A Study on Accuracy and Problems in using ISO/IEC 19794-2 Finger Minutiae Formats for Automated Fingerprint Verification

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Abstract. For the purpose of clarifying the problems in using ISO/IEC 19794-2 formats, the minutiae detection software MINDTCT and the fingerprint matching software BOZORTH3 included in NBIS were modified to accept the standardized fingerprint data. From experimental results, the EERs of authentication system using the ISO/IEC 19794-2 formats become slightly worse than that of the system using original XYT format. The degradation of EERs, 0.1%~0.77%, shows the validity of the use of the ISO/IEC 19794-2 formats from the viewpoint of the EER. However, many problems such as no existence of the minutiae quality and header field in Card formats, or limitations of the number of minutiae and maximum size of fingerprint image are found in conversion and authentication processes. In this paper, accuracy and problems in accepting the ISO/IEC 19794-2 data format are given.

Keywords: Fingerprint authentication, Minutiae, ISO/IEC19794-2, EER

1 Introduction

In considering usability and interoperability of automated fingerprint recognition and authentication system, the ISO/IEC 19794 Part 2 [1] specifies the biometric data interchange formats for finger minutiae data. This standard defines "Finger Minutiae Record format", "Normal size Finger Minutiae Card format", and "Compact size Finger Minutiae Card format". However, these formats have different resolution in minutiae coordinates and direction angle. In addition, the information involved in the card format is limited. Furthermore, in the format, the fields of additional information such as fingerprint image size and minutiae quality value is not included. It is easily expected that these differences influence to automated fingerprint authentication accuracy in conversion process. Therefore, it is necessary to investigate the problems and influence in accepting the ISO/IEC 19794-2 data formats.

In this study, the most popular minutiae detection software, e.g., MINDTCT, and the minutiae based matching software, e.g., BOZORTH3 included in NBIS (NIST Biometric Image Software) [2], are modified to accept and feed through ISO/IEC 19794-2 data formats, and used for automated fingerprint authentication. The problems and influence on the authentication accuracy in accepting the ISO/IEC 19794-2 data formats are examined in this work.

2 Definition of Minutiae Data in the ISO/IEC 19794-2

2.1 X and Y Coordinates of Minutia Location

The definition of X and Y coordinates of minutia location of each format is shown in Table 1. The XYT format is a minutiae text file which is used for transmitting the minutiae data from the MINDTCT to the BOZORTH3. For the Record format, 14 bits are assigned for the XY coordinates respectively. The resolution is 0.01 mm/unit in the Normal size format and 0.1 mm/unit in the Compact size format.

There is no error in the coordinate's conversion from the XYT to the Record format, because the resolution of coordinates is same. However, the Card formats involve errors in the coordinate's conversion from the pixel unit to the metric unit.

The origin of the coordinate system of the ISO/IEC 19794-2 formats is the upper left corner of the original image with X increasing to the right and Y increasing downward. In contrast, the origin of the XYT format is the lower left corner. Only the value of vertical size of the fingerprint image is necessary to convert the origin.

Table 1. Definition of coordinates of minutia location.

Format	Resolution	Coordinate	
XYT format (Used in NBIS)	Depend on fingerprint image	1 pixel, Integer value	y, 0, x
ISO/IEC 19794-2 Record format	Depend on fingerprint image	1 pixel, 14bit binary	0, x, y
ISO/IEC 19794-2 Card format (Normal size)	Fixed 2540ppi	0.01mm, 14bit binary	0, x, y
ISO/IEC 19794-2 Card format (Compact size)	Fixed 254ppi	0.1mm, 8 bit binary	0, x, y

Table 2. Definition of X and Y coordinates.

Format	Resolution	Field Type
XYT format (Used in NBIS)	1°	Text
ISO/IEC 19794-2 Record format	1.40625°	8bit
ISO/IEC 19794-2 Card format (Normal size)	1.40625°	8bit
ISO/IEC 19794-2 Card format (Compact size)	5.624°	6bit

2.2 Angle of Minutia Direction

The definition of the angle θ of minutia direction of each format is shown in Table 2. The resolution of the angle is different in each format. For example, in the XYT format, the resolution is 1°. However, the resolution in the Record format and Card format (Normal size) is 1.40625°, and 5.624° in the Card format (Compact size). Therefore, the ISO/IEC19794-2 formats have errors in the angle conversion. The definitions of directions of ridge ending, and bifurcation valley are also different between the XYT format and the ISO/IEC 19794-2 formats.

3 Experiment of Automated Fingerprint Verification

3.1 Experimental Condition

The NIST Special Database 9, Volume 1 [3] is used as the test dataset for automated fingerprint verification experiments. This database consists of mated fingerprint image pairs for each person and each finger. The fingerprint images named “File” are used for making reference, and ”Search” are used for verification process in the experiment. The finger print images are 832 pixels width by 768 pixels height, and gray scale that have 8 bit depth with the resolution of 500 pixels/inch.

In this experiment, two kinds of dataset are used. The test dataset 1 consists of 1800 fingerprints. The mate 900 fingerprints are used as the reference data, i.e. 90 persons X 10 fingers. The other mate 900 fingerprints are used for the verification data. The fingerprint verification experiments are done with round robin. The False Reject Rate (FRR) is calculated after 900 verification tests, and the False Accept Rate (FAR) is also calculated after 809100 verification tests. The test dataset 2 consists of 200 fingerprints. The mate 100 fingerprints are used as the reference data, i.e. 10 persons X 10 fingers. The other mate 100 fingerprints are used for the verification data. The FRR is calculated after 900 verification tests, and the FAR is also calculated after 9900 verification tests.

3.2 The Sequence of the Experiment

The sequence of the experiment is as follows;
(1) The fingerprint images of Special Database 9 are converted to RAW formatted images by the conversion program DJPEGLSD, which is a part of the NBIS.
(2) The RAW formatted fingerprint images are converted to WSQ formatted images by the image compression program CWSQ, which is also a part of the NBIS. The bit rate setting of the CWSQ is 2.25.
(3) The MINDTCT software loads the WSQ formatted fingerprint image and feed through the extracted minutiae to each formatted files. The number of output minutiae is limited to 150 with the order of quality. The XY coordinates of minutiae of the Card format (Compact size) are normalized by the size of fingerprint image.
(4) The BOZORTH3 software loads the minutiae files and calculates matching score.
(5) The characteristic curves of the FAR and FRR against the threshold value are calculated from the matching scores. Equal Error Rate (EER) is decided from the threshold when the FRR is equal to the FAR.

3.3 Experimental Results of the Verification Accuracy

In this experiment, the verification accuracy of each format is examined with the test dataset 1. This experiment is done by the best experimental conditions to avoid the problems described in section 4. The comparison of EERs of each format is shown in Fig. 1. From the figure, it is found that the EERs of the ISO/IEC 19794-2 formats are slightly worse than that of the XYT format. The degradation of EERs of the Record format and Card format (Normal size) is only 0.1%. This is because these formats have enough resolution in comparison with the XYT format. The degradation of EER of the Card format (Compact size), which has the small data size and low resolution, is 0.77%.

The characteristic of the FAR and FRR of each format with changing the threshold value is shown in

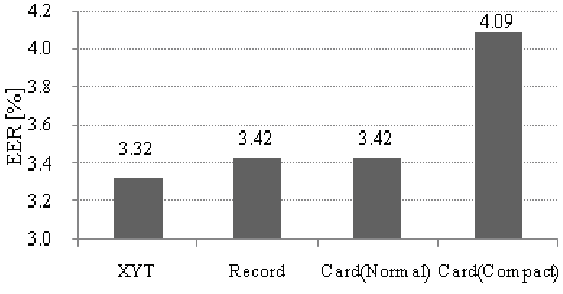
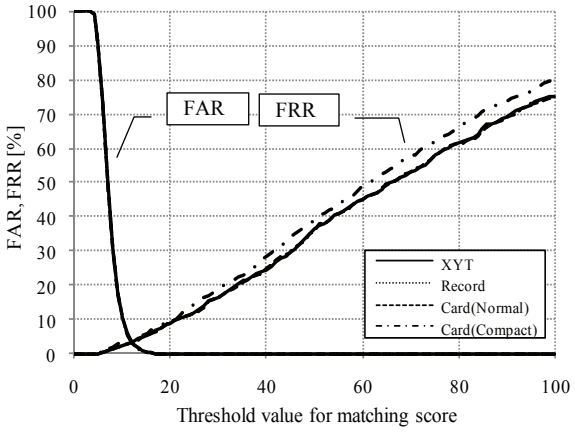
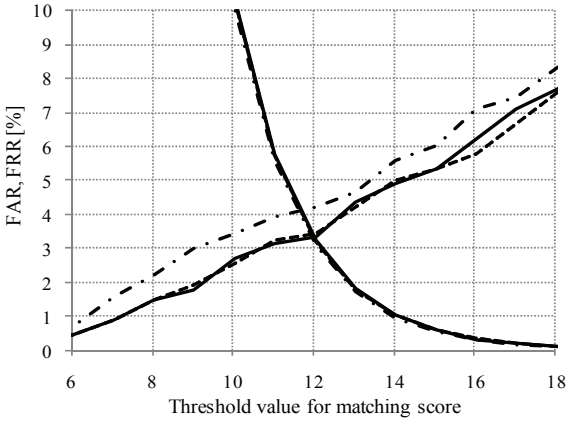


Fig. 1. Comparison of EERs of each format. (Test Dataset 1)



(a) Overall view



(b) Magnified view around EER

Fig. 2. Characteristic of the FAR and the FRR of each format with changing the threshold value. (Test Dataset 1)

Fig. 2. From the figure, it is found that only the FRR curve of the Card format (Compact size) becomes worse. This leads to the degradation of the EER of this format. The curves of other formats are very similar. From these results, the use of the ISO/IEC 19794-2 formats has no problem from the viewpoint of the EER.

4 Noticed Problems in Using the ISO/IEC 19794-2 Formats

In this chapter, noticed problems in applying the ISO/IEC 19794-2 formats to the MINDTCT and BOZORTH3 are discussed in detail. The problems under considerations are as follows;

(1) Error of the minutiae coordinates and angle by the ISO/IEC 19794-2 formats.

(2) No existence of the minutiae quality field in the Card formats.

(3) Limitation of the number of minutiae.

(4) No existence of the header field in the Card formats.

(5) Limitation of the maximum size of fingerprint image in the Card format (Compact size).

4.1 Error of the Coordinates and Angle by the ISO/IEC 19794-2 Formats

In minutiae extraction process in the MINDTCT, the XY coordinates are recorded by pixel base. This process also truncates the angle of minutiae direction to 32 directions, i.e., 11.25° resolution. After the truncation, the format conversion for minutiae data is done for each format. The conversion error, which degrades EER, is occurred in this process.

4.1.1. Error in Converting Process to the ISO/IEC 19794-2 Formats

The conversion error in each format is as follows;

(1) From the XYT format to the Record format

The XY coordinates has no error, because this resolution is same between the XYT format and Record format. However, the angle of minutiae direction has the conversion error caused by converting from 1° to 1.40625°.

(2) From the XYT format to the Card format (Normal size)

The XY coordinates has the conversion error caused by converting from 1 pixel unit to 0.01mm unit. The angle of minutiae direction also has the conversion error caused by converting from 1° to 1.40625°.

(3) From the XYT format to the Card format (Compact size)

The XY coordinates has bigger conversion error caused by converting from 1 pixel unit to 0.1mm unit. The angle of minutiae direction also has bigger conversion error caused by converting from 1° to 5.624°. In addition, the XY coordinate normalization process to avoid the limitation of the maximum size of fingerprint image in the Card format (Compact size) occurs serious error.

4.1.2. Difference of the BOZORTH3 Matching Score of the XYT Format and ISO/IEC 19794-2 Formats

In this section, the difference between the BOZORTH3 matching score of the XYT format and ISO/IEC 19794-2 formats is cleared by the test dataset 2. The BOZORTH3 calculates matching score from two minutiae files. The score means similarity between two fingerprints. Relationship of the matching score using a pair of fingerprints between the XYT and ISO/IEC 19794-2 formats is shown in Fig. 3. Relationship of the matching score using non-matched fingerprints is shown in Fig. 4.

In these figures, the plots under y=x line shows the decrease of the matching score for the ISO/IEC19794-2 formats.

From Fig. 3, it is found that the distribution of the score of the Record format and Card format (Normal size) is not affected by this software. However, the Card format (Compact size) is greatly affected. This leads to the degradation of the FRR. The score of the Card format (Compact size) to non-matched fingerprints is

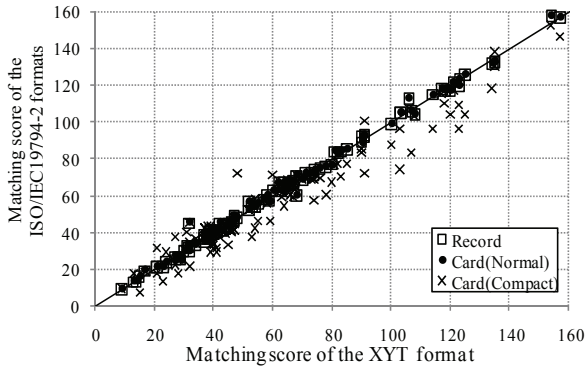


Fig. 3. Relationship of the matching score using a pair of fingerprints between the XYT format and ISO/IEC 19794-2 formats. (Test dataset 2)

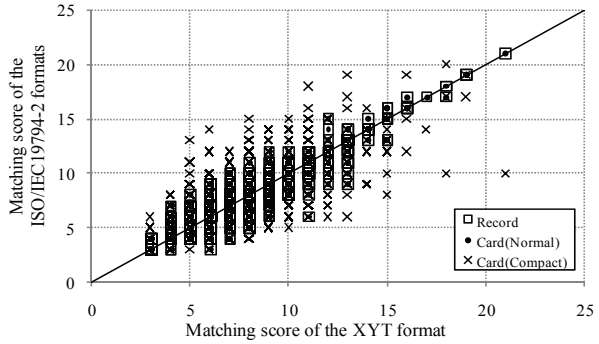


Fig. 4. Relationship of the matching score using non-matched fingerprints between the XYT format and ISO/IEC 19794-2 formats. (Test dataset 2)

more changeable than that of the Card format (Normal size) as shown in Fig. 4.

4.2 No Existence of the Minutiae Quality Field in the Card Formats

When the Card format is used, the selection of 150 minutiae based on the quality is necessary in the MINDTCT. The reason is that this format does not have the minutiae quality field. The BOZORTH3 calculates matching score and feeds through 150 minutiae with higher quality order when the number of minutiae is over 150. In case of no quality information, the BOZORTH3 cannot use qualified 150 minutiae, and this causes the degradation of the score. In this study, the selection process of the top quality 150 minutiae is implemented in the MINDTCT to avoid this problem. From the experimental results by the Card format (Compact size) using the test dataset 2, the quality information improves the EER by 1%.

4.3 Limitation of the Number of Minutiae

The number of minutiae included in the ISO/IEC 19794-2 formats is limited to 255. This limitation is caused by the 1 byte field length of the number of minutiae in the header. From experimental results using 200 fingerprints, there are 17 fingerprints which exceed 255 minutiae. In this study, the selection process of the top quality 255 minutiae is implemented in the MINDTCT to avoid this problem.

4.4 No Existence of the Header Field in the Card Formats

The origin of Y coordinate in the XYT format is different from ISO/IEC 19794-2 formats as shown in Table 1. Thus, the BOZORTH3 has to convert the Y coordinate by using the vertical size of the fingerprint image after loading the minutiae file. However, the BOZORTH3 cannot acquire the vertical size of the fingerprint, because the Card formats do not have the header field.

In this study, we give the vertical size manually in loading minutiae files to the BOZORTH3 in order to avoid this problem. For this problem, the whole system design from the minutiae extraction process to the matching score calculation process should be reconsidered as suitable to the ISO/IEC 19794-2 formats.

4.5 Limitation of the Maximum Size of Fingerprint Image in the Card Format (Compact Size)

As the resolution of X and Y coordinates is fixed in the Card formats, there is a limitation of the maximum size of fingerprint image. The limitation is 163.83 mm in the Card format (Normal size), i.e. 0.01mm unit by 16383 steps (14 bit), and 25.5 mm in the Card format (Compact size), i.e. 0.1mm unit by 255 steps (8 bit).

As the image size of the Special Database 9 is width 42.3 mm by height 39.0 mm, both of width and height exceed the limit of the Card format (Compact size) and overflowed. In this study, the X and Y coordinates of minutiae are normalized linearly by the actual fingerprint size in the MINDTCT and the BOZORTH3. However, this normalization process occurs the degradation of the coordinate's resolution.

The method of "X or Y coordinate extension for compact format" as specified in ISO/IEC 19785 Data Object can avoid this problem. However, this method does not support in the case of both of X and Y overflowing. It is necessary to trim the examined area from the fingerprint image.

5 Conclusion

In this study, the MINDTCT and BOZORTH3 were modified to accept the data based on ISO/IEC 19794-2 formats, and used for automated fingerprint authentication experiment. The problems and influence

on the authentication accuracy of the ISO/IEC 19794-2 formats are also examined.

From experimental results, the EERs of the ISO/IEC 19794-2 formats become slightly worse than that of the XYT format. The degradation of EERs of the Record format, Card format (Normal size), and Card format (Compact size) are 0.1%, 0.1%, and 0.77% respectively. This result show that the use of the ISO/IEC 19794-2 formats in commonly available software is accepted from the viewpoint of the EER. The problems and influence in applying the ISO/IEC 19794-2 formats may be solved if the whole system design from the minutiae extraction process to the matching score calculation process is reconfigured as suitable to the ISO/IEC 19794-2 formats.

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