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Finger Data Interchange Format, Standardization

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Synonyms

Fingerprint Data Interchange Format; Encoded Finger Data.

Definition

Set of ISO Standards that define a common formats to encode information related to finger-based biometrics. Those formats are defined to allow interoperability among different vendors worldwide, and have been developed by the international community taking part in ISO/IEC JTC1/SC37 standardization subcommittee. Those documents define not only the way a fingerprint image has to be encoded, but also the way a feature vector composed of minutiae points is to be stored and/or transmitted. Furthermore, formats for the spectral data of the finger, as well as its skeletal data are defined.

Main Body Text

Introduction

Standardization is essential for the wide-spread adoption of technologies in open mass applications. Fingerprint recognition is not only the most prominent biometric measure, but also the biometric trait with the largest databases and the best long-term experience. Fingerprints are used in applications such as physical access control and digital signature creation but also national ID card schemes and other governmental projects. The need for standardization is conspicuous in every single area where it was not applied.

The SC37 Subcommittee from ISO/IEC JTC1 deals with the standardization of biometrics. Among the many aspects of its work, SC37's Working Group 3 is devoted to defining Interchange Data Formats for a variety of biometric modalities. To accomplish this, a multipart standard is under development, covering several biometric modalities. Such multipart standard is know as ISO/IEC 19794. There are 4 parts in this standard which cover finger-based biometrics, or what can be better understood as fingerprint biometrics:

1. Part 2 of the Standard series, deals with the way a minutiae-based feature vector or template has to be coded;
2. Part 3 standardizes the way to code information referring to the spectral information of the fingerprint;
3. Part 4 determines the coding of a fingerprint raw image; and
4. and Part 8 establishes a way to code a fingerprint by its skeleton.

Figure 1 shows the basic architecture of a typical fingerprint verification system. A finger is presented to a sensor and a raw image acquired. Image processing techniques enhance the image quality before a feature vector of characteristic features can be extracted. The features are compared with a previously recorded reference data set to determine the similarity between the two sets before the user presenting the finger is authenticated. The reference data is stored in a database or on a portable data carrier.

The following subsections explain the basic characteristics of each type of finger-based standard. The image standard (Part 4) is presented first as it is the first step in the fingerprint comparison process as shown in the architecture above. This is followed by the other finger based standards, each of which deal with samples already processed.

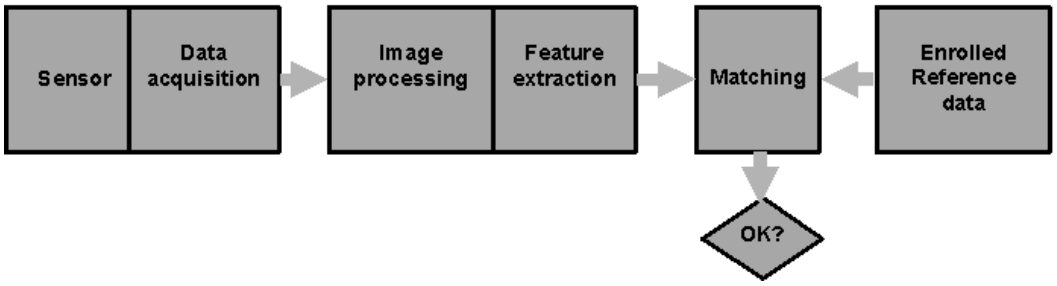

Fig. 1. Typical Biometric Verif cation System

Finger Images

As already mentioned, the way a f ngerprint image is to coded is def ned in ISO/IEC 19794-4 International Standard[1], whose title is "Information technology - Biometric data interchange formats - Part 4: Finger image data". The way the f nger is scanned is out of the scope of the standard, but after image acquisition, the image shall represent a f nger in an upright position, i.e. vertical and with the tip of the f nger in the upper part of the image. The way to code such an image is represented in Fig. 2, where the top line is the f rst to be stored and/or transmitted. This is in contradiction to mathematical graphing practice but in conjunction with typical digital image processing. For those image that require two or more bytes per pixel intensity, the most signif cant byte is stored/transmitted f rst, and bytes follow most signif cant bit coding.

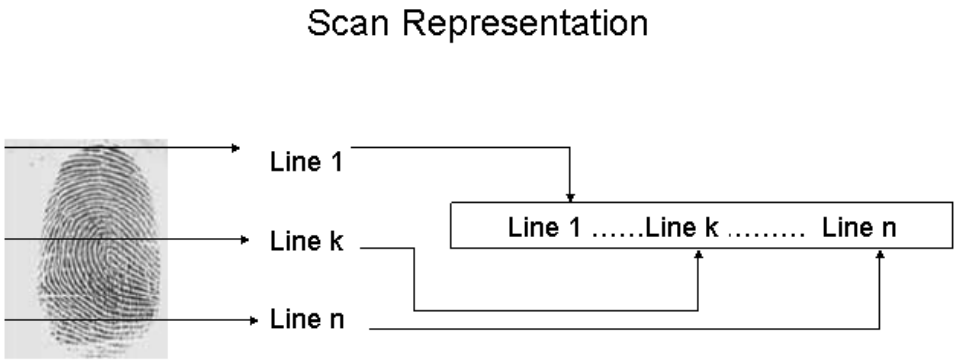

Fig. 2. Coding structure of a f ngerprint image. Image taken from [1]

This International Standard also includes a set of constraints for image acquisition. It determines the pixel aspect ratio, which shall be between 0.99 and 1.01 (horizontal/vertical sizes), as well as several image acquisition levels, as stated in Table 1.

After the requirements for the image to be stored or transmitted have been specif ed, this International Standards details the structure of the data record referring to a f nger image. Following CBEFF specif cations [2] (see entry "Common Biometric Exchange Framework Formats"), a record referring to a f nger image has the following structure (for details refer to the last version of this International Standard [1]):

- A single f xed-length (32-byte) general record header containing information about the overall record, with the following f elds:
  - Format identif er (4 bytes with the hexadecimal value 0x46495200) and version number (coded in another 4 bytes);
  - Record length (in bytes) including all f nger images within that record (coded in 6 bytes);
  - Capture device ID (2 bytes) and Image acquisition level (2 bytes);

Table 1. Image acquisition levels for f nger biometrics. Extract from Table 1 in [1].

Setting level	Scan Resolution (dpi)	Pixel Depth (bits)	Gray Levels
10	125	1	2
20	250	3	5
30	500	8	80
31	500	8	200
35	750	8	100
40	1000	8	120
41	1000	8	200

  - Number of f ngers (1 byte), Scale units used (1 byte) and Scan resolution used (2 bytes for horizontal and another 2 for vertical resolution);
  - Image resolution, coded the same way as the scan resolution, and whose value shall be less or equal to scan resolution;
  - Pixel depth (1 byte) and Image compression algorithm used (coded in 1 byte);
  - 2 bytes reserved for future use.
- A single f nger record for each f nger, view, multi-f nger image, or palm consisting of:
  - A f xed-length (14-byte) f nger header containing information pertaining to the data for a single or multi-f nger image, which gives information about:
    · Length of the f nger data block (in 4 bytes);
    · Finger/palm position (in 1 byte);
    · Count of views (1 byte) and View number (1 byte);
    · Finger/palm image quality (1 byte) and Impression type (1 byte);
    · Number of pixels per horizontal line (2 bytes) and Number of horizontal lines (2 bytes);
    · 1 byte reserved for future use.
  - Compressed or uncompressed image data view for a single, multi-f nger, or palm image, which has to be smaller than $43 * 10^8$ bytes.

The raw f nger format is used, for example, in databases containing standard f ngerprints. Law enforcement agencies are typical applicants of the standard. The largest f ngerprint image databases are maintained by the FBI in the United States and are encoded with a national counterpart of this standard.

Fingerprint Minutiae

While Part 4 of the 19794 Series of Standards is dedicated to raw biometric sample data, Part 2 refers to the format in which a minutiae-based feature vector or template has to be coded. Therefore ISO/IEC 19794-2 “Information Technology Biometric data interchange Formats Part 2: Finger minutiae data”[3] deals with processed biometric data, ready to be sent to a comparison block in order to obtain a matching score.

Finger minutiae are local point patterns present in a f ngerprint image. The comparison of these characteristic features is suff cient to positively identify a person. Sir Francis Galton f rst def ned the features of a f ngerprint [4].

In order to reach interoperability, this International Standard def nes not only the record format, but also the rules for f ngerprint minutiae extraction. Regarding record formats, due to the application of f ngerprint biometrics to systems based on smart cards, compact record formats are also def ned to cope with memory and transmission speed limitations of such devices.

Fingerprint scientists have def ned more than 150 different types of minutiae [5]. Within this Standard, minutiae types are simplif ed to the following: a)ridge ending, b) ridge bifurcation and c) other. The location of each minutiae is determined by its horizontal and vertical position within the image. To determine such location a coordinate system is to be def ned. Figure 3 shows how such coordinate system is chosen. Granularity to be taken to determine location is of one hundredth of millimetre for the normal format, while just one tenth of a millimetre for card compact formats.

Figure 4 shows the different ways to consider the location of a minutiae. a) represents a Ridge Ending, encoded as a Valley Skeleton Bifurcation Point. b) shows how to locate a Ridge Bifurcation, encoded as a Ridge Skeleton Bifurcation Point. Finally, c) illustrates how to locate a Ridge Ending encoded as a Ridge Skeleton Endpoint. How to determine the encoding

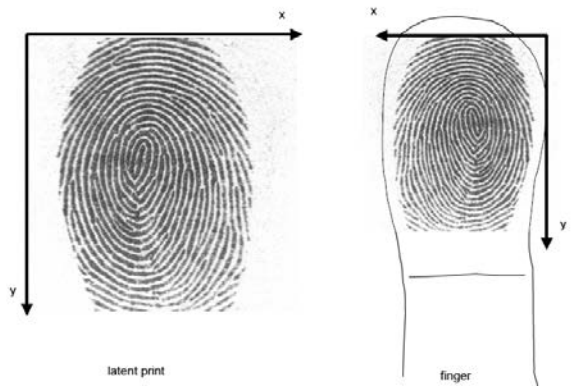

Fig. 3. Coordinate System for Minutiae Location. Image taken from [3]

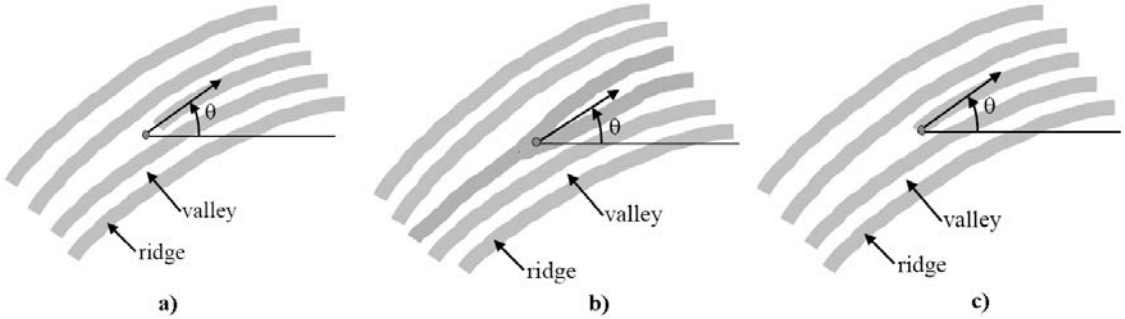

Fig. 4. Illustration of location of minutia. Image taken from [3]

of ridge ending actually used in a specif c dataset is a subject currently under revision in the standard. The other types of minutia have to be coded consistent with the Standards (see details in [3]).

To def ne the minutiae direction, its angle has to be determined. This Standards specif es that the angle is obtained increasing counter-clockwise rotation starting from the horizontal axis to the right of the location of the minutiae point. The angle is encoded in a unsigned single byte, so the granularity is 1.40625 degrees per bit ($360/256$). Fig. 4 also illustrates how the angle is determined.

Additional information that may be included in a minutiae-based record are cores, deltas and ridge crossings to neighboring minutiae.

With all these def nitions, the two major format types def ned by this International Standard are: a) record format; and b) card format. The structure of the record format is summarized in the following paragraphs but for additional details refer to the standard [3]:

- A f xed-length (24-byte) record header containing information about the overall record, including the number of f ngers represented and the overall record length in bytes:
  - Format identif er (4 bytes with the hexadecimal value 0x464D5200) and Version number (coded in another 4 bytes);
  - Record length (in bytes) including all f nger images within that record (coded in 4 bytes);
  - Capture device ID (2 bytes);
  - Size of the image in pixels (2 bytes for X dimension, and 2 bytes for Y dimension);
  - Image resolution in pixels per centimetre (2 bytes for X and 2 bytes for Y);
  - Number of f nger views included in the record;
  - 1 byte reserved for future use.
- A Single Finger record for each f nger/view, consisting of:
  - A f xed-length (4-byte) header containing information about the data for a single f nger, including the number of minutiae:

  - Finger position (1 byte);
  - View number (4 bits) and Impression type (4 bits, to make a 1 byte in total);
  - Finger quality (1 byte);
  - Number of minutia (1 byte).
- A series of fixed-length(6-byte) minutia descriptions:
  - Minutia type (2 bits) and X location in pixels (14 bits);
  - 2 bits reserved and Y location in pixels (14 bits);
  - Minutiae angle (1 byte);
  - Quality of minutiae (1 byte).
- One or more "extended" data areas for each finger/view, containing optional or vendor-specific information. It starts always with 2 bytes which determine the length of Extended Data Block. If this is 0x0000, no Extended Data is included. If it has a non-null value, then it is followed by vendor-specific data which could include information about ridge count, cores and deltas, or cell information.

Regarding the card formats, the current version of the standard allows 2 sub-formats: a) normal format (also referred as 5-byte minutiae); and b) compact format (also known as 3-byte minutiae). The way minutia are coded in each format is:

- Card normal format (like the record format, but removing quality information):
  - Minutia type (2 bits) and X location in pixels (14 bits);
  - 2 bits reserved and Y location in pixels (14 bits);
  - Minutiae angle (1 byte);
- Card compact format:
  - X coordinate (8 bits) considering a unit of 10^-1mm;
  - Y coordinate (8 bits) considering a unit of 10^-1mm;
  - Minutia type (2 bits) using the same coding as with the card normal format;
  - Angle (6 bits) having a granularity of $360/64$.

Another important aspect related to card formats, is that as they are intended to be used with devices with limited memory and processing power, the number of minutia may be restricted, and in such case, truncation is needed. Additionally in Match-on-Card systems, in order to reduce algorithm complexity, minutia may need to be sorted in a certain way. And finally, the way data is exchanged differs from the traditional CBEFF format. This International Standard covers all such cases. The reader is suggested to refer to the last version of the Standard [3] for further details.

The minutia standard is used e.g. by the ILO (international labour organization) in its seafearers identity card and in several national ID card implementations including Thailand and Spain[6].

Spectral Data of a Fingerprint

Part 3 of the 19794 series of standards deals with a format suitable to process fingerprints when using morphological approaches. But as seen in additional Fingerprint entries in this Encyclopaedia, there are other approaches to perform biometric identification using fingerprints. Some of those approaches relate to the spectral information of the fingerprint. Algorithms using spectral data look at the global structure of a finger image rather than certain local point patterns. In such cases, 19794-2 is of no use, and the only possibility would be to use the whole image, as stated in 19794-4, which has the inconvenience of requiring the storage and/or transmission of a large amount of data. This could be inconvenient if not blocking for some applications.

In order to provide a new data format that could increase interoperability among spectral based solutions, reducing the amount of data to be used, 19794-3 has been developed under the title of "Information technology - Biometric data interchange formats - Part 3: Finger pattern spectral data" [7]. In fact, this International Standard deals with three major approaches in spectral based biometrics (wavelet based approaches are not supported by this standard):

1. Quantized co-sinusoidal triplets,
2. Discrete Fourier transform,
3. Gabor filters.

After declaring the basic requirements for the original image in order to be considered for these algorithms (same coordinate system as in 19794-2, 255 levels of grey with 0 representing black and 255 being white, and dark colours corresponding to ridges while light pixels corresponding to valleys), and describing all the above mentioned technologies, the Standards focuses on the record structure (for details refer to [7]), which is:

- A variable-length record header containing information about the overall record, including:
  - Format identif er (4 bytes with the hexadecimal value 0x46535000) and Version number (coded in another 4 bytes);
  - Record length (in bytes) including all f ngers within that record (coded in 4 bytes);
  - Number of f nger records included (1 byte);
  - Image resolution in pixels per centimetre (2 bytes for X direction and 2 bytes for Y direction);
  - Number of cells (2 bytes for X direction and 2 bytes for Y direction);
  - Number of pixels in cells (2 bytes for X direction and 2 bytes for Y direction);
  - Number of pixels between cells centres (2 bytes for X direction and 2 bytes for Y direction);
  - SCSM (Spectral component selection method - 1 byte), which can be 0, 1 or 2. Depending on the value of this f eld the following f elds could refer to type of window, standard deviation, number of frequencies, frequencies, number of orientations and spectral components per cell, and bit-depths (propagation angle, wavelength, phase and/or magnitude);
  - Bit-depth of quality score (1 byte);
  - Cell quality group granularity (1 byte);
  - 2 bytes reserved for future use.
- A single f nger record for each f nger, consisting of:
  - A f xed-length (6-byte) header containing information about the data for a single f nger:
    - Finger location (1 byte);
    - Impression type (1 byte);
    - Number of views in single f nger record (1 byte);
    - Finger pattern quality (1 byte);
    - Length of f nger pattern spectral data block (2 bytes).
  - A f nger pattern spectral data block:
    - View number (1 byte);
    - Finger pattern spectral data;
    - Cell quality data.
  - An extended data block containing vendor-specif c data, composed of block length (2 bytes), area type code (2 bytes), area length, and area.

As in 19794-2, this International Standard also def nes the Data Objects to be included for a card format, with the reduction in granularity recommended (for further details see [7]).

Some of the leading f ngerprint verif cation algorithms rely on spectral data or a combination of spectral data and minutiae. This standard could enhance the interoperability and performance of large scale identif cation systems such as criminal or civil Automatic Fingerprint Identif cation Systems (AFIS).

Skeletal Data of a Fingerprint

Finally 19794-8 titled “Information technology Biometric data interchange formats Part 8: Finger pattern skeletal data” [8] deals with the format for representing f ngerprint images by a skeleton with ridges represented by a sequence of lines. Skeletonization is a standard procedure in image processing and generates a single pixel wide skeleton of a binary image. Moreover the start and endpoints of the skeleton ridge lines are included as real or virtual minutiae, and the line from start to endpoint is encoded by successive direction changes.

For minutiae location and coding, much of the 19794-2 card format is used, but here the position of a ridge bifurcation minutiae shall be def ned as the point of forking of the skeleton of the ridge. In other words, the point where three or more ridges intersect is the location of the minutia. No valley representation is accepted under this International Standard. Another differences with 19794-2 card formats, is that in this Standard no other-type minutiae is considered (if a minutiae has more than three arms, like a trifurcation, it is considered a bifurcation), and that along this standard codes for “virtual minutiae” are used.

Skeleton lines are coded as polygons. Every line starts with a minutiae, and it is followed by a chain of direction changes (coded with the granularity stated in the record header), until it reaches the final minutiae. Several rules are defined in the standard (see [8] for further reference).

All that information is coded in a record with the following structure (limiting values as well as recommended values can be found in [8]):

- A fixed-length (24-byte) record header containing:
  - Format identifier (4 bytes with the hexadecimal value 0x46534B00) and Version number (coded in another 4 bytes);
  - Record length (in bytes) including all finger images within that record (coded in 4 bytes);
  - Capture device ID (2 bytes);
  - Number of finger views in record (1 byte);
  - Resolution of finger pattern in pixels per centimetre (1 byte);
  - Bit depth of direction code start and stop point coordinates (1 byte);
  - Bit depth of direction code start and stop direction (1 byte);
  - Bit depth of direction in direction code (1 byte);
  - Step size of direction code (1 byte);
  - Relative perpendicular step size (1 byte);
  - Number of directions on 180 degrees (1 byte);
  - 2 bytes reserved for future use.
- A single finger record for each finger/view, consisting of:
  - A fixed-length (10 bytes) header:
    - View number (1 byte);
    - Finger position (1 byte);
    - Impression type (1 byte);
    - Finger quality (1 byte);
    - Skeleton image size in pixels (2 bytes for X-direction, 2 bytes for Y-direction);
    - Length of finger pattern skeletal data block (2 bytes).
  - The variable length fingerprint pattern skeletal description:
    - Length of finger pattern skeletal data (2 bytes);
    - Finger pattern skeletal data;
    - Length of skeleton line neighbourhood index data (2 bytes);
    - Skeleton line neighbourhood index data.
  - An extended data block containing the extended data block length and zero or more extended data areas for each finger/view, defining length (2 bytes), area type code (2 bytes), area length (2 bytes) and data.

This International Standard also defines 2 card formats, a normal one and a compact one. As with other parts, this means more limiting constraints to code data tighter and the definition of the Data Objects needed (for details refer to [8]).

The skeleton format is used in scientific research [9] and by vendors implementing Match-on-Card.

Further steps

The fingerprint parts of ISO 19794 were published as International Standards in 2005 and 2006. All parts are currently under revision. A major task in the revision process is to address some defects and include a common header format for all parts. Some references and vocabulary need to be updated to harmonize the relation of these standards within the ISO standardization landscape. The finger minutia standard ISO 19794-2 is probably the most prominent format in this series and is most frequently used by industry, government and science. Interoperability tests have shown that the current standard allows for some room of interpretation. This will be compensated by an amendment to describe the location, orientation and type in more detail. Another aspect in the current revision of the standard is to reduce the number of format types from currently ten to a maximum of two. Experts from all continents and various background meet on a regular basis to lay down the future of the standards. The delegates take care of current requirements in terms of technology and applications.

Summary

To provide interoperability in storing and transmitting f nger-related biometric information, 4 standards are already developed to def ne the formats needed for raw images, minutia-based feature vectors, spectral information, and skeletal representation of a f ngerprint. Beyond that, other standards deal with conformance and quality control, as well as interfaces or performance evaluation and reporting (see relevant entries in this Encyclopaedia for further information).

Related Entries

Biometric Data Interchange Format, Common Biometric Exchange Framework Formats, Fingerprint Recognition, International Standardization of Biometrics, Standardization of Conformance Testing Methodologies for Biometric Data Interchange Formats.

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Def nitional Entries

Minutiae

Friction ridge characteristics that are used to individualize a f ngerprint. Minutiae occur at points where a single friction ridge deviates from an uninterrupted f ow. Deviation may take the form of ending, bifurcation, or a more complicated “composite” type.

Finger pattern spectral data

Set of spectral components derived from a f ngerprint image that may be processed (by cropping and/or down-sampling, for example).

Skeleton

Line representation of an object that is one-pixel wide, through the “middle” of the object and preserves the topology of the object.