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Biometric Data Interchange Formats —

Part 3: Finger Pattern Spectral Data

Élément introductif — Élément principal — Partie n: Titre de la partie

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ISO/IEC CD 19794-3

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Foreword

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

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

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

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

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

ISO/IEC 19794 consists of the following parts, under the general title 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 Data

— *Part 8:* Finger Pattern Skeletal Data

ISO/IEC CD 19794-3

FINGER PATTERN SPECTRAL DATA FORMAT

Introduction

In the interest of implementing interoperable personal biometric recognition systems, this ISO/IEC Standard establishes a data interchange format for fingerprint spectral data exchange. Goal of the standard: 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. Further, we wish the standard to be useful to many aspects of the fingerprint recognition process, possibly including flow field extraction, level 1 characterization, "core" location, quality assessment, comparison methods, and (possibly) "privacy" assurance.

This standard would allow for representation of both 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.

Previous versions of this proposed standard will be seen as a particular example of this standard using non-overlapping local areas and retaining the phase, wavelength and offset of the highest energy spectral components from each local "cell". This standard 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" 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 format that can be used with portable devices and media, such as smart cards.
•Encourage the adoption of biometrics in applications where interoperability is required.

Note that it is recommended that biometric data protection techniques in ANSI/X9 X9.84 or ISO/IEC 15408:1999 are used to safeguard the biometric data defined herein for confidentiality, integrity and availability.

1 Scope

This standard specifies the interchange format for the exchange of spectral-based fingerprint characterization data.

2 Conformance

A biometric system or algorithm conforms to this standard if it satisfies the mandatory requirements for the generation of the finger pattern spectral cell information as defined in section 5 and the generation of the data record as described in section 6.

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.
ANSI/INCITS 358-2002 - Information technology - BioAPI Specification
ANSI/NIST-ITL 1-2000, Standard Data Format for the Interchange of Fingerprint, Facial, & Scar mark & Tattoo (SMT) Information
ISO/IEC CD3 19785-1.3 - Common Biometric Exchange Formats Framework (CBEFF)
ISO/IEC 15408:1999 - Evaluation criteria for IT security

4 Terms and definitions

For the purposes of this -International Standard, the following terms and definitions apply.

4.1 Biometric measure

A measurable, physical characteristic or personal behavioural trait used to recognize individuals.

4.2 Biometric Matching Algorithm

A sequence of instructions used by a biometric system to process biometric information. A biometric matching algorithm is used by the biometric system to compute whether a biometric sample and a reference template/model originate from the same source (the same human body).

4.3 Biometric Data

Information extracted from a biometric sample and used either to build a reference template (template data), reference model, or to compare against a previously created reference template (comparison data) or model.

4.4 Biometric Sample

Raw data representing a biometric characteristic of an end-user as captured by a biometric system (for example, the image of a fingerprint).

4.5 Biometric System

An automated system capable of:
capturing a biometric sample from an end user;
extracting biometric data from that sample;
comparing the biometric data with that contained in one or more reference templates or models;
deciding how well they match; and
indicating whether or not a recognition has been made.

4.6 Bit-Depth

The number of bits used to represent a data record parameter.

4.7 Capture

The method of taking a biometric sample from the end user.

4.8 Cell

Overlapping or non-overlapping regions of a fingerprint image (see 4.17) of single size across the entire image. Multi-scale cells are not accommodated in this standard.

4.9 Cell Structure

Structure used to represent the information contents of cell.

4.10 Cell Quality Group

The Group of Cells to which the Finger Quality parameter refers.

4.11 Comparison

The process of measuring the similarity or difference between a biometric sample and a previously stored reference template or pattern generated by a model.

4.12 Crop

Remove the outer regions of an image to reduce the size.

4.13 Dimension

Number of pixels in an acquired biometric sample image either x- or y-direction.

4.14 Down-sample

Reduce the resolution of an image by re-sampling the image with a reduced number of pixels. Proper filtering is implied to prevent aliasing.

4.15 Encryption

The act of converting plain text into cipher-text through a reversible mathematical process.

4.16 Enrollment

The process of collecting biometric samples from an individual and the subsequent preparation and storage of biometric reference templates or models.

4.17 Reduced resolution finger image

Sub-portion and/or down-sampled version of a raw fingerprint image (see 4.22).

4.18 Finger Pattern Spectral Data Interchange Data

Spectral data derived from the Finger Pattern.

4.19 Minimal Spatial Wavelength

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

4.20 Packed Data Format

Data are stored in a compacted bit form with no record separators or field tags - fields are separated by bit count only.

4.21 Pad

Embed an image in a larger array (usually filled with zeroes) to produce a resulting image of greater dimension.

4.22 Raw Fingerprint Image

Biometric sample as captured by a fingerprint sensor. This raw image will usually retain the full resolution and spatial extent permitted by the sensor.

4.23 Reference Template

Processed Biometric Data stored as representative of the user’s biometric sample.

4.24 Resolution

The number of picture elements (pixels) per unit length in a sampled fingerprint image. Pixels per cm (ppcm) will be used in this standard as the units of resolution. Note that 1 pixel per cm (ppcm) = 2.54 pixels per inch (ppi).

4.25 Template Size

The amount of computer (or storage medium) memory taken up by the biometric reference template.

5 Finger Pattern Spectral Interchange Data

5.1 Overview

This ISO/IEC standard for finger pattern spectral interchange data is based on:
1) conversion of the raw fingerprint image to a cropped and down-sampled finger pattern, followed by;
2) cellular representation of the finger pattern image to create the finger pattern spectral interchange data.

5.2 Step 1) Reduction in resolution

Spectral pattern-based fingerprint processing may require less image resolution than is traditionally provided by sensors. Therefore, the first step in data reduction typically involves a re-sampling of the data to a lower resolution.

5.3 Step 2) Cellular Representation

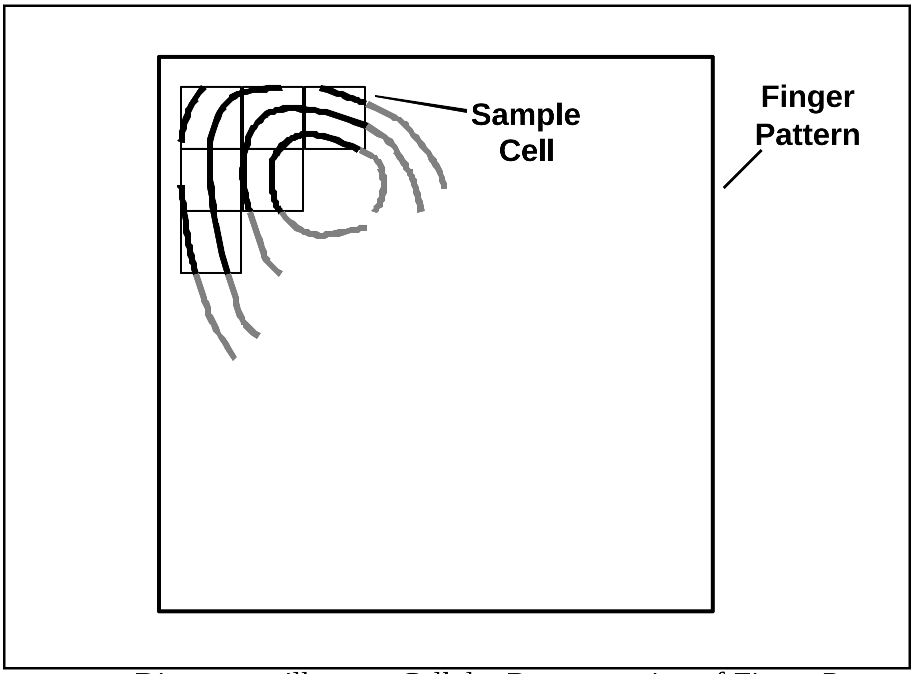


Figure 1. Diagram to illustrate Cellular Representation of Finger Pattern.

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. At each cell, the finger pattern will be represented by one of a number of different cell structures, as described below.

5.3.1 Cell Structure

Each of the cells can be decomposed into a two-dimensional spectral representation. In the case of square cells of side N, a two-dimensional Discrete Fourier Transform (DFT) will result in N/2 complex spectral components in one dimension and N complex components in the other. Each component will be characterized by a wavelength in the x and y directions (which combined indicate propagation direction), an amplitude, and a phase. For each spectral component, the spatial frequency,f, is given by SQRT($f^2_x + f^2_y$). The wavelength, λ, is given by the inverse of the spatial frequency. The propagation angle, θ, for each component is given by ARCTAN (f_y, f_x).

In the case of the cell dimension being the same as that of the entire image, the DFT spectral representation becomes a global decomposition. An NxM image will have N/2 by M/2 discrete frequencies in spectral decomposition. If all N*M/4 frequency magnitude/phase or complex components are stored, the image can be exactly reconstructed by these N*M/2 components. 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 two-dimensional spectral decomposition of an entire image using a 2-d Discrete Fourier Transform (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 pixel wavelength when the original sampling is at 500dpi. Of course other image resolutions will have different spatial wavelengths.

In the case of cell dimensions on the order of a ridge wavelength, the DFT spectral decomposition of the finger pattern may be dominated by a single component of high amplitude and a spatial wavelength on the order of the finger pattern ridge wavelength. Such a case is shown in Figure 2.

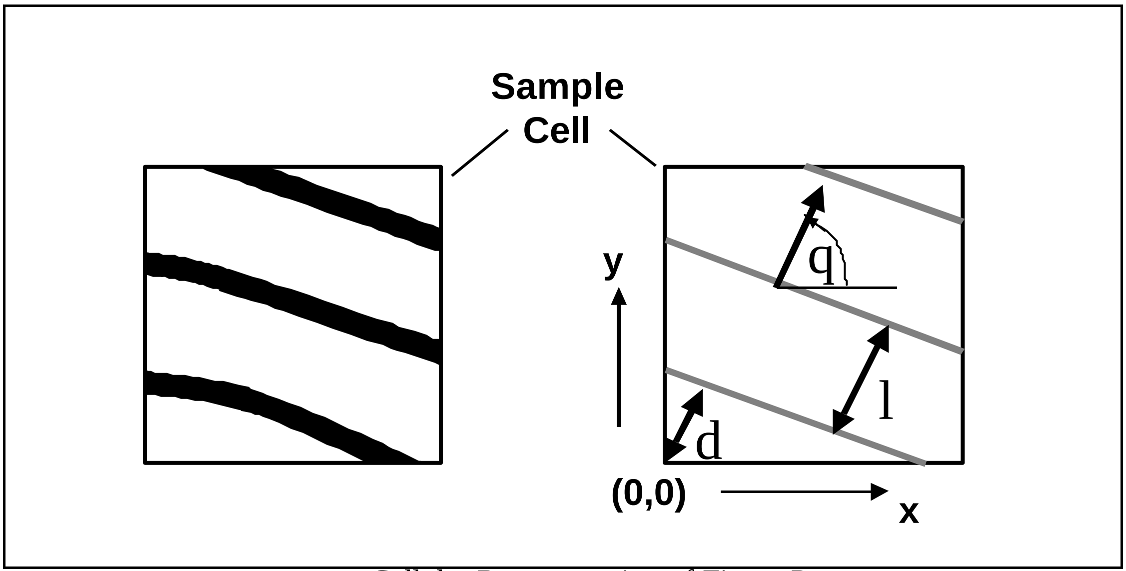


Figure 2. Cellular Representation of Finger Pattern.

The range of each of these parameters is given below:
θ: 0 to 180 degrees

- Note that 0 degrees is defined as parallel to the x, or horizontal, axis, and θ increases in a counter-clockwise rotation.

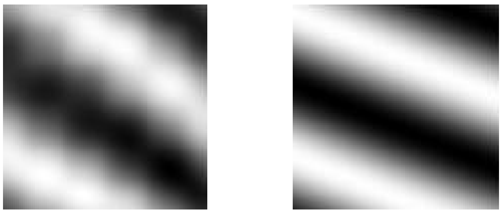
λ, minimal spatial wavelength to ∞ (but limited in practice to twice the number of pixels across the longest diagonal in the image)

f: 0 to Maximal Spatial Frequency

δ: 0 to 360 degrees

- Note that δ is defined between the origin of the cell (at the bottom-left corner) and the location of the first crest of the co-sinusoidal function in a positive direction in either x or y (or both) directions.

Figure 3 below demonstrates an example of the primary spectral component of a finger pattern cell of size on the order of a ridge wavelength. Both of the images in this figure were enhanced for illustrative purposes.



a) **b)**

Figure 3. a) Example of the local finger pattern information in a cell, and b) the resulting cell structure chosen for representation.

In this manner, each of the finger pattern cells is represented by one of the possible permutations of cell structure. In the case of cells of size on the order of a ridge wavelength, the resulting data will comprise the majority of the public portion of the Finger Pattern Spectral Data Record.

Note that in the case of a cell containing a bifurcation, a ridge ending, or both, the cell permutation shall be chosen purely on the basis of finding the closest matching candidate cell structure with the information contained within the cell.

To prevent aliasing 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. This standard accommodates the reporting of Gabor amplitudes for each of the selected filters on each cell.

5.4 Quality

For each group of cells defined above, a quality parameter provides an indication of the quality of the information in that group of cells, with higher numbers indicating better quality. 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 1x1 cells; and a value of 2 indicates that a group comprises 2x2 cells. Some factors that contribute to the quality of the finger pattern cell information are gray scale resolution, gray scale linearity, spatial distortions, and location of the finger core within the raw fingerprint image.

6 Finger Pattern Spectral Data Record

6.1 Introduction

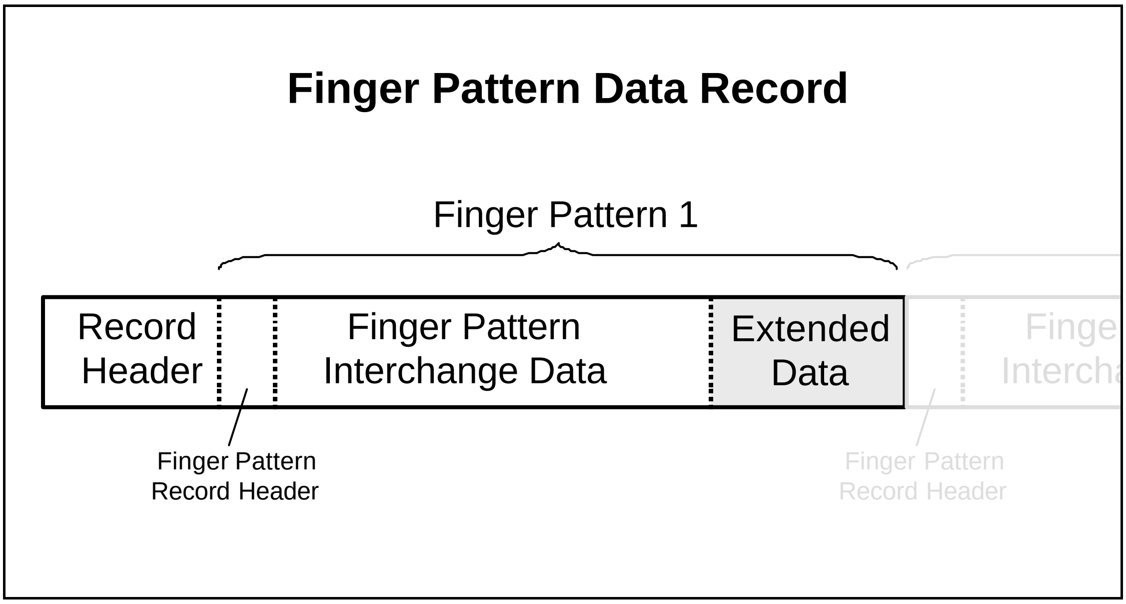
The finger pattern spectral data record format is used to provide interoperability between fingerprint recognition systems using spectral data in some way. The record format contains both public and extended (proprietary) finger pattern spectral interchange data. With the exception of the Format Identifier and the Version number for the standard, which are null-terminated ASCII character strings, all data is represented in binary format. There are no record separators or field tags; fields are parsed by byte count. The biometric data record specified in this standard shall be embedded in a CBEFF-compliant structure in the CBEFF Biometric Data Block (BDB).

The BDB_PID shall be defined by CBEFF. The CBEFF BDB_biometric_organization shall be assigned by the International Biometric Industry Association (IBIA) to JTC 1 SC 37 shall be used. This is the sixteen bit value 0x0101 (hexadecimal 101 or decimal 257). There are two different CBEFF BDB_format codes codes assigned to this standard: one for a record without an extended data portion, and one for a format with the extended data portion. If the record has no extended data, the associated CBEFF BDB_format shall be the sixteen-bit value 0x0301; if the record has an extended area, the associated CBEFF BDB_format shall be the sixteen-bit value 0x0302.

The organization of the record is as follows:
A fixed-length (49 bytes) Record Header containing information about the overall record, including the number of fingers represented and the overall record length in bytes;

A single Finger Pattern Spectral Data Record for each finger, consisting of:
Fixed length header (8 bytes) containing information about the data for a single finger
Finger pattern spectral interchange data block (the block of cell data is followed by a block of quality data).

Extended data block - containing vendor-specific data.



All multi-byte quantities are represented in Big-Endian format; that is, the more significant bytes of any multibyte quantity are stored at lower addresses in memory than (and are transmitted before) less significant bytes. All numeric values are fixed-length integer quantities, and are unsigned quantities.

6.2 Record Header

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

6.2.1 Format Identifier

For this standard, the Format Identifier shall consist of three characters "FPR" followed by the null character (0x0).

6.2.2 Version Number

The version number for the version of this standard used in constructing the pattern spectral record shall be placed in four bytes. This version number shall consist of three ASCII numerals followed by a zero byte as a NULL string terminator. The first and second character will represent the major revision number and the third character will represent the minor revision number. Upon approval of this specification, the version number shall be " 10" (an ASCII space followed by an ASCII '1' and an ASCII '0').

6.2.3 Length of Record

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

6.2.4 Capture Device ID

The Capture Device ID shall be recorded in two bytes. A value of all zeros will be acceptable and will indicate that the Capture Device ID is unreported.

6.2.5 Number of Finger Patterns in Record

The total number of finger patterns in the record shall be contained in 1 byte.

6.2.6 Resolution of Finger Pattern in x-direction

The resolution (in ppcm) of the finger image(s) in the x-direction shall be record in 2 bytes. The stored valued shall be ROUND(ppcm).

6.2.7 Resolution of Finger Pattern in y-direction

The resolution (in ppcm) of the finger images(s) in the y-direction shall be record in 2 bytes. The stored valued shall be ROUND(ppcm).

6.2.8 Number of Cells in x-direction

The number of finger pattern cells in the x-direction shall be recorded in 1 byte.

6.2.9 Number of Cells in y-direction

The number of finger pattern cells in the y-direction shall be recorded in 1 byte.

6.2.10 Number of Pixels in Cells in x-direction

The number of pixels in the x-direction of each cell shall be recorded in 2 bytes.

6.2.11 Number of Pixels in Cells in y-direction

The number of pixels in the y-direction of each cell shall be recorded in 2 bytes.

6.2.12 Cellular x-offset

The number of pixels in the x-direction of the finger image before the first cell shall be recorded in 1 byte.

6.2.13 Cellular y-offset

The number of pixels in the y-direction of the finger image before the first cell shall be recorded in 1 byte.

6.2.14 Number of Pixels between Cell Centers in x-direction

The number of pixels in the x-direction of the finger image between centers of adjacent or overlapping cells. This will require 1 byte.

6.2.15 Number of Pixels between Cell Centers in y-direction

The number of pixels in the y-direction of the finger image between centers of adjacent or overlapping cells. This will require 1 byte.

6.2.16 Number of Components Extracted from each cell

Number of DFT components or filters applied to each cell. Not all of these components are necessarily stored in the record. This will require 2 bytes.

6.2.17 Type of window

This field will specify any window used on the cells prior to spectral decomposition and the window parameters. In the case of Gabor filtering, this field will specify Gaussian window and give the value of the single Gaussian parameter, σ, in units of pixels. Multi-scale windowing parameters will not be accommodated. This will require 2 bytes.

6.2.18 Wavelength and angle generating mechanism for each filter

This field is used for specifying the wavelength parameters of the Gabor filters used on the cells. Values for all of the filter outputs might not be saved, however, in the record. Multi-scale Gabor filtering will not be accommodated. In the case of two-dimensional DFT, this field can simply indicate DFT. This will require 1 byte.

6.2.19 Method for selecting retained components

This field will specify retention of all components, the K highest energy components or components above a threshold energy. This will require 1 byte.

6.2.20 Naming and ordering of retained components

In the case where only some of the spectral components are retained, it will be necessary to specify the meaning of each of the stored components. Example of data in the field – (Spatial wavelength, magnitude, propagation angle, magnitude, phase angle, magnitude) or (x wavelength, complex magnitude, y wavelength, complex magnitude). This will require 1 byte.

6.2.21 Bit-depth of Cell Structure Angle

The bit-depth used to represent the Cell Structure Angle shall be recorded in 1 byte.

6.2.22 Bit-depth of Cell Structure Wavelength

The bit-depth used to represent the Cell Structure Wavelength shall be recorded in 1 byte.

6.2.23 Bit-depth of Cell Structure Phase Offset

The bit-depth used to represent the Cell Structure Phase Offset shall be recorded in 1 byte.

6.2.24 Bit-depth of Cell Structure Quality

The bit-depth used to represent the Cell Structure Quality shall be recorded in 1 byte.

6.2.25 Cell Quality Granularity

The granularity of the cell quality shall be recorded in 1 byte. The granularity is calculated as SQRT(Number of Cells in Cell Quality Group).

6.2.26 Reserved Bytes

Two bytes are reserved for future revision of this specification. For Version 1.0 of this standard, these byte values must be set to 0.

6.3 Single Finger Pattern Spectral Record Format

6.3.1 Finger Pattern Record Header

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

6.3.1.1 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 1 for convenience. Only codes 0 through 10 shall be used; the "plain" codes are not relevant for this standard.

Table 1 - 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*

6.3.1.2 Impression type

The impression type of the finger image(s) shall be recorded in this one byte field. Nonlive entries refer to images scanned from cards or other media. These codes are compatible with Table 4 of ANSI/NIST-ITL 1-200, "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 standard.

Table 2 - 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

6.3.1.3 Number of Views in Finger Pattern

Some systems may have more than one finger record for the same finger. Each of these records represents a different view of the finger. The total number of views within each Finger Pattern Record shall be recorded in 1 byte.

6.3.1.4 Finger Pattern Quality

The quality of the overall finger pattern shall be between 0 and 100 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 will be set in accordance with the general guidelines contained in Section 2.1.42 of ANSI/INCITS 358-2002, "BioAPI H-Level Specification Version 1.1". Further, a quality value of 101 indicates that the raw image from which the finger pattern was derived complied with Appendix F of the Electronic Fingerprint Transmission Specification (http://www.fbi.gov/hq/cjisd/iafis/efts_70.pdf).

6.3.1.5 Length of Data Block

The total length of the finger data block (including the extended data) shall be contained in 2 bytes.

6.3.2 Finger Pattern Spectral Data

6.3.2.1 Finger Pattern Spectral Interchange Data

6.3.2.1.1 View Number

Preceding the Finger Pattern Cell Data is the View Number, which is a number starting from 0 that sequentially identifies each of the views of a finger contained in this finger pattern record. The view number shall be recorded in 1 byte.

6.3.2.1.2 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 first row and then subsequent rows are stored.

6.3.2.1.3 Cell Quality Data

The Cell Quality Data shall follow the Finger Pattern Spectral Data and shall be stored in an identical manner, starting with the upper left value.

6.3.3 Extended Data

The extended data section of the finger pattern spectral 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 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.

6.3.3.1 Extended Data Fields

6.3.3.1.1 Extended Data Block Length

All finger pattern spectral interchange data records shall contain the extended data block length. This field will signify the existence of extended data. A value of all zeros (0x0000 hexadecimal) will indicate that there is no extended data and that the file will end or continue with the next finger view. A nonzero value will indicate the length of all extended data starting with the next byte. The block length (6.3.3.1.1) will then be followed by the type identification code (6.3.3.1.2), length of data field (6.3.3.1.3) and the data area (6.3.3.1.4). This will require two bytes.

6.3.3.1.2 Extended Data Area Type Code

The type identification code shall be recorded in two bytes, and shall distinguish the format of the extended data area (as defined by the Vendor specified by the PID code in the CBEFF header). A value of zero in both bytes is a reserved value and shall not be used. A value of zero in the first byte, followed by a non-zero value in the second byte, shall indicate that the extended data section has a format defined in this standard. A non-zero value in the first byte shall indicate a vendor specified format, with a code maintained by the vendor. Refer to Table 3 for a summary of the type identification codes. If the Extended Data Block Length (6.3.3.1.1) for the finger view is zero, indicating no extended data, this field shall not be present.

Table 3 - Extended Data Area Type Codes

First byte	Second byte	Identification
0x00	0x00	Reserved
0x00	0x01	reserved
0x00	0x02	core and delta data (Section 6.3.3.3)
0x00	0x03	Reserved
0x00	0x04-0xFF	Reserved
0x01-0xFF	0x00	Reserved
0x01-0xFF	0x01-0xFF	vendor-defined extended data

6.3.3.1.3 Extended Data Area Length

The length of the extended data section, 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 (6.3.3.1.1) for the finger view is zero, indicating no extended data, this field shall not be present.

6.3.3.1.4 Data Section

The data field of the extended data 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 standard. If the Extended Data Block Length (6.3.3.1.1) for the finger view is zero, indicating no extended data, this field shall not be present.

6.3.3.2 Core and Delta Data Format

If the extended data area type code is 0x0002, the extended data area contains core and delta information. This format is provided to contain optional information about the placement and characteristics of the cores and deltas on the original fingerprint image. Core and delta points are determined by the overall pattern of ridges in the fingerprint. There may be one 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 core and delta information shall be represented as follows. The first byte shall contain the core information type and the number of core points included; legal values are 0 or greater. This length byte shall be followed by the position and angular information for the cores. The next byte shall contain the delta information type and the number of delta points included; legal values are 0 or greater. This length byte shall be followed by the position and angular information for the deltas.

6.3.3.2.1 Core Information Type

The core information type shall be recorded in the first two bits of the upper byte of the number of cores. The bits "01" will indicate that the core has angular information while "00" will indicate that no angular information is relevant for the core type. If this field is "00", then the angle fields shall not be present for the cores.

6.3.3.2.2 Number of Cores

The number of core points represented shall be recorded in the least significant four bits of this byte. Valid values are from 0 to 15.

6.3.3.2.3 Core Position

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

6.3.3.2.4 Core Angle

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 Section 6.3.3.2.1), then this field shall not be present.

6.3.3.2.5 Delta Information Type

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

6.3.3.2.6 Number of Deltas

The number of delta points represented shall be recorded in the least significant four bits of this byte. Valid values are from 0 to 15.

6.3.3.2.7 Delta Position

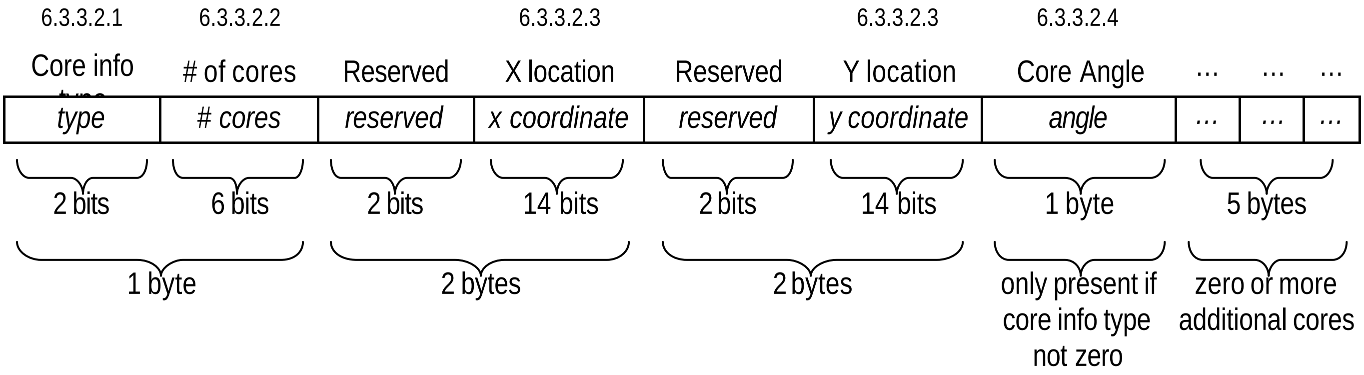
The X coordinate of the delta shall be recorded in the lower fourteen bits of the first two bytes (fourteen bits). The Y coordinate shall be placed in the lower fourteen bits of the following two bytes. The coordinates shall be expressed in pixels at the resolution indicated in the record header.

6.3.3.2.8 Delta Angles

The three angle attributes of the delta shall each be recorded in one byte in units of 1.40625 (360/256) degrees. The value shall be a non-negative value between 0 and 255, inclusive. For example, an angle value of 16 represents 22.5 degrees. If the delta information type is zero (see Section 6.3.3.2.5), then this field shall not be present.

6.3.3.2.9 Core and Delta Format Summary

The core and delta format shall be as follows:



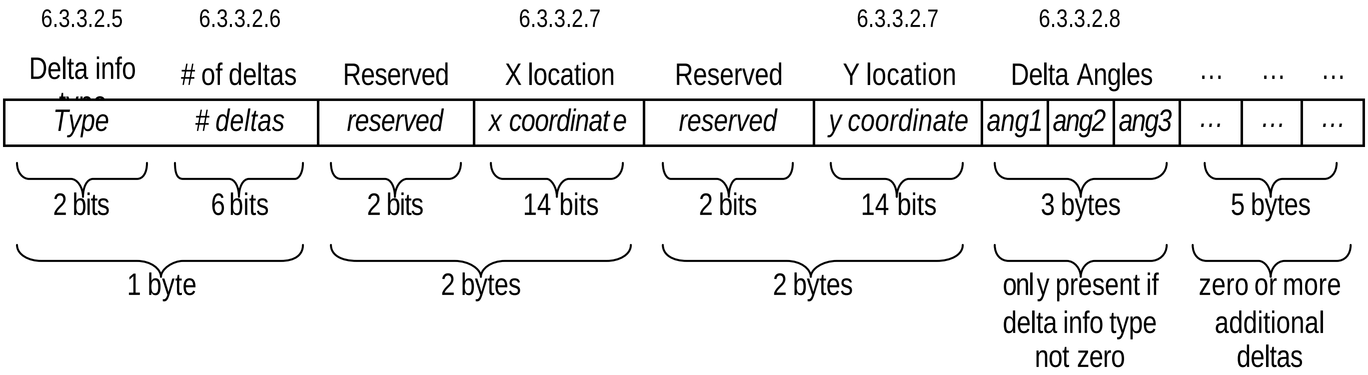


Table 4. Summary of Finger Pattern Spectral Data Record

Record Header			
Field	Size	Valid values	Reference
Format Identifier	4 bytes	0x46505200 ('F 'P 'R 0x0)	6.2.1
Version Number	4 bytes		6.2.2
Length of Record	4 bytes		6.2.3
Capture Device ID	2 bytes		6.2.4
Number of Finger Patterns in Record	1 byte	1-255	6.2.5
Resolution of finger pattern in x-direction ROUND(ppcm)	2 bytes	1-788	6.2.6
Resolution of finger pattern in y-direction ROUND(ppcm)	2 bytes	1-788	6.2.7
Number of Cells in x-direction	2 bytes	1-(size of finger pattern in x-direction)	6.2.8
Number of Cells in y-direction	2 bytes	1-(size of finger pattern in y-direction)	6.2.9
Number of Pixels in Cells in x-direction	2 bytes	1-(size of finger pattern in x-direction)	6.2.10
Number of Pixels in Cells in y-direction	2 bytes	1-(size of finger pattern in y-direction)	6.2.11
Cellular x-offset	2 bytes	0 - (size of finger pattern in x-direction)	6.2.12
Cellular y-offset	2 bytes	0 - (size of finger pattern in y-direction)	6.2.13
Number of Pixels between Cell Centers in x-direction	2 bytes	0 – (size of finger pattern in x-direction)	6.2.14
Number of Pixels between Cell Centers in y-direction	2 bytes	0 – (size of finger pattern in x-direction)	6.2.15

Number of components extracted from each cell	2 bytes	1 – (total number of pixels in the cell)	6.2.16
Type of window and parameter	2 bytes	Name of window and controlling parameters	6.2.17
Wavelength and angle generating mechanism for filters	1 byte	Starting spatial wavelength and delta wavelength, or listing of wavelengths; starting angle and delta angle, or listing of angles	6.2.18
Method of selecting retained components	1 byte	All, top k energy, components above an energy thr eshold	6.2.19
Naming and ordering of retained components	1 byte	Naming of component descriptors and component values	6.2.20
Bit-depth of Cell Structure Angle	1 byte	1-8	6.2.21
Bit-depth of Cell Structure Wavelength	1 byte	1-8	6.2.22
Bit-depth of Cell Structure Phase Offset	1 byte	1-8	6.2.23
Bit-depth of Cell Structure Quality	1 byte	1-8	6.2.24
Cell Quality Granularity	1 byte	1-8	6.2.25
Reserved Bytes	2 bytes		6.2.26
Finger Pattern Spectral Record Header			
Field	Size	Values	Reference
Finger Location Impression Type	1 byte 1 byte	0-11 0-5	Table 1 Table 2
Number of Views in Finger Pattern Record	1 byte	0-255	6.3.1.3
Fingerprint Pattern Quality	1 byte	0-100	6.3.1.4

Length of data block (in bytes) including extended data	2 bytes		6.3.1.5
Extended Data Block Length	2 bytes		6.3.3.1.1

Finger Pattern Spectral Data			
Field	Size	Content	Reference
View Number	1 byte		6.3.2.1.1
Finger pattern spectral Cell Data			6.3.2.1.2
Cell Quality Data			6.3.2.1.3
Finger pattern spectral Extended Data			6.3.3

7 Annex A (informative) - Finger Pattern Spectral Data Record Example 1

This informative annex provides an example of finger pattern spectral interchange data.

A.1 Reduction in Resolution

An example of a re-sampled image is shown below in figure 5, where an original 128x128 image, sampled at 98.5 ppcm (250 ppi), is first cropped to 120x120 pixels and then re-sampled to 78.8 ppcm (200 ppi), to produce an image of dimensions 96x96 pixels.

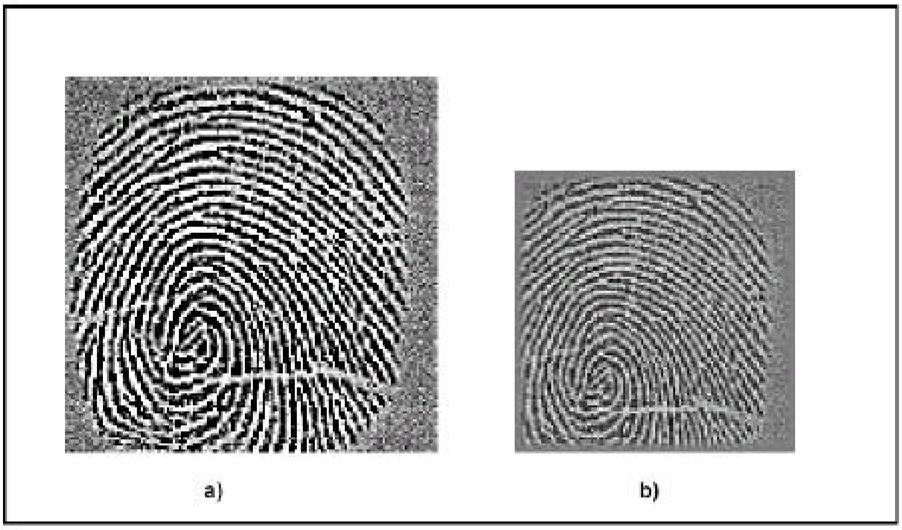


Figure 5. a) original 128x128 image sampled at 98.5 ppcm (250 ppi). b) resulting image after cropping image in a) to 120x120 pixels, and re-sampling image at 78.8 ppcm (200 ppi), to produce a 96x96 pixel dimensioned array.

A.2 Cellular Representation

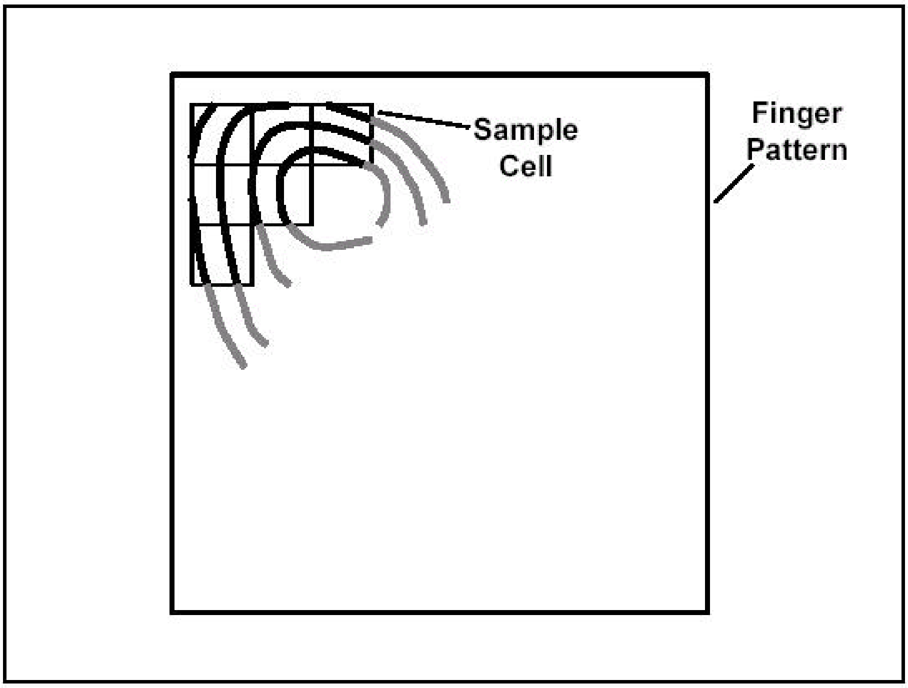


Figure 6. Diagram to illustrate Cellular Representation of Finger Pattern.

In this example, the cellular representation of the finger pattern spectral data comprises dividing the central portion (at an offset of 13 pixels in the x-direction and 8 pixels in the y-direction) of the finger pattern into a grid of cells of dimension 5x5 pixels. Therefore, the cellular representation grid contains 14x16 cells, which represents an image area of 70x80 pixels, or 8.9x10.1 mm. At each cell the finger pattern will be represented by one of 1024 different cell structures, as described below.

A.3 Cell Structure

Each of the candidate cell structures for representing the local finger pattern spectral data at each cell is defined by a two dimensional cosinusoidal pattern (see figures 7)

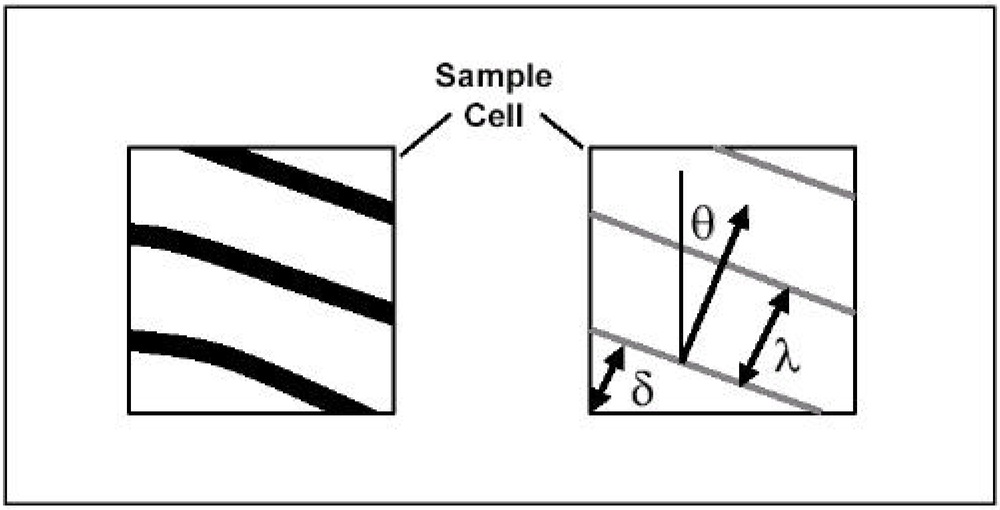


Figure 7. Cellular Representation of Finger Pattern.

The range and resolution of each of these parameters for this example is given below:
θ: 0 to 180 degrees (16 equal increments - i.e. 4 bits of information).
λ: 0 to 7/8 of the wavelength of the Maximal Spatial Frequency (8 increments - i.e. 3 bits of information). Therefore, for this 78.8 ppcm (200 ppi) example, a spatial frequency of 0 to 3.4 line pairs per mm is represented).
δ: 0 to 315 degrees (8 equal increments - i.e. 3 bits of information). In this example, each of the finger pattern cells is represented by the most similar of the 1024 (16x8x8) permutations of cell structure. Therefore, each cell structure requires 10 bits of data storage (reduced from 5x5x8 bits = 200 bits per cell). In this manner, each of the finger pattern cells is represented by one of the 1024 permutations of cell structure. The resulting data will comprise the majority of the public portion of the Finger Pattern Spectral Data Record. In this example, the finger pattern is represented by 14x16x10 bits (14 cells by 16 cells by 10 bits), which requires 280 bytes of storage.

A.4 Quality

A value of 2 indicates that a group comprises 2x2 cells. For the example stated here with 14x16 cells, and a quality granularity of 2 (2x2 cells), 56 quality parameter values will be required, at a bit-depth of 4, thus adding 28 bytes to the interchange data.

A.5 Data Record

For the example stated here, the data record comprises the following values and occupies a total of 365 bytes:

Table 5. Finger Pattern Spectral Data Record

Record Header		
Field	Size	Value
Format Identifier	4 bytes	0x46505200 ('F 'P 'R 0x0)
Version Number	4 bytes	
Length of Record	4 bytes	365
Capture Device ID	2 bytes	
Number of Finger Patterns in Record	1 byte	1
Image Resolution of finger pattern in x-direction ROUND(ppcm)	2 bytes	79
Image Resolution of finger pattern in y-direction ROUND(ppmm)	2 bytes	79
Number of Cells in x-direction	2 bytes	14
Number of Cells in y-direction	2 bytes	16
Number of Pixels in Cells in x-direction	2 bytes	5
Number of Pixels in Cells in y-direction	2 bytes	5
Cellular x-offset	2 bytes	13
Cellular y-offset Number of Pixels between Cell Centers in x-direction	2 bytes 2 bytes	8 5
Number of Pixels between Cell Centers in y-direction	2 bytes	5
Number of components extracted from each cell	2 bytes	16

Type of window and parameter	2 bytes	G,3
Wavelength and angle generating mechanism for filters	1 bytes	14 (only spatial wavelength), 0 (Starting angle), 11.3 degrees (delta angle)
Method of selecting retained components	1 byte	top 1 energy
Naming and ordering of components	1 byte	Angle, wavelength, phase
Bit-depth of Cell Structure Angle	1 byte	4
Bit-depth of Cell Structure Wavelength	1 byte	3
Bit-depth of Cell Structure Phase Offset	1 byte	3
Bit-depth of Cell Structure Quality	1 byte	4
Cell Quality Granularity	1 byte	2
Reserved Bytes	2 byte	
Field	Size	Value
Finger Location	1 byte	2
Finger Impression	1 byte	0
View Number	1 byte	0
Fingerprint Pattern Quality	1 byte	80
Length of data block (in bytes) including private data	2 bytes	308
Extended Data Block Length	2 bytes	0
Finger Pattern Cell Data	308 bytes	
Finger pattern spectral Extended Data	0 bytes	

8 Annex B (informative) - Finger Pattern Spectral Data Record Example 2

This informative annex provides an example of finger pattern spectral interchange data for a global DFT on a 400x600 pixel image with retention of all components to allow lossless invertibility.

B.1 Cell structure
In this example, there is one cell for each finger view. The 400 x 600 pixel images are padded with zeros equally on left and right sides and equally top and bottom to create a 512x1024 image. A global DFT is performed with retention of all components 512x512 complex components to allow lossless invertibility. There will be no windowing.

The Nyquist number of components will be generated (in this case 512). Selection criteria will be all Nyquist frequencies, N. All 524,288 components will be retained as complex (C) coefficients (requiring TBD bytes of storage each).

Table 6. Finger Pattern Spectral Data Record

Record Header		
Field	Size	Value
Format Identifier	4 bytes	0x46505200 ('F 'P 'R 0x0)
Version Number	4 bytes	
Length of Record	4 bytes	TBD
Capture Device ID	2 bytes	
Number of Finger Patterns in Record	1 byte	1
Image Resolution of finger pattern in x-direction ROUND(ppcm)	2 bytes	79
Image Resolution of finger pattern in y-direction ROUND(ppmm)	2 bytes	79
Number of Cells in x-direction	2 bytes	1
Number of Cells in y-direction	2 bytes	1
Number of Pixels in Cells in x-direction	2 bytes	512
Number of Pixels in Cells in y-direction	2 bytes	1024
Cellular x-offset	2 bytes	0
Cellular y-offset	2 bytes	0

Number of Pixels between Cell Centers in x-direction	2 bytes	0
Number of Pixels between Cell Centers in y-direction	2 bytes	0
Number of components extracted from each cell	2 bytes	524,288
Type of window and parameter	2 bytes	0
Wavelength and angle generating mechanism for filters	1 byte	Nyquist
Method of selecting retained components	1 byte	All
Naming and ordering of components	1 byte	x-wavelength, complex amplitude, y-wavelength, complex amplitude
Bit-depth of Cell Structure Angle	1 byte	4
Bit-depth of Cell Structure Wavelength	1 byte	3
Bit-depth of Cell Structure Phase Offset	1 byte	3
Bit-depth of Cell Structure Quality	1 byte	4
Cell Quality Granularity	1 byte	2
Reserved Bytes	2 byte	
Field	Size	Value
Finger Location	1 byte	2
Finger Impression	1 byte	0
Number of Views	1 byte	1
View Number	1 byte	0
Fingerprint Pattern Quality	1 byte	80

Length of data block (in bytes) including private data	2 bytes	TBD
Extended Data Block Length	2 bytes	0

9 Annex C (informative) - Finger Pattern Spectral Data Record Example 3

This informative annex provides an example of finger pattern spectral interchange data for a ridge flow field extracted on a 400x600 pixel image using Gabor filters on 15x15 regions with 7 pixel overlap.

C.1 Cell structure
In this example, there are 53 cells in the x-direction and 80 cells in the y-direction for one finger view. 18 Gabor filters are used with wavelength of 14 pixels and Gaussian parameter of 3 pixels. Angle of rotation of successive filters is 10 degrees, starting from 0 degrees, as shown in Figure 7. Only the angle of rotation of the filter with highest energy will be retained, but 90 degrees will be added to this angle so that the ridge flow, not the filter orientation, will be indicated.

Table 7. Finger Pattern Spectral Data Record

Record Header		
Field	Size	Value
Format Identifier	4 bytes	0x46505200 ('F 'P 'R 0x0)
Version Number	4 bytes	
Length of Record	4 bytes	2177
Capture Device ID	2 bytes	
Number of Finger Patterns in Record	1 byte	1
Image Resolution of finger pattern in x-direction ROUND(ppcm)	2 bytes	79
Image Resolution of finger pattern in y-direction ROUND(ppmm)	2 bytes	79
Number of Cells in x-direction	2 bytes	53
Number of Cells in y-direction	2 bytes	80
Number of Pixels in Cells in x-direction	2 bytes	15
Number of Pixels in Cells in y-direction	2 bytes	15
Cellular x-offset	2 bytes	0
Cellular y-offset	2 bytes	0
Number of Pixels between Cell Centers in x-direction	2 bytes	7

Number of Pixels between Cell Centers in y-direction	2 bytes	7
Number of components extracted from each cell	2 bytes	18
Type of window and parameter	3 byte	G, 3
Wavelength and angle generating mechanism for filters	2 bytes	14
Method of selecting retained components	1 byte	Top energy
Naming and ordering of components	1	Angle + 90 degrees
Bit-depth of Cell Structure Angle	1 byte	4
Bit-depth of Cell Structure Wavelength	1 byte	0
Bit-depth of Cell Structure Phase Offset	1 byte	0
Bit-depth of Cell Structure Quality	1 byte	0
Cell Quality Granularity	1 byte	0
Reserved Bytes	2 byte	
Field	Size	Value
Finger Location	1 byte	2
Finger Impression	1 byte	0
Number of Views	1 byte	1
View Number	1 byte	0
Fingerprint Pattern Quality	1 byte	0
Length of data block (in bytes) including private data	2 bytes	2120
Extended Data Block Length	2 bytes	0