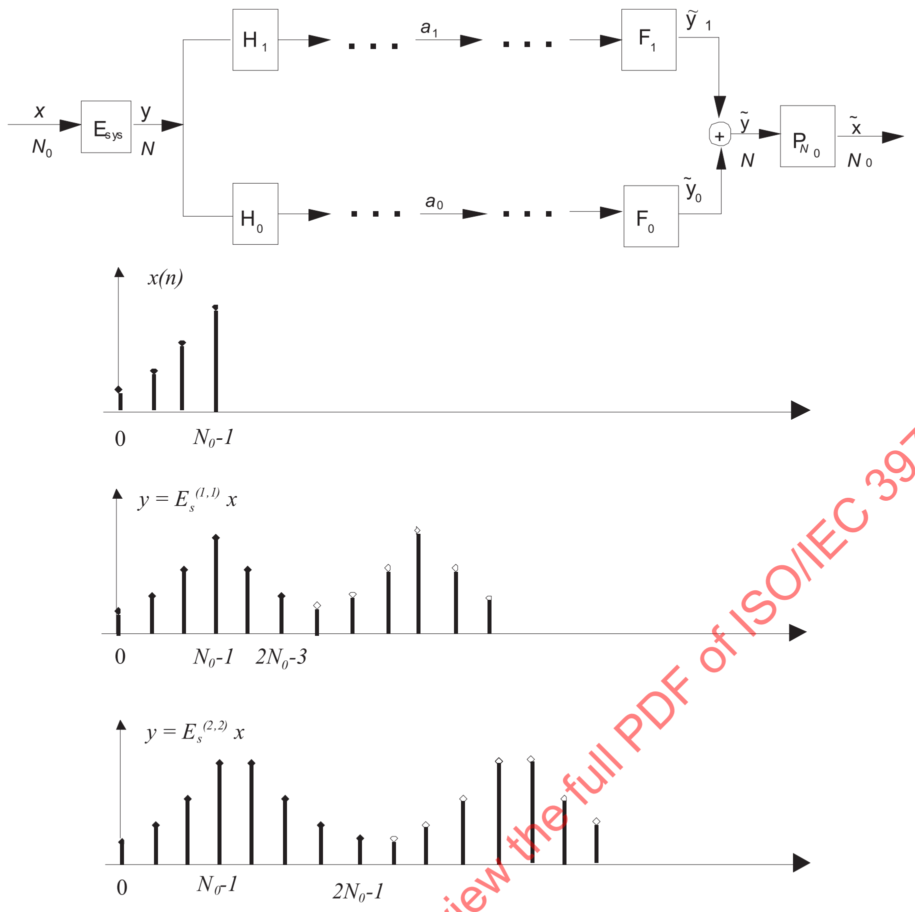

Figure F.3 — Symmetric DWT extension

With the choices of filter and signal symmetries described above, this system generates symmetric DWT subbands, of which only the first half (now denoted a_i) needs to be computed and stored. For instance, with WSS filters and N_0 even, the coefficients

$$a_i(k) = \sum_{n=0}^{N-1} y(n) h_i(2k-n)$$

only need to be computed and stored for $k = 0, \ldots, N_0/2 - 1$, even though

$$b_i = \downarrow(y * h_i)$$

has period $N/2 = N_0 - 1$. This is possible because b_i is itself symmetric and can be reconstructed from the first $N_0/2$ values, $a_i(k)$.

The sequences a_i generated in this fashion can in turn be extended to whole- or half-sample symmetric signals and cascaded back through the analysis bank, Figure F.3, to achieve a multiband decomposition of the input. The composition of mappings

$$x \xrightarrow{E_{sys}} y \xrightarrow{DWT} \{a_0, a_1\}$$

will be referred to as a one-dimensional symmetric wavelet transform (SWT)[7]. Note that, in spite of the extension of the input signal, x, the SWT still maps an input of length N_0 to a pair of subbands $\{a_0, a_1\}$ containing a total of just N_0 values. When N_0 is odd, a_0 will have length $(N_0 + 1)/2$, and a_1 will have length $(N_0 - 1)/2$ for both WSS and HS-type extensions.

F.2.2.5 Symmetric subband synthesis

This subclause describes the symmetry properties of the subbands $b_i = \downarrow(y*h_i)$, giving the number of non-redundant samples that need to be transmitted,

$$a_i(k)=b_i(k);\qquad 0\le k\le \rho_i-1$$

and specifies the procedures for extending the quantized transmitted coefficients in the decoding process:

$$\hat{b}_i = E_i\hat{a}_i;\qquad \hat{y}_i = f_i*(\uparrow \hat{b}_i)$$

If an N-periodic signal is symmetric about n=0 then it is also necessarily symmetric about $n = N/2$; in relation to $y = E_s^{(1,1)}x$ in Figure F.3 for $N = 2N_0-2$. When N is even, such signals are called "(1,1)-symmetric" since they are whole-sample symmetric about both centres. Similarly, an N-periodic signal symmetric about −1/2 is also necessarily symmetric about $(N-1)/2$; in relation to $y = E_s^{(2,2)}x$ in Figure F.3 for $N = 2N_0$. When N is even, such signals are called "(2,2)-symmetric" since they are half-sample symmetric about both centres. When N is odd, signals that are WSS about one centre and HSS about the other are given; such signals are called "(1,2)-symmetric" if they are WSS about 0, and "(2,1)-symmetric" if they are HSS about −1/2. There are obvious antisymmetric analogues of these symmetry properties.

Given a signal $w(n)$, $0 \le n \le K-1$, let $E_s^{(i,j)}w$ (resp., $E_a^{(i,j)}w$) denote the (i,j)-symmetric (with respect to, (i,j)-antisymmetric) extension of $w(n)$, where i,j = 1 or 2, generalizing the two extensions shown in Figure F.3 for w=x. If a subband $b(k)$ is (i,j)-symmetric and

$$a(k)=b(k);\qquad 0\le k\le \rho-1$$

is a complete, non-redundant half-period of b, then b can be reconstructed from a via the extension $b = E_s^{(i,j)}a$. A similar statement holds for antisymmetric subbands. Since the symmetry of b is completely determined by the symmetry of the extension $y = E_{sys}x$ and the symmetry of the analysis filter, h, it suffices to quantize and transmit only the half-period, a, reconstructing b in the decoder using a known extension operator, E. This method of applying a DWT filter bank to a finite-duration input signal, x, is referred to as the symmetric wavelet transform (SWT) algorithm; a detailed treatment is presented in Reference [7].

Table F.1 lists the symmetry properties of the subbands, b, and their "ranks" ρ, which specifies the number of coefficients, $a(k)$, that need to be transmitted. The table is divided into two cases: one case for WSS filter banks, which use the analysis extension $y = E_s^{(1,1)}x$ (the "(1,1)-SWT"), and a second case for HS-type filter banks, which use the analysis extension $y = E_s^{(2,2)}x$ (the "(2,2)-SWT"). These filter banks are described in F.2.2.2.

Table F.1 — Symmetry, rank of SWT subbands

		Case 1: WSS filters input length, N_0		Case 2: HS-type filters input length, N_0	
		Even	**Odd**	**Even**	**Odd**
Filter	h_0	(1,2) - sym. $\rho_0 = N_0/2$	(1,1) - sym. $\rho_0 = (N_0+1)/2$	(2,2) - sym. $\rho_0 = N_0/2$	(2,1) - sym. $\rho_0 = (N_0+1)/2$
	h_1	(2,1) - sym. $\rho_1 = N_0/2$	(2,2) - sym. $\rho_1 = (N_0-1)/2$	(2,2) - antisym. $\rho_1 = N_0/2$	(2,1) - antisym. $\rho_1 = (N_0-1)/2$

F.2.2.6 Wavelet decomposition in two dimensions

The tree structure for a single level of a 2-dimensional image decomposition system is depicted in Figure F.4. The row vectors of the image are filtered by applying the SWT algorithm described in F.2.2.5. The same procedure is then applied to the column vectors of the resulting array, giving a decomposition