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Information technology — Biometric data interchange formats —

Part 3: Finger pattern spectral data

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

Partie 3: Données spectrales de la forme du doigt

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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. In the field of information technology, ISO and IEC have established a joint technical committee, ISO/IEC JTC 1.

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

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

ISO/IEC 19794-3 was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 37, *Biometrics*.

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

— *Part 1: Framework*

— *Part 2: Finger minutiae data*

— *Part 3: Finger pattern spectral data*

— *Part 4: Finger image data*

— *Part 5: Face image data*

— *Part 6: Iris image data*

— *Part 7: Signature/sign time series data*

— *Part 8: Finger pattern skeletal data*

— *Part 9: Vascular image data*

— *Part 10: Hand geometry silhouette data*

— *Part 11: Signature/sign processed dynamic data*

Introduction

In the interest of implementing interoperable personal biometric recognition systems, this part of ISO/IEC 19794 establishes a data interchange format for finger pattern spectral data. The goal of this part of ISO/IEC 19794 is to allow the exchange of local or global spectral data derived from a fingerprint image without the exchange of the entire image. This will allow more compact data representations.

This part of ISO/IEC 19794 allows for representation of spectral components, such as Discrete Fourier Transform and (single-scale) Gabor Filter components, extracted from global or stationary (not image dependent and not varying over the image) local overlapping or non-overlapping uniform-sized regions of the original intensity (non-color) image. Some or all of the extracted spectral components will be stored in the data format, depending upon the implementation. This part of ISO/IEC 19794 does not accommodate multi-scale (wavelet) decompositions.

There are fingerprint recognition algorithms that use spectral data directly for pattern matching. Spectral data-based recognition algorithms process “globally” local sections (cells) of biometric images, in contrast to morphological-based algorithms, which extract singularities in the morphological features. At the current time, there is no established mechanism for the interchange of finger pattern spectral information for use with spectral-based fingerprint matching algorithms.

By establishing a standard for spectral-based representation of fingerprints, we

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

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

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

— encourage the adoption of biometrics in applications where interoperability is required.

The International Organization for Standardization (ISO) and the International Electrotechnical Commission (IEC) draw attention to the fact that it is claimed that compliance with this document may involve the use of patents concerning the quantized co-sinusoidal triplets method of formatting the pattern spectral data. ISO and IEC take no position concerning the evidence, validity and scope of this patent right. The holder of this patent right has assured the ISO and IEC that he/she is willing to negotiate licenses under reasonable and non-discriminatory terms and conditions with applications throughout the world. In this respect, the statement of the holder of this patent right is registered with ISO and IEC. Information may be obtained from:

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Markham, Ontario, Canada
L3R 8E3

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

Information technology — Biometric data interchange formats —

Part 3: Finger pattern spectral data

1 Scope

This part of ISO/IEC 19794 specifies the interchange format for the exchange of spectral-based fingerprint data.

2 Conformance

A biometric system or algorithm conforms to this part of ISO/IEC 19794 if it satisfies the mandatory requirements for the generation of the finger pattern spectral data as defined in Clause 7 and the generation of the data record as described in Clause 8.

3 Normative references

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

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

ISO/IEC 19785-1:2006, *Information technology — Common Biometric Exchange Formats Framework — Part 1: Data element specification*

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

ANSI/IEEE Std 754-1985, IEEE *Standard for Binary Floating-Point Arithmetic*

4 Terms and definitions

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

4.1
biometric data
biometric sample at any stage of processing, biometric reference, biometric feature or biometric property

NOTE For the purpose of this document, biometric data refers to finger pattern spectral data, quality data, and other data derived from an acquired biometric sample.

4.2
biometric feature
concise representation of information extracted from an acquired or intermediate biometric sample by applying a mathematical transformation

NOTE 1 The use of this term should be consistent with its use by the pattern recognition and mathematics communities.

NOTE 2 For the purpose of this document, biometric features are finger pattern spectral components.

4.3
biometric sample
data obtained from a biometric device, either directly or after processing

4.4
acquired biometric sample
analog or digital representation of biometric characteristics directly taken from an individual by a sensor

NOTE 1 For this document, the sensor will acquire representations of fingerprints.

NOTE 2 An acquired biometric sample will usually retain the full resolution and spatial extent permitted by the sensor.

4.5
intermediate biometric sample
biometric sample that is obtained by modifying an acquired biometric sample to allow better feature extraction, and that is not suitable as yet for automated matching in the biometric system under consideration

EXAMPLE Examples of modifications include cropping, down-sampling, compression, conversion to data interchange formats standard and image enhancement.

NOTE For the purpose of this document, the concept of an intermediate biometric sample relates to finger pattern.

4.6
biometric system
an automated system capable of:

— capturing an acquired biometric sample from an individual;

— optionally extracting biometric features from that acquired biometric sample;

— comparing the biometric features (or acquired biometric sample) with those contained in one or more reference templates or models;

— deciding how well they match; and

— indicating whether or not a recognition has been made.

4.7
bit-depth
the number of bits used to represent a data record parameter

4.8
cell
designated array of pixels within a finger pattern

NOTE Multi-scale cells are not accommodated in this part of ISO/IEC 19794.

4.9
cell structure
an array of pixels, each of which has a greyscale value, defined by a co-sinusoidal pattern with parameters θ, λ, and δ

NOTE This concept applies only to the quantized co-sinusoidal triplet method.

4.10
cell quality group
square array of cells of a finger pattern for which a quality score is specified

4.11
comparison
the process of measuring the similarity or difference between the biometric features of an acquired biometric sample and a previously stored reference template or model

4.12
core
a singular point in the fingerprint where the curvature of the ridges reaches a maximum

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

4.13
crop
remove the outer regions of an image to reduce the size

4.14
delta
that point on a ridge at or nearest to the point of divergence of two typelines, and located at or directly in front of the point of divergence

4.15
dimension
number of pixels in an acquired biometric sample image either x or y direction

4.16
down-sample
reduce the resolution of an image by re-sampling the image with a reduced number of pixels

NOTE Proper filtering is implied to prevent aliasing.

4.17
enrolment
the process of collecting acquired biometric samples from an individual and the subsequent preparation and storage of biometric reference templates or models

4.18
finger pattern
fingerprint image that may be processed (by cropping and/or down-sampling, for example)

NOTE For the purpose of this document, the concept of a finger pattern relates to an intermediate biometric sample.

4.19
finger pattern spectral data
set of spectral components derived from a finger pattern

4.20
minimal spatial wavelength
the (spatial) wavelength (measured in pixels) at which exactly two samples of an image span a complete period of a (co)sinusoidal pattern

NOTE This is therefore the maximal spatial frequency that can be supported by a sampling resolution, and is known as the Nyquist frequency. The minimal spatial wavelength is the inverse of the Nyquist frequency. Be aware the minimum Nyquist frequency is established by the resolution of the down-sampled fingerprint image. The required resolution for any subpopulation should be determined according to the application.

4.21
pad
embed an image in a larger array (usually filled with zeroes) to produce a resulting image of greater dimension

4.22
re-sampling
sample an image at a different frequency from that used to sample the original image

4.23
resolution
number of pixels per unit length

NOTE Pixels per cm (ppcm) will be used in this part of ISO/IEC 19794 as the units of resolution. Note that 1 pixel per cm (ppcm) = 2.54 pixels per inch (ppi).

4.24
typeline
two innermost ridges that start parallel, diverge and surround or tend to surround the pattern area

5 Symbols and abbreviated terms

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

2D two dimensional

CBEFF Common Biometric Exchange Formats Framework

DFT Discrete Fourier Transform

ppcm pixels per centimetre

ppi pixels per inch

Variables are represented in this document by:

$a, b, c, \ldots, S, T$ italicized, lower and upper case letters

$\alpha, \theta, \lambda, \ldots, \Gamma$ italicized, lower and upper case Greek letters

$[a, b)$ range of values from (and including) a up to (but not including) b

$[a, b]$ range of values from (and including) a up to (and including) b

$\lfloor a \rfloor$ largest integer less than or equal to a

$\lceil a \rceil$ smallest integer greater than or equal to a

ROUND(a) nearest integer to a. If a equals a half integer, then ROUND(a) shall be replaced with the nearest integer larger than a.

a(b, c) function, a , that accepts variables b and c as input

| a(b, c) | magnitude of DFT or Gabor function, a, given inputs b and c

∠ a(b, c) phase of DFT or Gabor function, a, given inputs b and c

6 Data conventions

6.1 Byte and bit ordering

Each item of information, field, or logical record shall contain one or more bytes of data. Within a record all multibyte quantities are represented in Big-Endian format. That is, the more significant bytes of any multibyte quantity are stored at lower addresses in memory than less significant bytes. The order for transmission shall also be the most significant byte first and least significant byte last. Within a byte, the order of transmission shall be the most significant bit first and the least significant bit last. All numeric values are fixed-length unsigned integer quantities, unless otherwise specified. Floating point values shall be recorded as single precision 4-byte (32-bit) values as per ANSI/IEEE Std 754–1985.

6.2 Coordinate system

The coordinate system of a fingerprint used in this part of ISO/IEC 19794 shall be a Cartesian coordinate system. Pixel locations shall be represented by their x and y coordinates. The origin of the coordinate system shall be the upper left corner of the image with x increasing to the right and y increasing downward. Note that this is in agreement with most imaging and image processing use. The pixel location of the image origin shall be (0,0). When viewed on the finger, x increases from right to left as shown in Figure 1. All x and y values are non-negative.

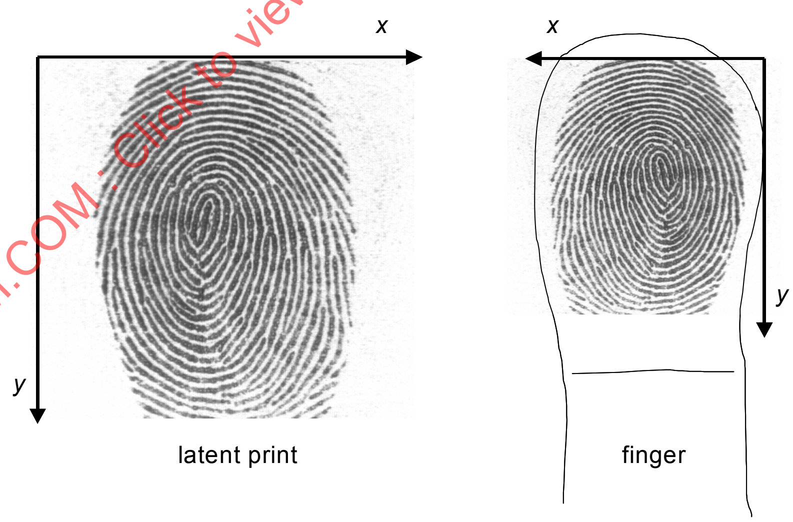


Figure 1 — Coordinate system

For the finger pattern spectral record format, the resolution of the coordinate system is specified in the record header, see 8.1.5, x (horizontal) resolution, and 8.1.6, y (vertical) resolution.

Similar to that of the image, the origin of a cell shall be the upper left pixel of the cell with x increasing to the right and y increasing downward.

6.3 Greyscale precision

The greyscale precision of the pixel data for this part of ISO/IEC 19794 shall be 8 bits, or 256 levels of grey. A black pixel will have value 0, while a white pixel will have value 255. However, the 'blackest" pixel in an image may have a value greater than "0" and the "whitest" pixel may have a value less than 255.

6.4 Image polarity

Images will have dark ridges and light valleys, otherwise a conversion to this convention is required. Grey lines in figures of fingerprints presented in this part of ISO/IEC 19794 correspond to fingerprint ridges.

6.5 Angle direction of rotation

Angles shall have a range of [0, 360) degrees, unless otherwise specified. An angle of 0 degrees is parallel to the x, or horizontal, axis extending from the point of origin in a positive x direction. Angles increase in a counter-clockwise rotation.

6.6 Phase and propagation angles

All phase and propagation angles introduced in this part of ISO/IEC 19794 are to be given in degrees.

7 Determination of finger pattern spectral data

7.1 Overview

To determine the finger pattern spectral data to be used to represent an acquired fingerprint image in the interchange format defined in this part of ISO/IEC 19794, the following shall be performed:

1) [Optional] Image pre-processing, for example, reduction in resolution and cropping of the image: conversion of the acquired fingerprint image to a cropped and down-sampled finger pattern;

2) Cellular partitioning: dividing the finger pattern from Step 0) into cells of size $S \times T$ pixels;

3) Spectral component selection: selection of the spectral components to represent each finger pattern cell.

7.2 Step 0) [Optional] Image pre-processing

Spectral pattern-based fingerprint processing may optionally perform image resolution reduction. Any resolution reduction performed should maintain compatibility with the finger characteristics of the target population (adult, child, etc.). Cropping may also occur as part of this step. If cropping is performed together with resolution reduction, it may occur either before or after down-sampling.

If performed, the result of Step 0) is a cropped and down-sampled version of the acquired fingerprint image known herein as the finger pattern. If Step 0) is not performed, the input to Step 1) below will be the acquired fingerprint image.

7.3 Step 1) Cellular partitioning

In general, cellular representation of the finger pattern data comprises dividing the central, or other, portion of the finger pattern into a grid of overlapping or non-overlapping cells. The first cell is considered to be the upper, leftmost cell within the finger pattern. The origin of the first cell may be offset from the origin of the finger pattern (as indicated by the x and y offsets shown in Figure 2). Any number of finger pattern pixels that are insufficient to create a full cell at the right of a row, or at the bottom of a column shall be excluded.

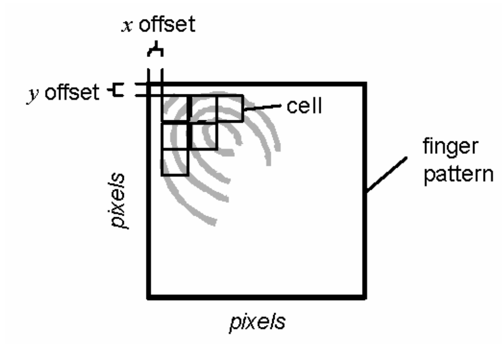


Figure 2 — Cellular partitioning of the finger pattern

At each cell, the finger pattern information will be represented by spectral components selected via one of the methods outlined in Clause 7.4.

7.4 Step 2) Spectral component selection

There are several approaches that can be taken to obtain the spectral information that will be stored to represent a finger pattern cell. Such approaches include Discrete Fourier Transforms, Gabor filtering, or selection of spectral components from a quantized set of co-sinusoidal triplets, as described below.

7.4.1 Quantized co-sinusoidal triplets

It is possible to represent the greyscale information within a finger pattern cell with the following 2D co-sinusoidal function: $Cell_{(\theta,\lambda,\delta)}(s,t) = \cos(PD \times 2\pi \times f + \delta)$, where $PD = s \times \cos(\theta) - t \times \sin(\theta)$, $f = 1/\lambda$, and s and t are the subscripts for the cell pixels on the x and y axes, respectively.

This 2D co-sinusoidal function is fully defined by the parameters θ, λ and δ, the propagation angle, wavelength and phase offset, respectively. These parameters are shown pictorially in Figure 3 below.

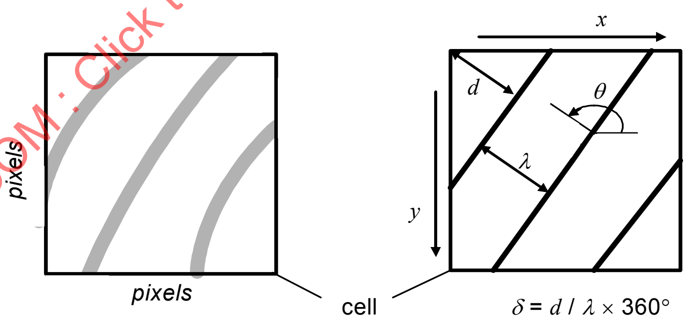


Figure 3 — Spectral component representation of a finger pattern cell

The range of each of these parameters is given below:

θ: [0, 180) degrees. θ is defined as the angle of propagation of the co-sinusoidal function, where the propagation direction is measured perpendicular to the crests of the co-sinusoidal function. θ will be 0 degrees when the crests are perpendicular to the x, or horizontal, axis. θ increases in a counter-clockwise rotation.

λ: (minimal spatial wavelength, ∞] pixels. λ is limited in practice to twice the number of pixels across the longest diagonal in the image. $\lambda = 1/f$ where f: [0,maximal spatial frequency). The maximal spatial frequency is the Nyquist frequency and is equal to the image resolution divided by 2.

δ: [0, 360) degrees. δ is defined as $(d/\lambda)\times 360°$, where d is the distance between the origin of the cell (upper-left corner of the cell) and the location of the first crest of the co-sinusoidal function in a positive direction in x (see Figure 3).

The value of each of these parameters can be quantized to create a limited set of discrete triplets (θ,λ,δ). Applying each triplet in this set to the co-sinusoidal function noted above will generate a corresponding set of finger pattern cell structures.

Consider then, representing θ, λ and δ by l, m and n bits, respectively. This implies that the values for θ, λ and δ will be as shown in the following tables:

Table 1 — *l*-bit representation for θ

Value (l-bits)	θ
0…000	0
0…001	$\frac{1}{2^l}\times 180$
0…010	$\frac{2}{2^l}\times 180$
…	…
1…110	$\frac{2^l-2}{2^l}\times 180$
1…111	$\frac{2^l-1}{2^l}\times 180$

Table 2 — *m*-bit representation for λ

Value (m-bits)	f	λ
0…000	0	∞
0…001	$\frac{1}{2^m}\times$ Nyquist	$\frac{1}{f}$
0…010	$\frac{2}{2^m}\times$ Nyquist	$\frac{1}{f}$
…	…	…
1…110	$\left(\frac{2^m-2}{2^m}\right)\times$ Nyquist	$\frac{1}{f}$
1…111	$\left(\frac{1}{2^m}\right)\times$ Nyquist	$\frac{1}{f}$

Table 3 — n-bit representation for δ

Value (n-bits)	δ
0…000	0
0…001	$\frac{1}{2^n} \times 360$
0…010	$\frac{2}{2^n} \times 360$
…	…
1…110	$\frac{2^n - 2}{2^n} \times 360$
1…111	$\frac{2^n - 1}{2^n} \times 360$

This would result in a co-sinusoidal triplet set of size 2^{l+m+n}, and a corresponding set of 2^{l+m+n} cell structures.

To determine which specific quantized co-sinusoidal triplet should be chosen to represent the information in a given finger pattern cell the following closest match approach should be used:

1) Normalize the information within the finger pattern cell to the range [-1,1].

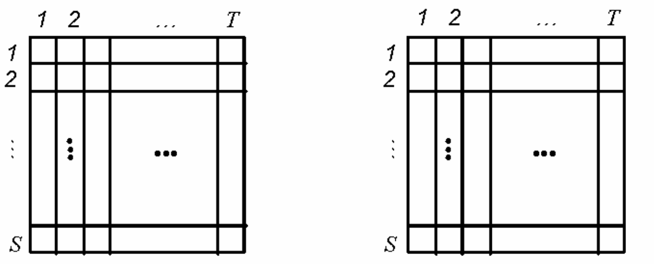
2) The distance between the finger pattern cell information and each cell structure in the set shall be calculated (see the example distance equation below).

3) The cell structure that results in the minimum distance with the finger pattern cell shall be determined.

4) The co-sinusoidal triplet that corresponds to the above cell structure shall be chosen to represent the finger pattern cell information.

For example, given a cell of size S pixels by T pixels, the distance may be calculated as:

$D = |A_{1,1} - B_{1,1}| + |A_{1,2} - B_{1,2}| + \cdots + |A_{S,T} - B_{S,T}|$ for *A* and *B* as shown in Figure 4.



A: finger pattern cell ***B***: candidate cell structure

Figure 4 — Matrix of $S \times T$ pixels for the finger pattern cell and candidate cell structure

NOTE Other distance functions (Euclidean distance, etc.) may also be used to determine the minimum distance cell structure from the finger pattern cell.

In the case of ambiguity due to more than one cell structure producing the minimum distance, a single co-sinusoidal triplet must be chosen from the set of co-sinusoidal triplets that correspond to this set of minimum distance cell structures. This single co-sinusoidal triplet shall be chosen from the minimum set as follows:

1) The co-sinusoidal triplet(s) with the lowest value of phase, δ, shall be chosen; then

2) The co-sinusoidal triplet(s) with the highest wavelength, λ, shall be chosen; then

3) The co-sinusoidal triplet with the lowest angle, θ, shall be chosen.

If a single co-sinusoidal triplet remains followings steps 1 or 2 above, then it shall be chosen to represent the finger pattern cell information. Otherwise, a single co-sinusoidal triplet will be isolated following step 3.

For this quantized co-sinusoidal triplets method, cell size should be selected so that the number of ridges contained in a single cell is approximately 2. Note that Figure 3 shows a cell with more than 2 ridges, but this is done for illustrative purposes only.

7.4.2 Discrete Fourier Transform

A finger pattern cell can be represented with spectral information derived from applying a two-dimensional (2D) Discrete Fourier Transform (DFT). The finger pattern cell information will consist of a real signal, h(s,t), of size $S\times T$, whose 2D DFT can be computed as:

$$\mathrm{H}(k,l)=\sum_{s=0}^{S-1}\sum_{t=0}^{T-1}\mathrm{h}(s,t)\times e^{-j2\pi\left(\frac{ks}{S}+\frac{lt}{T}\right)}, \text{ where } k=0,\ldots,S-1 \text{ and } l=0,\ldots,T-1 .$$

Note that H(k,l) has complex values even though h(s,t) was real-valued. The original image h(s,t) can be recovered from H(k,l) using the 2D inverse DFT formula:

$$\mathrm{h}(s,t)=\frac{1}{ST}\sum_{k=0}^{S-1}\sum_{l=0}^{T-1}\mathrm{H}(k,l)\times e^{j2\pi\left(\frac{ks}{S}+\frac{lt}{T}\right)}, \text{ where } s=0,\ldots,S-1 \text{ and } t=0,\ldots,T-1 .$$

Denote the spatial frequencies in the x and y directions as f_x and f_y, respectively. In addition, let NQ_x and NQ_y denote the Nyquist frequencies in the x and y directions, respectively, where NQ_x = (image resolution in the x direction)/2 and NQ_y = (image resolution in the y direction)/2. Then each 2D DFT component at location $\left(f_x=\frac{k}{S}\times \mathrm{NQ}_x, f_y=\frac{l}{T}\times \mathrm{NQ}_y\right)$ (for $k=0,\ldots,S-1$ and $l=0,\ldots,T-1$) consists of a complex component represented here by magnitude, $\alpha_{k,l}=\left|\mathrm{H}(k,l)\right|$, and phase, $\delta_{k,l}=\angle\mathrm{H}(k,l)$, with the following ranges:

$\alpha:[0,255\times S\times T)$, where 255 is considered the maximal greyscale value per pixel.

$\delta:[0,360)$ degrees.

The value of these parameters shall be quantized to p and q bits as shown in Tables 4 and 5.

Table 4 — p-bit representation for α

If α falls in range:	Store as p-bit value:	Read α as:
$\left[0, \frac{1}{2^p} \times 255 \times S \times T\right)$	0…000	0
$\left[\frac{1}{2^p} \times 255 \times S \times T, \frac{2}{2^p} \times 255 \times S \times T\right)$	0…001	$\frac{1}{2^p} \times 255 \times S \times T$
$\left[\frac{2}{2^p} \times 255 \times S \times T, \frac{3}{2^p} \times 255 \times S \times T\right)$	0…010	$\frac{2}{2^p} \times 255 \times S \times T$
…	…	…
$\left[\frac{2^p - 2}{2^p} \times 255 \times S \times T, \frac{2^p - 1}{2^p} \times 255 \times S \times T\right)$	1…110	$\frac{2^p - 2}{2^p} \times 255 \times S \times T$
$\left[\frac{2^p - 1}{2^p} \times 255 \times S \times T, 255 \times S \times T\right)$	1…111	$\frac{2^p - 1}{2^p} \times 255 \times S \times T$

Table 5 — q-bit representation for δ

If δ falls in range:	Store as q-bit value:	Read δ as:
$\left[0, \frac{1}{2^q} \times 360\right)$	0…000	0
$\left[\frac{1}{2^q} \times 360, \frac{2}{2^q} \times 360\right)$	0…001	$\frac{1}{2^q} \times 360$
$\left[\frac{2}{2^q} \times 360, \frac{3}{2^q} \times 360\right)$	0…010	$\frac{2}{2^q} \times 360$
…	…	…
$\left[\frac{2^q - 2}{2^q} \times 360, \frac{2^q - 1}{2^q} \times 360\right)$	1…110	$\frac{2^q - 2}{2^q} \times 360$
$\left[\frac{2^q - 1}{2^q} \times 360, 360\right)$	1…111	$\frac{2^q - 1}{2^q} \times 360$

The 2D DFT function for real signals satisfies the Hermitian symmetry property. That is, H(k,l) is the complex conjugate of H(S-k,T-l). This symmetry implies that there is redundancy in the 2D DFT array H(k,l). Assuming the 2D DFT of a real-valued cell of size $S \times T$ is accomplished in row-column decomposition, this will result in:

— $\left(\frac{S-1}{2}+1\right) \times T$ unique complex components if S is odd, and

— $\left(\frac{S}{2}+1\right) \times T$ unique complex components if S is even.

This implies that for full image reconstruction precision the first $\left(\frac{S-1}{2}+1\right)$ columns of the DFT array, in the case of S odd (or the first $\left(\frac{S}{2}+1\right)$ columns in the case of S even) must be stored. Storage and reconstruction from fewer components will result in information loss, meaning that the exact image will not be reconstructable from the reduced number of components. Depending upon the number and selection method, minutiae patterns may be reconstructable from some reduced sets of components.

A spectral decomposition of an entire image using a 2D DFT should show most of the spectral energy within an annulus of the frequency plane. For most people, this annulus will be at about the 14-18 pixels wavelength when the original sampling is at 500 dpi. Of course other image resolutions will have different spatial wavelengths.

In the case of cell dimensions that are bigger than a ridge wavelength (by at least a factor of two), the DFT spectral decomposition of the finger pattern may be dominated by a single component of high magnitude and a spatial wavelength on the same order as the finger pattern ridge wavelength.

In the case of cell dimensions on the order of a single ridge wavelength or smaller, or in the case of a cell containing a bifurcation, a ridge ending, or both, there may not be single dominant Fourier component.

To prevent ringing in the two-dimensional DFT, it could be desirable to window the image prior to spectral decomposition. One useful window is the two dimensional Gaussian. Closely related to the Gaussian windowed DFT is the application of Gabor filters of predetermined wavelength and direction to the image. See 7.4.3 for more information on Gabor filters.

7.4.3 Gabor filters

A finger pattern cell can be represented with spectral information derived from applying a 2D Gabor filter. A 2D Gabor filter is a product of a Gaussian envelope and a complex exponential function:

$$G_{(\sigma,f,\theta)}(s,t) = e^{-\frac{s_1^2+t_1^2}{2\sigma^2}} \times e^{j2\pi f(s_1+t_1)}, \text{ where } s_1 = s\cos\theta + t\sin\theta \ , \quad t_1 = -s\sin\theta + t\cos\theta ,$$

and σ represents the standard deviation of the Gaussian envelope, f is the frequency, and θ is the orientation from the x-axis. Note that the more general equation would include $\sigma = (\sigma_x, \sigma_y)$, however, for use with fingerprints, it is assumed that $\sigma_x = \sigma_y$ and thus only a single σ value is required.

The finger pattern cell information will consist of a real signal, h(s,t), of size $S \times T$. To apply this Gabor filter, multiply the finger pattern cell information, h(s,t), with the above function to obtain:

$$Z(s,t) = \sum_{x=0}^{S-1} \sum_{y=0}^{T-1} G_{(\sigma,f,\theta)}(s-x, t-y) \times h(s,t).$$

The Gabor magnitude is $\alpha_{s,t} = |Z(s,t)|$ and the Gabor phase is $\delta_{s,t} = \angle Z(s,t)$. The Gabor filter acts as a local band-pass filter with certain localization properties in both the image domain and frequency domain.

For use with fingerprint images, the frequency should be on the order of the inverse of the ridge spacing, while θ will typically vary from [0 to 180) degrees in equal increments.

The range of α and δ is given below:

$\alpha : [0, 255 \times S \times T)$, where 255 is considered the maximal greyscale value per pixel.

$\delta : [0, 360)$ degrees.

The value of these parameters shall be quantized to p and q bits as shown in Tables 6 and 7

Table 6 — p-bit representation for α

If α falls in range:	Store as p-bit value:	Read α as:
$\left[0, \frac{1}{2^p} \times 255 \times S \times T\right)$	0…000	0
$\left[\frac{1}{2^p} \times 255 \times S \times T, \frac{2}{2^p} \times 255 \times S \times T\right)$	0…001	$\frac{1}{2^p} \times 255 \times S \times T$
$\left[\frac{2}{2^p} \times 255 \times S \times T, \frac{3}{2^p} \times 255 \times S \times T\right)$	0…010	$\frac{2}{2^p} \times 255 \times S \times T$
…	…	…
$\left[\frac{2^p - 2}{2^p} \times 255 \times S \times T, \frac{2^p - 1}{2^p} \times 255 \times S \times T\right)$	1…110	$\frac{2^p - 2}{2^p} \times 255 \times S \times T$
$\left[\frac{2^p - 1}{2^p} \times 255 \times S \times T, 255 \times S \times T\right)$	1…111	$\frac{2^p - 1}{2^p} \times 255 \times S \times T$

Table 7 — q-bit representation for δ

If δ falls in range:	Store as q-bit value:	Read δ as:
$\left[0, \frac{1}{2^q} \times 360\right)$	0…000	0
$\left[\frac{1}{2^q} \times 360, \frac{2}{2^q} \times 360\right)$	0…001	$\frac{1}{2^q} \times 360$
$\left[\frac{2}{2^q} \times 360, \frac{3}{2^q} \times 360\right)$	0…010	$\frac{2}{2^q} \times 360$
…	…	…
$\left[\frac{2^q - 2}{2^q} \times 360, \frac{2^q - 1}{2^q} \times 360\right)$	1…110	$\frac{2^q - 2}{2^q} \times 360$
$\left[\frac{2^q - 1}{2^q} \times 360, 360\right)$	1…111	$\frac{2^q - 1}{2^q} \times 360$

The spectral components to be retained per cell, as well as the description of how these components become stored in the Finger Pattern Spectral Data Field will be outlined in Clause 8.2.2.2.

7.5 Quality

Finger pattern cells, defined above, are grouped into Cell Quality Groups. A quality granularity parameter will specify the number of cells in a Cell Quality Group: for example a value of 1 indicates a group comprises 1×1 cells; and a value of 2 indicates that a group comprises 2×2 cells. Quality scores are assigned to each of the Cell Quality Groups, where higher quality scores indicate better quality. Some factors that may contribute to the quality of the finger pattern cell information are greyscale resolution, greyscale linearity, spatial distortions, and location of the finger core within the acquired fingerprint image.

8 Finger pattern spectral data record

The finger pattern spectral data record format is used to provide interoperability between fingerprint recognition systems using spectral data in some way. The record format contains fields for storing both standardized and extended (non-standardized) finger pattern spectral data. The list of fields included in the record is found in Clause 8.1. Table 18 provides the list of fields in diagram format. With the exception of the format identifier and the version number for the standard, which are null-terminated ASCII character strings, all data is represented in binary format. There are no record separators or field tags; fields are parsed by byte count.

The biometric data record specified in this part of ISO/IEC 19794 shall be embedded in an ISO/IEC 19785-1 compliant structure as a CBEFF Biometric Data Block (BDB). There are three different 16-bit BDB_format types assigned to the finger pattern data record formats specified in this part of ISO/IEC 19794:

10 (000A Hex): finger-pattern-spectral-quantized-sinusoidal-triplets

12 (000C Hex): finger-pattern-spectral-discrete-fourier-transform

13 (000D Hex): finger-pattern-spectral-gabor-filter

Note that these BDB_format types appear in the ISO/IEC 19785-1 header and not in any field defined herein.

The organization of the finger pattern spectral data record is as follows:

— A variable-length record header containing information about the overall record, including the number of fingers represented and the overall record length in bytes; and

— A single finger record for each finger, consisting of:

  — A fixed-length (6-byte) header containing information about the data for a single finger;

  — A finger pattern spectral data block, including a series of spectral data representing each cell of the finger pattern, followed by quality data for the finger pattern; and

  — An extended data block containing vendor-specific data.

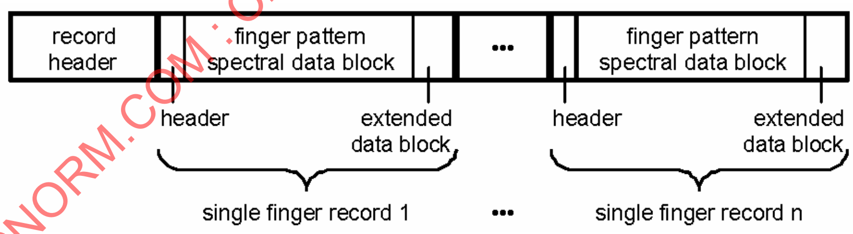


Figure 5 — Finger pattern spectral data record

8.1 Record header

There shall be a single record header for the finger pattern spectral data record to hold information describing the identity and characteristics of the device that generated the data.

8.1.1 Format identifier

For this part of ISO/IEC 19794, the format identifier shall consist of characters "FSP" followed by a zero byte as a NULL string terminator. The format identifier shall be recorded in four bytes.

8.1.2 Version number

The version number for the version of this part of ISO/IEC 19794 used in constructing the finger pattern spectral data record shall be recorded in four bytes. This version number shall consist of three ASCII numerals followed by a zero byte as a NULL string terminator. The first and second character will represent the major revision number and the third character will represent the minor revision number. Upon approval of this specification, the version number shall be "010" (an ASCII '0' followed by an ASCII '1' and an ASCII '0'); this represents version 1.0.

8.1.3 Length of record

The length (in bytes) of the entire finger pattern spectral data record shall be recorded in four bytes.

8.1.4 Number of single finger records

The total number of single finger records contained in the finger pattern spectral data record shall be recorded in one byte. A minimum of one single finger record is required.

8.1.5 x (horizontal) resolution

The resolution in the x-direction of the finger pattern represented in the single finger record(s) shall be recorded in two bytes and shall have the units of pixel per centimetre. The value of the x resolution shall be ROUND(ppcm) and shall not be zero.

8.1.6 y (vertical) resolution

The resolution in the y-direction of the finger pattern represented in the single finger record(s) shall be recorded in two bytes and shall have the units of pixel per centimetre. The value of the y resolution shall be ROUND(ppcm) and shall not be zero.

8.1.7 Number of cells in x-direction

The number of cells that span a finger pattern in the x-direction shall be recorded in two bytes. A minimum of one cell is required.

8.1.8 Number of cells in y-direction

The number of cells that span a finger pattern in the y-direction shall be recorded in two bytes. A minimum of one cell is required.

8.1.9 Number of pixels in cells in x-direction

The number of pixels that span a finger pattern cell in the x-direction shall be recorded in two bytes.

8.1.10 Number of pixels in cells in y-direction

The number of pixels that span a finger pattern cell in the y-direction shall be recorded in two bytes.

8.1.11 Number of pixels between cell centres in x-direction

The number of pixels between centres of adjacent or overlapping cells in the x-direction of the finger pattern shall be recorded in two bytes. A value of 0 in this field implies a single cell in the x-direction.

8.1.12 Number of pixels between cell centres in y-direction

The number of pixels between centres of adjacent or overlapping cells in the y-direction of the finger pattern shall be recorded in two bytes. A value of 0 in this field implies a single cell in the y-direction.

8.1.13 Spectral component selection method

Three methods are defined in this part of ISO/IEC 19794 for determining the spectral components to be used to represent finger pattern information. The specific method used for creating a record shall be recorded in one byte and shall be specified as follows:

Table 8 — Spectral component selection method

Method	Value
Quantized co-sinusoidal triplets	0
Discrete Fourier Transforms	1
Gabor filters	2

8.1.14 Type of window

In the case that the spectral component selection method field is:

— 0: this field is not required.

— 1: this field will specify the form of the window that will be placed on the cell. The window shall be recorded in one byte and specified as follows:

Table 9 — Type of DFT window

Type of window	Value
Rectangular	0
Gaussian	1

— 2: this field is not required.

8.1.15 Standard deviation

If the spectral component selection method field has value:

— 0: this field is not required.

— 1: and the type of window field has value:

  — 0: this field is not required.

  — 1: this field is required and will contain the standard deviation for the Gaussian window.

— 2: this field is required and will contain the standard deviation in the Gabor equation.

The standard deviation, σ, if required, will be recorded in 4 bytes as a floating-point value.

8.1.16 Number of frequencies

If the spectral component selection method field has value:

— 0 or 1: this field is not required.

— 2: this field is required and will specify the integer number of frequencies to be used in Gabor filters. This value will be recorded in 2 bytes. The integer number of frequencies specified in this field will be used to determine the length (in bytes) of the next field (frequencies).

8.1.17 Frequencies

If the spectral component selection method field has value:

— 0 or 1: this field is not required.

— 2: this field is required and will specify the frequencies used in the Gabor filter. Each frequency value will be recorded as a 4-byte floating-point value. If more than one frequency is specified, they shall be placed sequentially one after another.

8.1.18 Number of orientations

If the spectral component selection method field has value:

— 0 or 1: this field is not required.

— 2: this field is required and will specify the number of evenly spaced orientations on each cell of the Gabor filter. This value will be recorded in one byte. For example, if the number of orientations specified is 4, this specifies θ = {0,45,90,135}.

8.1.19 Number of spectral components to be retained per cell

Depending on the spectral component selection method the number of spectral components to be retained for each cell may vary. If the spectral component selection method field is:

— 0: the number of spectral components will be three (as defined in Clause 7.4.1) and this field is not present;

— 1: this field is mandatory and shall be recorded in five bytes, structured as follows:

Spectral components to be retained	Value of most significant byte	Parameter	Value of four least significant bytes
All unique components	0	<Not applicable>	0
K components, for $K \geq 1$	1	K	1 to (2^{32}-1)
Reserved for later use	2 to 255	<Not applicable>	0

— 2: this field is mandatory and shall be recorded in one byte and structured as follows:

Spectral components to be retained	Value
Angle of rotation of the filter with the highest energy[a]	0
All Gabor magnitude output	1
All Gabor magnitude and phase output	2
Reserved for later use	3 to 255
[a] Energy is defined here as the Gabor magnitude squared, α^2.	

8.1.20 Bit-depth of propagation angle of co-sinusoidal function

If the spectral component selection method field is:

- 0: this field is required and will contain the bit-depth used to represent the propagation angle of the co-sinusoidal function. The bit-depth shall be recorded in one byte.
- 1 or 2: this field is not required

8.1.21 Bit-depth of wavelength of co-sinusoidal function

If the spectral component selection method field is:

- 0: this field is required and will contain the bit-depth used to represent the wavelength of the co-sinusoidal function. The bit-depth shall be recorded in one byte.
- 1 or 2: this field is not required.

8.1.22 Bit-depth of phase

If the spectral component selection method field is:

- 0: this field is required and will contain the bit-depth used to represent the phase offset of the co-sinusoidal function. The bit-depth shall be recorded in one byte.
- 1: this field is required and will contain the bit-depth used to represent the phase of the DFT spectral components. The bit-depth shall be recorded in one byte.
- 2: and the number of spectral components to be retained per cell field has value:
  - 0 or 1: this field is not required.
  - 2: this field is required and will contain the bit-depth used to represent the phase information of the Gabor filtering. The bit-depth shall be recorded in one byte.

8.1.23 Bit-depth of magnitude

If the spectral component selection method field is:

- 0: this field is not required.
- 1: this field is required and will contain the bit-depth used to represent the magnitude of the DFT spectral components. The bit-depth shall be recorded in one byte.
- 2: and the number of spectral components to be retained per cell field has value:
  - 0: this field is not required.
  - 1 or 2: this field is required and will contain the bit-depth used to represent the magnitude information of the Gabor filtering. The bit-depth shall be recorded in one byte.

8.1.24 Bit-depth of quality score

The bit-depth used to represent the quality score of cell quality group shall be recorded in one byte.

8.1.25 Cell quality group granularity

The granularity of the cell quality group shall be recorded in one byte and specifies the number of cells in the x-direction of the cell quality groups. (It also indicates the number of cells in the y-direction of the cell quality groups as they are square). The size of the cell quality group is thus calculated as: (cell quality group granularity)^2. Any number of finger pattern cells that are insufficient to create a full cell quality group at the right of a row, or at the bottom of a column shall be excluded.

8.1.26 Reserved bytes

Two bytes are reserved for future revision of this specification. For Version 1.0 of this part of ISO/IEC 19794, these byte values shall be set to 0.

8.2 Single finger record

8.2.1 Header

A header shall start each section of a single finger record providing information for that finger pattern. There shall be one header for each finger pattern contained in the finger pattern spectral data record, and it will occupy a total of six bytes as described below.

8.2.1.1 Finger location

The finger location shall be recorded in one byte. The codes for this byte shall be as defined in Table 5 of ANSI/NIST-ITL 1-2000, "Data Format for the Interchange of Fingerprint Information". This table is reproduced here in Table 10 for convenience. Only codes 0 through 10 shall be used; the "plain" codes are not relevant for this part of ISO/IEC 19794, and are included here for informational purposes only.

Table 10 — Finger location codes

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

8.2.1.2 Impression type

The impression type of the finger image(s) shall be recorded in one byte. "Nonlive" entries refer to images scanned from cards or other media. These codes are compatible with Table 4 of ANSI/NIST-ITL 1-2000, "Data Format for the Interchange of fingerprint Information", with the addition of the "swipe" type. The swipe type identifies templates derived from the image streams generated by sliding the finger linearly across a small sensor surface. Only codes 0 through 3 and 8 shall be used; the "latent" codes are not relevant for this part of ISO/IEC 19794.

Table 11 — Finger impression type

Description	Code
Live-scan plain	0
Live-scan rolled	1
Nonlive-scan plain	2
Nonlive-scan rolled	3
Latent impression	*4*
Latent tracing	*5*
Latent photo	*6*
Latent lift	*7*
Swipe	8
Reserved	*9*

8.2.1.3 Number of views in single finger record

Some systems may have more than one view for the same finger pattern. The total number of views within each single finger record shall be recorded in one byte.

8.2.1.4 Finger pattern quality

The quality of the overall finger pattern shall be between 0 and 101 and recorded in one byte. This quality number is an overall expression of the quality of the finger pattern. A value of 0 shall represent the lowest possible quality and the value 100 shall represent the highest possible quality. The numeric values in this field shall be set in accordance with the general guidelines contained in Clause 7.56.5 of ISO/IEC 19784-1. Further, a quality value of 101 indicates that the acquired fingerprint image from which the finger pattern was derived complied with Appendix F of the Electronic Fingerprint Transmission Specification.

8.2.1.5 Length of finger pattern spectral data block

The total length of the finger pattern spectral data block and extended data block shall be recorded in two bytes.

8.2.2 Finger pattern spectral data block

8.2.2.1 View number

Preceding the finger pattern spectral data is the view number, which, starting from 0 sequentially identifies each of the views of a finger pattern contained in the single finger record. The view number shall be recorded in one byte.

8.2.2.2 Finger pattern spectral data

The finger pattern spectral data shall be stored in a packed format with the data corresponding to the upper left cell stored first, followed by the cell on right of this first cell, and so on until the last cell of the first row and then subsequent rows are stored. If the size (in bits) of the complete encoded finger pattern spectral data is not divisible by 8, pad the end of the data with zeroes until the size is divisible by 8.

Let n represent the number of bits required to represent a single cell. Then the length, ldb, (in bytes) of the finger pattern spectral data (including padding) can be calculated as follows:

$$a = (\text{number of cells in } x\text{-direction}) \times (\text{number of cells in } y\text{-direction}) \times n \text{ bits}$$

$$b = a(\text{modulo } 8)$$

If $b = 0$, then $\mathrm{ldb} = a/8$ bytes

If $b \neq 0$, then $\mathrm{ldb} = (a + (8 - b))/8$ bytes

The number of bits required to represent a single cell will vary depending on the spectral component selection method used. Given the fact that there are a variable number of spectral components that may be retained per cell, it is necessary to outline the naming and ordering of the spectral components that will be stored in the record.

In the case that the spectral component selection method field is:

— 0: the spectral components to be stored include the propagation angle, θ, the wavelength, λ and the phase offset, δ, in that order.

— 1: and the most significant byte of the number of spectral components to be retained per cell field has value:

  — 0: all unique 2D DFT spectral components shall be recorded with the magnitude, α, followed by the phase, δ. The elements shall be ordered in increasing increments of f_x, then f_y, as shown below:

$\alpha_{f_0 f_0}$	$\delta_{f_0 f_0}$	$\alpha_{f_1 f_0}$	$\delta_{f_1 f_0}$	$\ldots$	$\alpha_{f_{\text{final}} f_0}$	$\delta_{f_{\text{final}} f_0}$	$\alpha_{f_0 f_1}$	$\delta_{f_0 f_1}$	$\ldots$	$\delta_{f_{\text{final}} f_{\text{final}}}$

  — 1: K, for $K \geq 1$, 2D DFT spectral components shall be recorded in the following order: the indexes, k and l, associated with the frequencies f_x and f_y, respectively, followed by the magnitude, α, and phase, δ, information.

  Note that the actual floating point values of f_x and f_y need not be stored as these values can be recalculated with the integer valued indexes, $k \in \{0, \cdots, S-1\}$ and $l \in \{0, \cdots, T-1\}$, and the resolution of the image in the x and y directions. Here S and T denote the number of pixels in cells in the x and y directions, respectively.

  Each index, k and l, shall be recorded in a variable number of bits according to the value of S and T, respectively, where k requires encoding in $\lceil \log_2 S \rceil$ bits, and l requires encoding in $\lceil \log_2 T \rceil$ bits. The number of bits needed to store α and δ will vary depending on the bit-depths specified for these parameters.

— 2: and the number of spectral components to be retained per cell field has value:

  — 0: the index number, r, which represents the angle of rotation, θ, corresponding to the highest energy shall be recorded. When reading this field 90 degrees must be added to the angle if the ridge flow, not the filter orientation, is desired. The bit-depth required to store this index number is completely determined by the value in the number of orientations field. Denote this value as M. Then the bit-depth required for storing this index is: $m = \lceil \log_2 M \rceil$.

Table 12 — Gabor angle

Angle of rotation, θ	Store as m-bit value	Read as ridge flow
0	0…000	90
$\frac{1}{2^m} \times 180$	0…001	$\frac{1}{2^m} \times 180 + 90$
$\frac{2}{2^m} \times 180$	0…010	$\frac{2}{2^m} \times 180 + 90$
…	…	…
$\frac{2^m - 2}{2^m} \times 180$	1…110	$\frac{2^m - 2}{2^m} \times 180 + 90$
$\frac{2^m - 1}{2^m} \times 180$	1…111	$\frac{2^m - 1}{2^m} \times 180 + 90$

— 1: all Gabor magnitude for all specified frequencies and orientations shall be recorded. See Table 13 below for data ordering.

— 2: all Gabor magnitude, α, and phase, δ, for all specified frequencies and orientations shall be recorded. See Table 13 below for data ordering.

There may be several Gabor filters applied to the cell, as determined by Clauses 8.1.16 and 8.1.18, the number of frequencies and number of orientations, respectively. If there are several Gabor filters, the information in the finger pattern spectral data field will contain all information for the first cell, followed by all information for the next cell, as illustrated in Table 13 below.

Table 13 — Ordering of Gabor data

n-bits resulting from applying $G_{(\sigma,f_0,\theta_0)}(s,t)$ to first cell	n-bits resulting from applying $G_{(\sigma,f_0,\theta_1)}(s,t)$ to first cell	…	n-bits resulting from applying $G_{(\sigma,f_0,\theta_{\text{final}})}(s,t)$ to first cell	n-bits resulting from applying $G_{(\sigma,f_1,\theta_0)}(s,t)$ to first cell	…	n-bits resulting from applying $G_{(\sigma,f_{\text{final}},\theta_{\text{final}})}(s,t)$ to first cell	n-bits resulting from applying $G_{(\sigma,f_0,\theta_0)}(s,t)$ to second cell	…

Where the number of bits, n, needed for storing the spectral components will vary depending on the bit-depths specified for these parameters.

8.2.2.3 Cell quality data

The cell quality data shall follow the finger pattern spectral data and shall be stored in a packed format with the data corresponding to the upper left cell quality group stored first, followed by the cell quality group on right of this first cell quality group, and so on until the last cell quality group data of the first row and then subsequent rows are stored. If the size (in bits) of the complete encoded cell quality data is not divisible by 8, pad the end of the data with zeroes until the size is divisible by 8.

Let g represent the cell quality group granularity and let n represent the bit-depth of the quality score for each cell quality group. Then the length, lqd, (in bytes) of the quality data (including padding) can be calculated as follows:

$$a = \lfloor (\text{number of cells in } x\text{-direction})/g \rfloor \times \lfloor (\text{number of cells in } y\text{-direction})/g \rfloor \times n \text{ bits}$$

$$b = a(\text{modulo } 8)$$

If $b = 0$, then $\text{lqd} = a/8$ bytes

If $b \neq 0$, then $\text{lqd} = (a + (8 - b))/8$ bytes

The quality score range for each cell quality group shall be as follows:

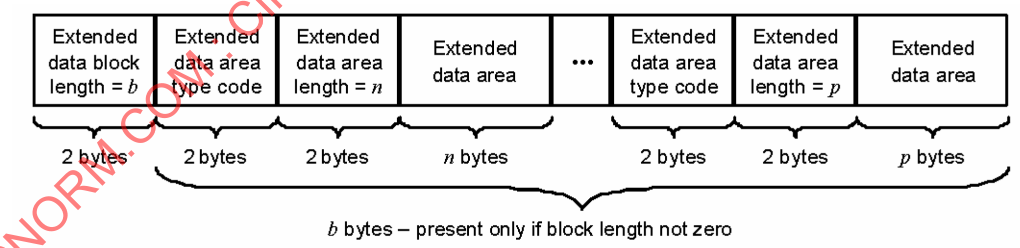
Table 14 — *n*-bit representation for quality score of each cell quality group

If quality score falls in range:	Store as *n*-bit value:	Read quality score as:
$[0,1)$	0…000	0
$[1,2)$	0…001	1
$[2,3)$	0…010	2
…	…	…
$[2^n - 2, 2^n - 1)$	1…110	$2^n - 2$
$[2^n - 1, 2^n)$	1…111	$2^n - 1$

8.2.3 Extended data block

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

Table 15 — Extended data block



8.2.3.1 Extended data block length

All finger pattern spectral data records shall contain the extended data block length. This field shall be recorded in two bytes and will signify the existence of extended data. A value of all zeros (0x0000 hexadecimal) will indicate that there is no extended data and that the file will end or continue with the next finger view. A nonzero value will indicate the length of all extended data (in bytes) starting with the next byte. The block length will then be followed by the extended data area type code (8.2.3.2), the extended data area length field (8.2.3.3) and the extended data area (8.2.3.4).

8.2.3.2 Extended data area type code

The extended data area type code shall be recorded in two bytes, and shall distinguish the format of the extended data area (as defined by the Vendor specified by the CBEFF_BDB_product_owner and

CBEFF_BDB_product_type in the ISO/IEC 19785-1 header). A value of zero in both bytes is a reserved value and shall not be used. A value of zero in the first byte, followed by a non-zero value in the second byte, shall indicate that the extended data section has a format defined in this part of ISO/IEC 19794. A non-zero value in the first byte shall indicate a vendor specified format, with a code maintained by the vendor. Refer to Table 16 for a summary of the extended data area type codes. If the extended data block length (8.2.3.1) for the finger view is zero, indicating no extended data, this field shall not be present.

NOTE If vendor-defined extended data is present and the ISO/IEC 19785-1 Standard Biometric Header does not support CBEFF_BDB_product_owner and CBEFF_BDB_product_type then the link between the extended data and vendor is lost.

Table 16 — Extended data area type codes

First byte	Second byte	Identification
0x00	0x00	Reserved
0x00	0x01	Reserved
0x00	0x02	Core and delta data (8.2.3.5)
0x00	0x03	Reserved
0x00	0x04-0xFF	Reserved
0x01-0xFF	0x00	Reserved
0x01-0xFF	0x01-0xFF	Vendor-defined extended data

8.2.3.3 Extended data area length

The length of the extended data area (in bytes), including the vendor identification and length of data fields, shall be recorded in two bytes. This value is used to skip to the next extended data if the matcher cannot decode and use this data. If the extended data block length (8.2.3.1) for the finger view is zero, indicating no extended data, this field shall not be present.

8.2.3.4 Extended data area

The extended data area is defined by the equipment that is generating the finger pattern spectral record, or by the core and delta extended data format contained in this part of ISO/IEC 19794. If the extended data block length (8.2.3.1) for the finger view is zero, indicating no extended data, this field shall not be present.

8.2.3.5 Core and delta data block

If the extended data area type code is 0x0002, the extended data area contains core and delta information. This format is provided to contain optional information about the placement and characteristics of the cores and deltas on the finger pattern. Only locations of core and delta that fall inside the bounds of the finger pattern cell data shall be included. Core and delta points are determined by the overall pattern of ridges in the fingerprint. There may be zero or more core points and zero or more delta points for any fingerprint. Core and delta points may or may not include angular information.

The following fields are available to store the core and delta information.

8.2.3.5.1 Number of cores

The number of core points represented shall be recorded in the most significant 4 bits of the first byte in the core and delta data block. Valid values are from 0 to 15.

8.2.3.5.2 Cell alignment flag

This field represents a flag and shall be recorded in two bits, immediately following the number of cores field. A value of 1 or 2 in this field indicates that cellular partitioning (see 7.3) was performed according to cell alignment to the first core or cell alignment to the first delta, respectively.

The first core (or delta) is considered to be the first enumerated core (or delta), raster-scanned from the upper left corner of the finger pattern[1].

Such alignment implies that the position of the first core (or delta) acts as a corner position for one or more cells. See Figure 6 for examples of the first core and first delta acting as the corner position for exactly 4 non-overlapping cells.

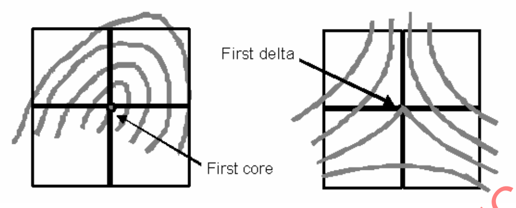


Figure 6 — Non-overlapping cells aligned to first core or first delta

For non-overlapping cells, additional information is required to determine which of the 4 possible cells surrounding the first core or first delta is used for the alignment. The two bits following this flag will provide this information.

Once the alignment cell is determined, all remaining cells of the finger pattern are aligned accordingly.

A value of 0 in this field indicates that no information is provided on whether or not cells were aligned to the first core or first delta, while a value of 3 is reserved for future use.

8.2.3.5.3 Cell alignment cell

This field shall be used in conjunction with the cell alignment flag to determine which of 4 possible cells, cell alignment is set to. This field shall be recorded in the two bits, immediately following the cell alignment flag. Valid values for this field shall be as defined in Table 17.

Table 17 — Cell alignment cell specification

Cell alignment cell	Value
Upper left cell	0
Upper right cell	1
Lower left cell	2
Lower right cell	3

If the value of the cell alignment flag is 0, indicating no cell alignment specified, this field shall be considered as a reserved field and shall be set to 0.

1) The finger pattern here is referring to the input to Step 1) of Clause 7.3.

8.2.3.5.4 Core information type

The next two bytes of the core and delta data block incorporate two fields: the core information type and the core x coordinate. The core information type shall be recorded in the most significant 2 bits of these bytes. The bits “01” will indicate that the core has angular information while “00” will indicate that no angular information is relevant for the core type. If this field is “00”, then the angle fields shall not be present for this core.

8.2.3.5.5 Core x coordinate

If there are ridge endings enclosed by the innermost recurving ridgeline, the ending next to the maximal curvature of the recurving ridgeline defines the core position. If the core is a u-turn of a ridgeline not enclosing ridge endings, the valley end gives the core position.

The core x coordinate shall be recorded in the least significant 14 bits of the 2nd and 3rd bytes of the core and delta data block. The coordinate shall be expressed in pixels at the resolution indicated in the record header and it shall be defined with respect to the origin of the upper left cell of the finger pattern.

8.2.3.5.6 Core y coordinate

The core y coordinate shall be recorded in the least significant 14 bits of the 2 bytes following the core x coordinate. The most significant 2 bits of this field are reserved bits and shall have the value 0. The core y coordinate shall be expressed in pixels at the resolution indicated in the record header and it shall be defined with respect to the origin of the upper left cell of the finger pattern.

8.2.3.5.7 Core angle

If the core has a direction it has to be encoded since having a direction characterises the type of core. The core has a direction if there is a ridge or a group of ridges pointing towards it. The direction is defined by the direction of the tangent to these ridge lines as close as possible to the core position. The tangent is pointing to the open side of the U-structured ridge.

The angle of the core shall be recorded in one byte in units of 1.40625 (360/256) degrees. The value shall be a non-negative value between 0 and 255, inclusive. For example, an angle value of 16 represents 22.5 degrees. If the core information type is zero (see 8.2.3.5.3), then this field shall not be present.

See Figure 7 for core and delta placement examples.

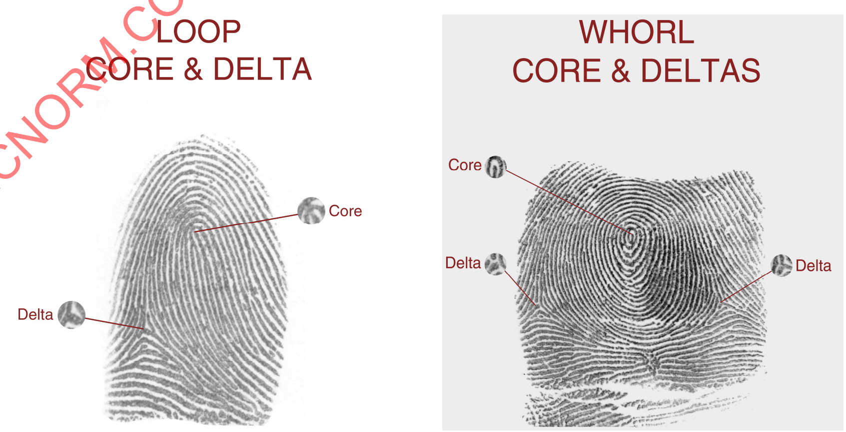


Figure 7 — Example core and delta placement

8.2.3.5.8 Number of deltas

The number of delta points represented shall be recorded in the most significant four bits of the next byte. Valid values are from 0 to 15. The least significant 4 bits of this byte shall be reserved and shall be set to zero.

8.2.3.5.9 Delta information type

The delta information type shall be recorded in the first two bits of the upper byte of the x coordinate of the delta. The bits “01” will indicate that the delta has angular information while “00” will indicate that no angular information is relevant for the delta type. If this field is “00”, then the angle fields shall not be present for the deltas.

8.2.3.5.10 Delta x coordinate

For a delta we find three points of divergences placed between the two ridges at the location where they start spreading apart. The position of the delta is defined by the mean of these three points. A divergence is spreading apart of two lines which have been running parallel or nearly parallel.

The x coordinate of the delta shall be recorded in the lower fourteen bits of the next two bytes (fourteen bits). The coordinate shall be expressed in pixels at the resolution indicated in the record header and it shall be defined with respect to the origin of the upper left cell of the finger pattern.

8.2.3.5.11 Delta y coordinate

The y coordinate of the delta shall be placed in the lower fourteen bits of the two bytes following the delta x coordinate. The most significant 2 bits of this field are reserved bits and shall have the value 0.The coordinate shall be expressed in pixels at the resolution indicated in the record header and it shall be defined with respect to the origin of the upper left cell of the finger pattern.

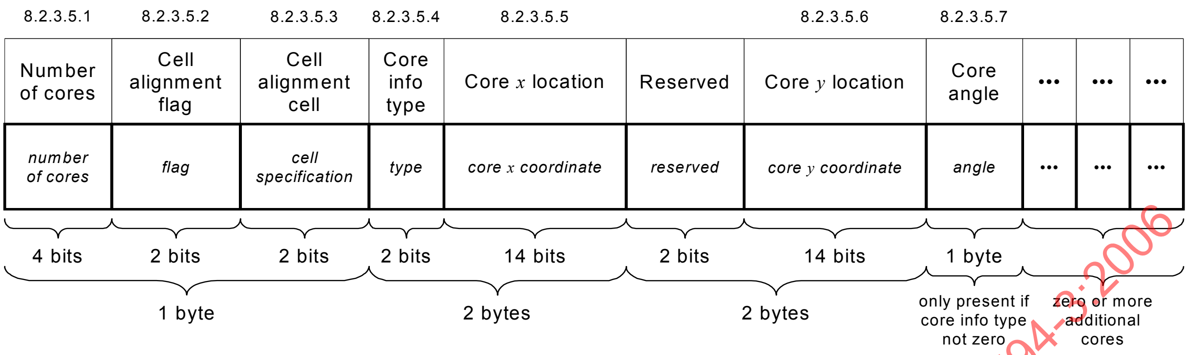
8.2.3.5.12 Delta angles

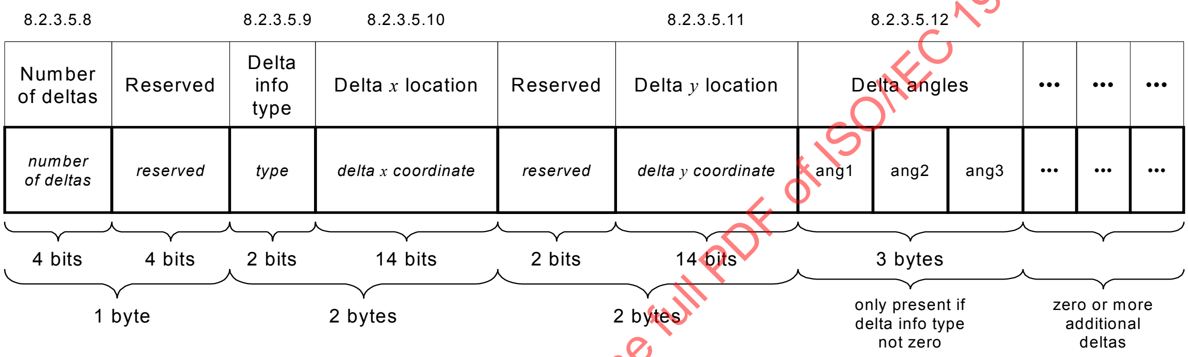
For all observable divergences the direction is defined by the direction of the tangent before the pair of ridges starts to diverge. The tangent shall point from divergent towards parallel running lines.

The three angle attributes of the delta shall each be recorded in one byte in units of 1.40625 (360/256) degrees. The value shall be a non-negative value between 0 and 255, inclusive. For example, an angle value of 16 represents 22.5 degrees. If not all three angles can be extracted from the image data because of noise or image boundary, the angle field is filled by repeating the determined values. If the delta information type is zero (see 8.2.3.5.9), then this field shall not be present.

8.2.3.5.13 Core and delta block summary

The core and delta format shall be as follows:





8.3 Summary of finger pattern spectral data record

Table 18 — Summary of finger pattern spectral data record

	Field	Size (bytes)	Valid values	Notes
Record header	Format identifier	4	0x46535000 ('F' 'S' 'P' 0x00)	"FSP" implies Finger pattern SPectral
	Version number	4	0x30313000 ('0' '1' '0' 0x00)	Major version number: 01 Minor version number: 0
	Length of record	4	47 to 2^{32}-1	Length provided specifies number of bytes. Every field of record to be included in length.
	Number of single finger records	1	1 to 255	
	x (horizontal) resolution	2	1 to 2^{16}-1	ROUND(ppcm)
	y (vertical) resolution	2	1 to 2^{16}-1	ROUND(ppcm)
	Number of cells in x-direction	2	1 to 2^{16}-1	
	Number of cells in y-direction	2	1 to 2^{16}-1	
	Number of pixels in cells in x-direction	2	1 to 2^{16}-1	
	Number of pixels in cells in y-direction	2	1 to 2^{16}-1	
	Number of pixels between cell centres in x-direction	2	0 to 255	0 would imply a single cell in the x-direction

Field	Size (bytes)	Valid values	Notes
Number of pixels between cell centres in y-direction	2	0 to 255	0 would imply a single cell in the y-direction
Spectral component selection method	1	0, 1, or 2	
Type of window			If SCSM[a]: 0 <field not present>
	1	0 or 1	1
			2 <field not present>
Standard deviation			SCSM: 0 <field not present>
			1 and type of window: 0 <field not present>
	4	0 to 2^{32}-1	1 and type of window: 1
		0 to 2^{32}-1	2
Number of frequencies			SCSM: 0 or 1 <field not present>
	2	1 to 2^{16}-1	2. The value in this field is used to determine the length (in bytes) of the next field.
Frequencies			SCSM: 0 or 1 <field not present>
	4 × number of frequencies	0 to 2^{32}-1 (for each frequency)	2
Number of orientations			SCSM: 0 or 1 <field not present>
	1	1 to 255	2
Number of spectral components to be retained per cell			SCSM: 0 <field not present>
	5	1 MSB[b]: 0 or 1 4 LSBs[c]: 0 to 2^{32}-1	1
	1	0, 1 or 2	2
Bit-depth of propagation angle of the co-sinusoidal function	1	1 to 8	SCSM: 0
			1 or 2 <field not present>
Bit-depth of wavelength of co-sinusoidal function	1	1 to 8	SCSM: 0
			1 or 2 <field not present>
Bit-depth of phase	1	1 to 8	SCSM: 0 or 1
			2 and the number of spectral components to be retained per cell: 0 or 1 <field not present>
	1	1 to 8	2 and the number of spectral components to be retained per cell: 2

	Field	Size (bytes)	Valid values	Notes
	Bit-depth of magnitude			SCSM: 0 <field not present>
		1	1 to 8	1
				2 and the number of spectral components to be retained per cell: 0 <field not present>
		1	1 to 8	2 and the number of spectral components to be retained per cell: 1 or 2
	Bit-depth of quality score	1	1 to 8	
	Cell quality group granularity	1	0 to 255	(Cell quality group granularity)^2 = number of cells in cell quality group
	Reserved Bytes	2	0	

		Field	Size (bytes)	Valid values	Notes
Single finger record	Header	Finger location	1	0 to 10	
		Impression type	1	0 to 3, 8	
		Number of views in single finger record	1	1 to 255	
		Finger pattern quality	1	0 to 101	
		Length of finger pattern spectral data block	2	0 to 2^{16}-1	Length provided specifies number of bytes
	Finger pattern spectral data block	View number	1	0 to 255	
		Finger pattern spectral data	ldb	0 to $2^{(8 \times ldb)}$ -1	Data Note: Let n represent the number of bits required to represent a single cell. Then the length, ldb, (in bytes) of the finger pattern spectral data (including padding) can be calculated as follows: a = (number of cells in x-direction) × (number of cells in y-direction) × n bits b = a (modulo 8) If b = 0, then ldb = a / 8 bytes If $b \neq 0$, then ldb = (a + (8-b)) / 8 bytes The number of bits, n, required to represent a single cell will vary depending on the spectral component selection method used.

		Field	Size (bytes)	Valid values	Notes
		Cell quality data	lqd	0 to $2^{(8 \times lqd)}$ -1	Data. Present only if cell quality group granularity $\neq 0$ Note: Let g represent the cell quality group granularity and let n represent the bit-depth of the quality score for each cell quality group. Then the length, lqd, (in bytes) of the cell quality data can be calculated as follows: $a = \lfloor (\text{number of cells in } x\text{-direction}) / g \rfloor \times \lfloor (\text{number of cells in } y\text{-direction}) / g \rfloor \times n$ bits $b = a$ (modulo 8) If $b = 0$, then lqd = a / 8 bytes If $b \neq 0$, then lqd = $(a + (8 - b))$ / 8 bytes
	Extended data block	Extended data block length	2	0 to 2^{16}-1	Length provided specifies number of bytes
		Extended data area type code	2	0 to 2^{16}-1	Present only if extended data block length $\neq 0$
		Extended data area length	2	0 to 2^{16}-1	Length provided specifies number of bytes. Field present only if extended data block length $\neq 0$
		Extended data area	Length of extended data area (lda)	1 to $2^{(8 \times lda)}$ -1	Field present only if extended data block length $\neq 0$

a SCSM = Spectral Component Selection Method

b MSB = Most Significant Byte

c LSBs = Least Significant Bytes

9 Finger pattern spectral data card format

Biometric matching algorithm parameters are used to indicate implementation specific values to be observed by the outside world when computing and structuring verification data. They can be encoded as Data Objects embedded in a Biometric Information Template as defined in ISO/IEC 7816-11.

For the finger pattern spectral card[2)] format, the header entries expected by the card are recorded in the Data Object as shown below:

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

Tag	Length	Parameters	
'91'	9	**Length**	**Description**
		2	Number of pixels in cells (both x and y-direction)
		2	Number of pixels between cell centres (both x and y-direction)
		1	Bit-depth of propagation angle of co-sinusoidal function
		1	Bit-depth of wavelength of co-sinusoidal function
		1	Bit-depth of phase
		1	Bit-depth of quality score
		1	Cell quality group granularity

If this Data Object is not present in the Biometric Information Template, the default values as shown in Table 19 will apply.

Table 19 — Finger pattern spectral data card format

Field	Value
x (horizontal) Resolution	100 ppcm
y (vertical) Resolution	100 ppcm
Number of pixels in cells in x-direction	5
Number of pixels in cells in y-direction	5
Number of pixels between cell Centres in x-direction	5
Number of pixels between cell Centres in y-direction	5
Spectral component selection method	0
Bit-depth of propagation angle of co-sinusoidal function	3
Bit-depth of wavelength of co-sinusoidal function	3
Bit-depth of phase	3
Bit-depth of quality score	3
Cell quality group granularity	2

NOTE For the finger pattern spectral data card format, the full finger pattern spectral data record is submitted for storage on the card.

The number of cells in x direction is stored in 1 byte at a resolution of 100 ppcm. The number of cells in y direction is stored in 1 byte at a resolution of 100 ppcm.

Annex A
(informative)

Finger pattern spectral data record examples – quantized co-sinusoidal triplet spectral component selection method

This informative annex provides two examples of finger pattern spectral interchange data using the quantized co-sinusoidal triplet spectral component selection method.

A.1 Example 1

Table A.1 represents an example finger pattern spectral data record created using an input image of size 400×600 pixels and sampled at 500 ppi (197 ppcm), with no reduction in resolution or image cropping prior to data storage.

The cellular partitioning of the finger pattern comprises dividing the entire finger pattern into a grid of cells of dimension 5×5 pixels. The cellular representation grid thus contains 80×120 cells.

Choosing bit-depths for θ, λ and δ as 4, 3 and 3, respectively, implies that each cell requires 10 bits of data storage. Since there are 80×120 cells, the finger pattern spectral data will have size 80×120×10 bits = 96000 bits, thus requiring 12000 bytes of storage.

Choosing a value of 2 for the cell quality group granularity indicates that a cell quality group comprises 2×2 cells. For the example stated here with 80×120 cells, and a quality granularity of 2, 2400 quality scores will be required. With a quality score bit-depth of 4, this implies 1200 bytes of quality information will be included in the record.

Table A.1 — Finger pattern spectral data record – quantized co-sinusoidal triplets example 1

Field	Size (bytes)	Values
Format identifier	4	0x46535000 ('F' 'S' 'P' 0x00)
Version number	4	0x20313000 ('0' '1' '0' 0x00)
Length of record	4	13246
Number of single finger records	1	1
x (horizontal) resolution	2	197 (ppcm)
y (vertical) resolution	2	197 (ppcm)
Number of cells in x-direction	2	80
Number of cells in y-direction	2	120
Number of pixels in cells in x-direction	2	5
Number of pixels in cells in y-direction	2	5
Number of pixels between cell centres in x-direction	2	5
Number of pixels between cell centres in y-direction	2	5
Spectral component selection method	1	0

Field	Size (bytes)	Values
Bit-depth of propagation angle of co-sinusoidal function	1	4
Bit-depth of wavelength of co-sinusoidal function	1	3
Bit-depth of phase	1	3
Bit-depth of quality score	1	4
Cell quality group granularity	1	2
Reserved bytes	2	0
Finger location	1	2
Impression type	1	0
Number of views in single finger record	1	1
Finger pattern quality	1	80
Length of finger pattern spectral data block	2	13201
View number	1	0
Finger pattern spectral data	12000	<data>
Cell quality data	1200	<data>
Extended data block length	2	0

A.2 Example 2

The following table represents an example finger pattern spectral data record created using an input image of size 400×600 pixels and sampled at 500 ppi, as in example 1, but with reduction in resolution and image cropping performed.

The example image is first cropped to 300×400 pixels and then re-sampled to 200 ppi (79 ppcm), to produce a finger pattern of dimension 120×160 pixels.

In this example, the cellular partitioning of the finger pattern comprises dividing the entire portion of the finger pattern into a grid of cells of dimension 5×5 pixels. The cellular representation grid thus contains 24×32 cells.

Choosing bit-depths for θ, λ and δ as 4, 3 and 3, respectively, implies there are $2^4 \times 2^3 \times 2^3 = 1024$ possible co-sinusoidal triplets (and corresponding cell structures) in the quantized set. The actual finger pattern cell will be represented by the most similar of the 1024 cell structures (using the closest match approach steps outlined in 7.4.1). Each cell requires 10 bits of data storage, reduced from 200 bits per cell (recall that in this example a cell consists of a grid of 5×5 pixels, each pixel represented by 1 byte = 8 bits, thus giving 5×5×8 = 200 bits of information). The resulting data will comprise the majority of the finger pattern spectral data record.

Since there are 24×32 cells in this example, the finger pattern is represented by 24×32×10 bits = 7680 bits, thus requiring 960 bytes of storage.

Choosing a value of 2 for the cell quality group granularity indicates that a cell quality group comprises 2×2 cells. For the example stated here with 24×32 cells, and a quality granularity of 2, 192 quality scores will be required. With a quality score bit-depth of 4, this implies 96 bytes of quality information will be included in the record.

This data record thus occupies a total of 1102 bytes. The values for the example record are provided in Table A.2 (all values, except the format identifier and version number, are given in decimal form).

