TECHNICAL REPORT

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Information technology — Biometric sample quality —

Part 4:
Finger image data

Technologies de l'information — Qualité d'échantillon biométrique —

Partie 4: Données d'image de doigt

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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 national bodies for voting. Publication as an International Standard requires approval by at least 75 % of the national bodies casting a vote.

In exceptional circumstances, the joint technical committee may propose the publication of a Technical Report of one of the following types:

— type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;

— type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;

— type 3, when the joint technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

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 TR 29794-4, which is a Technical Report of type 2, was prepared by Joint Technical Committee ISO/IEC JTC 1, *Information technology*, Subcommittee SC 37, *Biometrics*.

ISO/IEC 29794 consists of the following parts, under the general title *Information technology — Biometric sample quality*:

— *Part 1: Framework*

— *Part 4: Finger image data* [Technical Report]

— *Part 5: Face image data* [Technical Report]

Introduction

The quality of finger image data is defined to be the predicted behavior of the image in a matching environment. Thus, the quality information is useful in many applications. ISO/IEC 19784-1 and ISO/IEC 19785-1 do allocate a quality field and specify the allowable range for the scores, with the recommendation that the score be divided into four categories with a qualitative interpretation for each category. Image quality fields are also provided in the fingerprint data interchange formats standardized in ISO/IEC 19794-2, ISO/IEC 19794-3, ISO/IEC 19794-4, and ISO/IEC 19794-8. However, there is no standard way to interpret the quality score that facilitates the interpretation and interchange of the finger image quality scores.

The purpose of this part of ISO/IEC 29794 is to provide an informative technical report on methodologies for objective, quantitative quality score expression and interpretation for finger images. It will complement ISO/IEC 29794-1 in developing a reference finger image corpus. Such a reference corpus can be built upon the availability of public finger images, which should then be used for quality score normalization.

Information technology — Biometric sample quality —

Part 4:
Finger image data

1 Scope

For aspects of quality specific to the finger image modality, this part of ISO/IEC 29794:

- specifies terms and definitions that are useful in the specification, use, and test of finger image quality metrics;
- defines the interpretation of finger image quality scores;
- identifies or defines finger image corpora for the purpose of serving as information for algorithm developers and users;
- develops statistical methodologies specific to finger image corpora for characterizing quality metrics to facilitate interpretation of scores and their relation to matching performance.

Performance assessment of quality algorithms and standardization of quality algorithms are outside the scope of this part of ISO/IEC 29794.

2 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 29794-1, *Information technology — Biometric sample quality — Part 1: Framework*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 29794-1 and the following apply.

3.1
foreground region
region of a finger image that contains valid finger image patterns

NOTE The most evident structural characteristic of a valid finger image is a pattern of interleaved ridges and valleys.

3.2
local region
block of *m* x *n* pixels of the foreground of a finger image, where m and n are smaller than the width and the height of the finger image

3.3
finger image quality assessment algorithm
algorithm that reports a quality score for a given finger image sample

3.4
finger image corpus
collection of finger image samples

3.5
finger image quality category
common attribute or property of a group of finger images that causes them to perform or behave similarly for a class of fingerprint matchers

4 Symbols and abbreviated terms

FQAA finger image quality assessment algorithm

DFT discrete Fourier Transform

QSN quality score normalization

QAID quality algorithm identification

ppi pixel per inch, which is analogous to dot per inch (dpi).

5 Finger Image Quality

5.1 Defect factors of finger image

A finger image obtained from a scanner is not always perfect. It may contain defects caused by the user character (e.g user's skin condition), user behavior (e.g. improper finger placement), imaging (e.g scanner limitation or imperfection), or environment (e.g. impurities on the scanner surface). Some of the defects and their factors can be listed as follows:

1. Defect caused by user character
   A. Extreme skin conditions such as very wet, very dry, etc.
   B. Scars
   C. Wrinkles
   D. Blisters
   E. Eczema
   F. Impurities such as dirt, latent print, etc.
2. Defect caused by imaging
   A. Sampling error
   B. Low contrast or signal-to-noise ratio
   C. Distortion
   D. Erroneous or streak lines
   E. Uneven background
   F. Insufficient dynamic range
   G. Non-linear or non-uniform grayscale output
   H. Pixels not available due to hardware failure
   I. Aliasing problems
3. Defect caused by user behavior
   A. Elastic deformation
   B. Improper finger placement such as too low, rotated, etc.
   C. Insufficient area of finger image
4. Defect caused by environment
   A. Humidity
   B. Light
   C. Impurities on the scanner surface

The performance of an automated fingerprint recognition system will be affected by the amount of defects or the degree of imperfection present in the finger image. Therefore, it is necessary to compute the quality score of the finger image produced. Section 6 suggests several possible approaches to compute the finger image quality. The quality score shall be predictive of the performance of an automatic fingerprint recognition system. Furthermore, the quality score should preferably be scanner-independent and source-independent.

5.2 Standardization approaches for exchange of finger image quality

As the finger image quality affects the performance of the fingerprint recognition system, the knowledge of quality can and is currently being used to process finger images differently, by for example, invoking some image enhancement methods prior to feature extraction, invoking different matchers based on quality or simply changing the threshold of the system. In fact, the use of finger image quality to enhance the overall performance of the system is increasingly growing. Therefore, there is a need to standardize the quantitative quality score expression and interpretation so that a common interpretation of the quality scores is achieved. This can be done, as suggested in ISO/IEC 29794-1, by either Quality Algorithm Identification (QAID), or Quality Percentile Rank upon standardization of a Quality Score Normalization (QSN) corpus.

6 Finger Image Quality Analysis

6.1 Introduction

A complete finger image quality analysis should examine both the local and global structures of the finger image. Fingerprint local structure constitutes the main texture-like pattern of ridges and valleys within a local region while valid global structure puts the ridges and valleys into a smooth flow for the entire fingerprint. The quality of a finger image is determined by both its local and global structures. This section describes the current most significant features and characteristics of finger images at both local and global structures that are related to performance of fingerprint recognition systems. Some of these algorithms are described in 6.2 and 6.3 and can also be found in [5-8,10,11].

The finger image is assumed to have resolution of 500 ppi. For other resolutions, the resolution dependent parameters should be scaled accordingly. Possible initial finger image corpuses are the publicly available Fingerprint Verification Competition (FVC) 2000, 2002, 2004, and 2006 [4] corpuses.

6.2 Local Analysis

6.2.1 Constituent of Local Analysis

A finger image is partitioned into blocks such that each block contains sufficient ridge-valley information, preferably having at least 2 clear ridges, while not overly constraining the high curvature ridges. For images with a resolution of 500 ppi, the ridge separation usually varies between 8 to 12 pixels [2]. A ridge separation comprises a ridge and a valley. In order to cover two clear ridges, the block size has to be bigger than 24 pixels. Thus the suggested size for each block is 32 x 32 pixels, which is sufficient to cover 2 clear ridges. Nevertheless, other sizes could also be used. Instead of Cartesian coordinate, curvilinear coordinate along the ridge can also be used. This is followed by a segmentation process where each block is tagged as background or foreground. There are several segmentation approaches, such as using the average magnitude of the gradient in each block etc [2]. Local quality analysis is performed on the foreground blocks with a local quality metric computed for each of them.

6.2.2 Approaches to Local Analysis of Finger Image

This section reviews some of the existing approaches for determining aspects of local quality of the finger image.

6.2.2.1 Orientation Certainty Level

The finger image within a small block (as shown in Figure 1) generally consists of dark ridge lines separated by white valley lines along the same orientation. The consistent ridge orientation and the appropriate ridge and valley structure are distinguishable local characteristics of the fingerprint block.

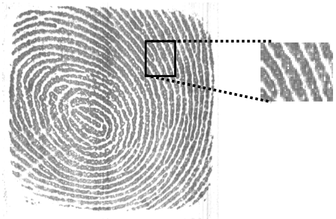

Figure 1 — A typical texture-like ridge block

The grey level gradient (*dx*, *dy*) at a pixel describes the orientation and its strength at the pixel level. As an example, [7] describes a method of measuring orientation certainty level. By performing Principal Component Analysis on the image gradients in an image block, an orthogonal basis for an image block can be formed by finding its eigenvalues and eigenvectors. Principal Components Analysis is a multivariate procedure which rotates the data such that maximum variability is projected onto orthogonal axes. The resultant first principal component contains the largest variance contributed by the maximum total gradient change in the direction orthogonal to ridge orientation. The direction is given by the first eigenvector and the value of the variance corresponds to the first eigenvalue, λ_{max}. On the other hand, the resultant second principal component has the minimum change of gradient in the direction of ridge flow which corresponds to the second eigenvalue, λ_{min}. The ratio between the two eigenvalues thus gives an indication of how strong the energy is concentrated along the dominant direction with two vectors pointing to the normal and tangential direction of the average ridge flow respectively. The covariance matrix *C* of the gradient vector for an *N* points image block is given by

$$C = \frac{1}{N}\sum_{N}\left(\begin{bmatrix} dx \\ dy \end{bmatrix}\begin{bmatrix} dx & dy \end{bmatrix}\right) = \begin{bmatrix} a & c \\ c & b \end{bmatrix}. \quad (1)$$

For the covariance matrix in (1), eigenvalues λ are given by:

$$\lambda_{max} = \frac{(a+b)+\sqrt{(a-b)^2+4c^2}}{2} \quad (2)$$

$$\lambda_{min} = \frac{(a+b)-\sqrt{(a-b)^2+4c^2}}{2} \quad (3)$$

For a finger image block, orientation certainty level (*ocl*), or the ratio between λ_{min} and λ_{max} is then:

$$ocl = \frac{\lambda_{min}}{\lambda_{max}} = \frac{(a+b)-\sqrt{(a-b)^2+4c^2}}{(a+b)+\sqrt{(a-b)^2+4c^2}} \quad (4)$$

The range of the *ocl* value is between 0 and 1 as *a*,*b*>0. It gives an indication of how strong the energy is concentrated along the ridge-valley orientation. The lower the value the stronger it is. The value of *ocl* can then be used to indicate the quality of the finger image block. The orientation certainty level fails to predict match-ability when there exist some marks or residual in the samples that have strong orientation strength, such as those exhibited by latent prints left by the previous user.

6.2.2.2 Ridge-valley Structure

Good quality fingerprints exhibit clear ridge-valley structure. Thus the measure of the ridge-valley structure clarity is a useful indicator of the quality of a fingerprint.

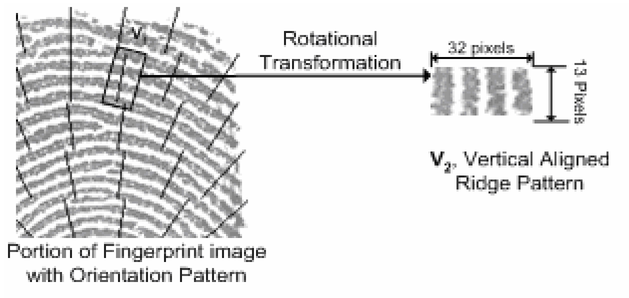

Figure 2 — Extraction of a local region and transformation to vertical aligned ridge pattern

6.2.2.2.1 Ridge-valley Structure Analysis

An example of methods assessing clarity of ridge and valleys is explained in [7]. To perform ridge-valley structure analysis, the finger image is quantized into blocks, preferably of size 32 × 32 pixels. Inside each block, an orientation line, which is perpendicular to the ridge direction, is computed. At the centre of the block along the ridge direction, a 2-D vector V_1 (slanted square in Figure 2) of smaller size than the block size, such as with size 32 × 16 pixels is extracted and transformed to a vertical aligned 2-D Vector V_2. By using equation (5), a 1-D Vector V_3, that is the average profile of V_2, can be calculated.

$$V_3(i) = \frac{\sum_{j=1}^{m} V_2(i,j)}{m}, \; i = 1..32 \qquad (5)$$

where m is the block height (16 pixels) and i is the horizontal index.

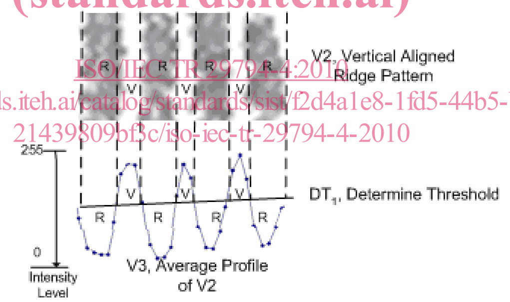

Figure 3 — Region Segmentation of Vector V_2

Once V_3 has been calculated, linear regression (or least square fitting) is then applied to V_3 to find the parameter, called Determine Threshold (DT_1). DT_1 is the line positioned at the centre of the Vector V_3, and is used to segment the image block into the ridge or valley region. Regions with grey level intensity lower than DT_1 are classified as ridges; else they are classified as valleys. The process of segmenting the fingerprint region into ridge and valley using DT_1 is shown in Figure 3. The top portion of Figure 3 shows the ridge pattern. The gray scale distribution of the ridge pattern projected as a one dimensional cumulative intensity profile is shown at the lower portion. The Y-axis is the intensity level, while the x-axis the cross section of the ridge pattern. Each local block will have its own DT_1.

From the one-dimensional signal in Figure 3, several useful parameters are computed, such as valley thickness and ridge thickness. Since good finger images cannot have ridges that are too close or too far apart, thus the nominal ridge and valley thickness can be used as a measure of the quality of the finger image captured. Similarly, ridges that are unreasonably thick or thin indicate that the finger image may not be captured properly, such as pressing too hard or too soft, or the image is a residual sample. Thus, the finger image quality can be determined by comparing the ridge and valley thickness to each of their nominal range of values. Any value out of the nominal range may imply a bad quality ridge pattern. The ridge and valley thickness values are dependent on the resolution of the fingerprint scanner. To normalize these values, a factor is computed by dividing the scanner resolution with 125 ppi which is the minimum resolution permitted in ISO/IEC 19794-4. To normalize the range of the thickness values, a pre-set maximum thickness is used.

