Finger Minutiae Extraction and Format Standard for One-to-One Matching

Introduction

This standard provides interoperability between different finger matchers for the purposes of one-to-one verification of an individual's identity against a previously collected and stored finger record. The interoperability is based on defining the finger minutiae extraction rules and record format that are common to most all finger matchers for acceptable matching accuracy, while allowing for proprietary data to be attached so that the highest accuracy can be maintained for matching accomplished with the same matcher type.

1. Conformance

< Insert any reference to external standards that need to be conformed to >

2. Definitions

< Insert any definitions of terms needed >

~~3.~~Action item to Peter to pull together all the relevant glossaries and definitions.

Minutiae Description

~~3.1.~~2.1. Principle *(Numbering is no doubt off due to changes from WORD 6 to Word Office 98 to Word 6 for Windows.)*

Fingerprint images can be represented with "light ridges" or "dark ridges". The minutia points shall located in such a way that the points and their directions do not change when the polarity (define or substitute other words) of the image is inverted. This decision not only provides for consistent data extraction regardless of image polarity, but also ensures equal behavior of ending and bifurcation points with respect to image degradations such as noise and contrast variance. The definition needs to be tied to the finger geometry, i.e., ridges are ridges independent of scanner type. The specifications of minutia location and minutia direction list below accomplish this. See Figure 1 for an illustration of the definitions below. Is it important to note minutiae type – ridge ending or a bifurcation? The worst case is where a scanner is substituted that has opposite polarity – should algorithm check both cases each time a verification is done?

~~3.2.~~2.2. Minutia Location

~~3.2.1.~~2.2.1. Coordinate System

The coordinate system used to express the minutia points of a fingerprint shall be a Cartesian coordinate system. Points shall be represented by their X and Y coordinates where X is increasing to the right and Y is increasing downward. Note that this is in agreement with most imaging and image processing use, but the Y-axis is the opposite of typical mathematical graphing practice. The spatial resolution of the minutia points shall be in pixel units, with the spatial resolution of a pixel given in the "Resolution" field of the format. Revert to the ANSI-NIST definition as shown on graph.

~~3.2.2.~~2.2.2. Minutia Placement on a Ridge Ending

The minutia point for a ridge ending shall be defined as the point of forking of the medial skeleton of the valley area immediately in front of the ridge ending. In simpler terms, the point where the valley "Y"'s, or (equivalently) where the three legs of the thinned valley area intersect.

~~3.2.3.~~2.2.3. Minutia Placement on a Ridge Bifurcation

In corresponding fashion, the minutia point for a ridge bifurcation shall be defined as the point of forking of the medial skeleton of the ridge. If the ridge were thinned down to a single-pixel-wide skeleton, the point where the three legs intersect is the location of the minutia.

2.2.4. Minutia Placement on Other Minutiae

For minutiae other than a bifurcation or ridge ending the placement and angle of direction shall be vendor defined.

~~3.3.~~2.3. Minutia Direction

~~3.3.1.~~2.3.1. Angle Conventions

Angles are expressed in standard mathematical format, with zero degrees to the right and angles increasing in the counterclockwise direction.

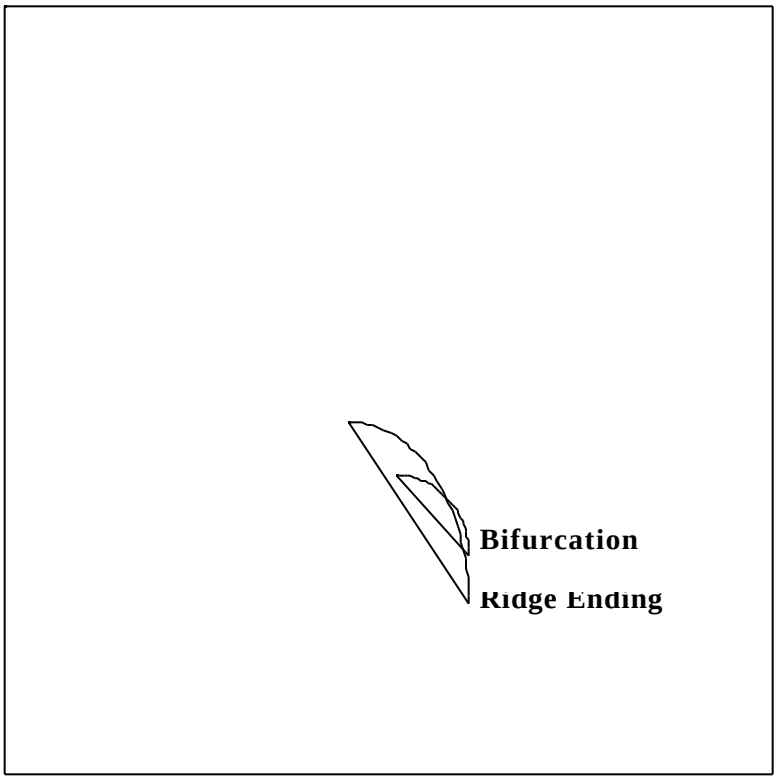
~~3.3.2.~~2.3.2. Angle of a Ridge Ending

The angle of a ridge ending is defined as the angle of a line segment originating at the minutia point location, and extending to the end of the medial skeleton of the ridge itself. In other words, the line from the minutia point to the point at the end of the thinned ridge.

~~3.3.3.~~2.3.3. Angle of a Ridge Bifurcation

The angle of a ridge bifurcation is defined as the angle of a line segment originating at the minutia point location, and extending to the end of the medial skeleton of the area between the two ridge branches. In other words, the line from the minutia point to the endpoint of the enclosed valley..

Figure 1. Definition of Finger Minutiae



~~4.~~3. Finger Minutiae Record Format *Put some intro words here that say we start with a Record header, then a common minutiae record per finger. These are all followed by any proprietary minutiae records per finger.*

The minutiae record format describes the format that shall be used to achieve interoperability between finger matchers providing a one-to-one verification. Went to binary data format with unsigned integer values only. All finger data shall be acquired from the same scanner and feature extraction engine.
< Need to decide on little endian ~~vs~~vs. big endian for numeric values, signed ~~vs~~vs. unsigned values >

~~4.1.~~3.1. Record Header

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

~~4.1.1.~~3.1.1. Format Identifier

The Finger Minutiae Record shall begin with the four ASCII characters “FMR ” to identify the record as following this standard.

~~4.1.2.~~3.1.2. Version Number

The version number for the version of this standard used in constructing the minutiae record shall be placed in four bytes.

< Need to assign this initial version number and decide on future control of this field >

~~4.1.3.~~3.1.3. Length of Record

The length of the entire record excluding the eight bytes used in the format Identifier and Version Number shall be placed in two bytes.

~~4.1.4.~~3.1.4. Impression Type

The impression type of the finger images that the minutiae data was derived from shall be record in one byte. The codes for this byte shall be as follows:
Refer to Table 5 in ANSI/NIST Standard. Is there a need to mark live scan source type (i.e., capacitance vs. optical vs. ultrasound, etc.)?
~~*< Need to generate or adopt an impression type code table >*~~

~~4.1.5.~~3.1.5. ~~Scan System~~System ID

The identification of the system generating the minutiae data shall be recorded in 12 bytes. The first 2~~4~~ bytes shall be a engine ID~~-~~ representing the owner or vendor. The registration of engine ID shall be controlled by ~~*< need a registration authority*~~*the BIOAPI registration process.* ~~>~~. The feature extraction version shall be contained in the next 2~~4~~ bytes. The scanner ID shall be contained in the last two~~our~~ bytes (there is a problem operationally with how this field will be updated in the field when a new scanner is used?~~-~~) A value of all zeros will be acceptable and mean - unreported. The value of these last two sub-fields may be decided by the vendor.

~~4.1.6.~~3.1.6. ~~Pixel Aspect Ratio~~Scan Rate in X direction

~~The pixel aspect ratio of the device used to scan the finger(s) and generate the minutiae data shall be placed in two bytes. The first byte shall be numerator of the ratio and the second byte shall be the denominator of the ratio. The smallest possible non-zero values shall be used to represent the ratio. It is expected in most system the ratio value will be equal to one.~~The resolution of the finger scanner shall be placed in 2 bytes having the units of pixels per inch in hundredths of an inch increments (or pixels per centimeter?) The value of the sensor X resolution shall not be zero. (When NEC raised the issue of accepting verifications on low resolution images, I made the observation that for higher security when there is a low scan rate you might raise the threshold for a match. Is this going to work?)

3.1.7. Scan Rate in Y direction

The resolution of the finger scanner shall be placed in 2 bytes having the units of pixels per inch increments in hundredths of an inch increments (or pixels per centimeter?) The value of the sensor Y resolution shall not be zero.

~~5.Sensor X Resolution~~

~~The resolution of the finger scanner shall be placed in 2 bytes having the units pixels per inch. The value of the sensor X resolution shall not be zero.~~

< should we replace the two bytes for the aspect ratio with a Y resolution instead? >

~~5.1.1.~~3.1.8. Number Of Fingers

The number of fingers contained in the minutiae record shall be placed in one byte.

4. Finger Minutiae Record Format

~~5.2.~~4.1. Finger 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 minutiae record.

~~5.2.1.~~4.1.1. Finger Position

The finger position shall be placed in one byte using the following code definitions: Use the ANSI-NIST table of finger positions.

~~*< need to generate or adopt a finger position code. Be aware of people with more than ten fingers >*~~

~~5.2.2.~~4.1.2. Finger Quality

The quality of the overall finger minutiae data shall be between 0 and 100 and placed in one byte. A value 0 shall represent the lowest possible quality and the value 100 shall represent the higher possible quality. Consider using the BIOAPI approach to having four bands of score: unacceptable,

poor, good, excellent. Zero would be used as "undetermined or not used". If BIOAPI approach is used, reference it here instead of duplicating it. This value may be used by the matcher to determine its certainty of verification. (We had a short discussion and agreed that the point of verification the algorithm will ask for the highest quality finger for verification not just the first finger or ...)

< Need to create certification process the ensure similar values are used between matchers >

~~5.2.3.~~4.1.3. Number of Minutiae

The number of minutiae recorded for the finger shall be placed in one byte. There was a discussion of minimums and we decided there would be no minimum.

~~5.3.~~4.2. Finger Minutiae Data

The finger minutiae data shall be recorded in block of 5 bytes. The order of the minutiae is not specified.

~~5.3.1.~~4.2.1. Minutiae Type ~~Minutiae Position~~

The type of minutiae will be placed in the first two bits of the first Byte. There will be two bits set aside at the beginning of the third byte for future use. Zero will represent "other"; 1 for ridge ending and 2 for bifurcation.

4.2.2. Minutiae Position

The X coordinate of the minutia shall be placed in the ~~first~~ rest of the first two bytes. The Y coordinate shall be placed in the ~~next~~ following two bytes. The coordinates shall be expressed in the unit of pixels at the resolution indicated in the record header.

~~5.3.2.~~4.2.3. Minutiae Angle

The angle of the minutia shall be place in one byte in units of 2 degrees. The value shall be a non-negative value between 0 and 179, inclusive. For example, an angle value of 5 represents 10 degrees.

4.2.4. Minutiae Quality

The quality of each minutia shall be provided. (Details to follow – Sagem Morpho uses 0 for great and 32 for very poor.) This shall be stored in one byte. This is out for *consensus vote* – Creed Jones is looking for comments from vendors.)

~~5.4.~~4.3. Proprietary Data This might become Section 6. ***This would be used if the vendors have additional factors they want to use when they verify against their own extracted fingerprints.***

The optional section of the finger minutiae record is open to placing ~~propreitary~~proprietary data required by the matcher to maintain its highest performance level. The size of this section should be kept to as small as possible, augmenting the data stored in the standard minutiae section. The proprietary data for each finger shall immediately follow the standard minutiae data.

~~5.4.1.~~4.3.1. Vendor ~~Identificaion~~Identification

The vendor identification code shall be place in two bytes. A value of zero shall indicate that there is no follow proprietary data. The vendor identification codes shall be assigned by
<need a registration authority>

~~5.4.2.~~4.3.2. Length of Data

The length of the proprietary data section excluding the vendor identification and length of data fields shall be placed in two bytes. This value is used to skip to the next finger minutiae data if the matcher cannot decode and use this data.

~~5.4.3.~~4.3.3. Data

The data field of the ~~propreitary~~proprietary data is left specific for each matcher that is generating the finger minutiae record.

Table 1. Minutiae Record Format This table needs quite a bit of updating.

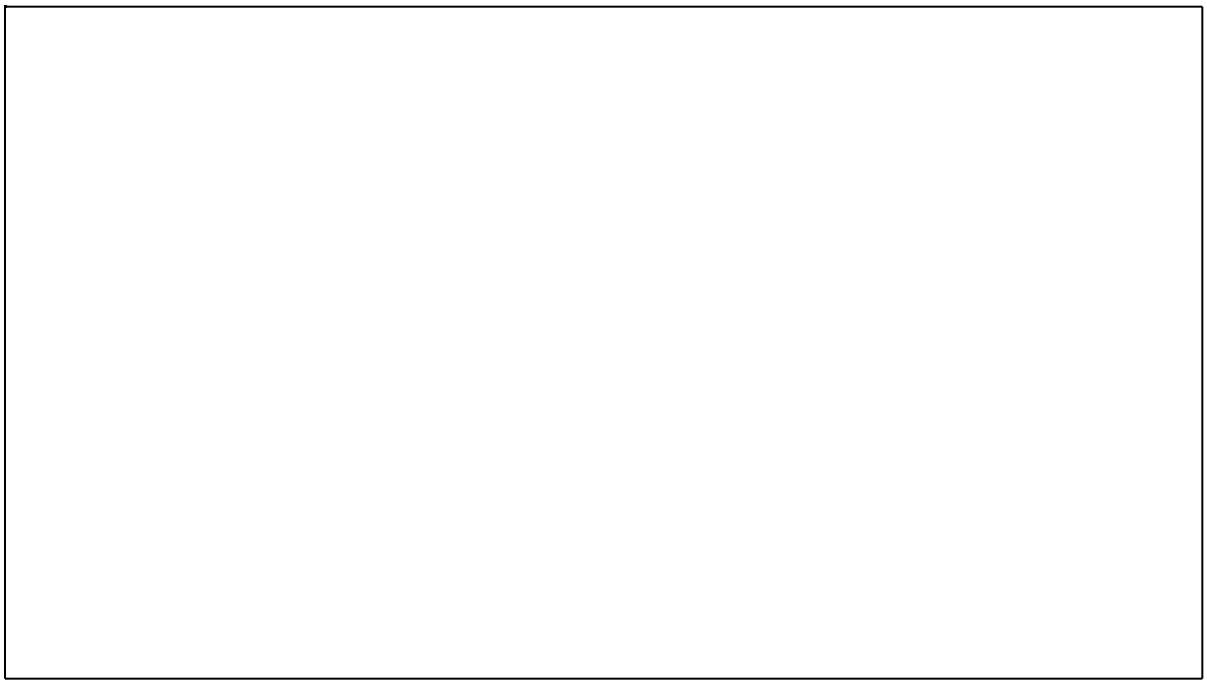
	Field	Size	Notes
One per record	Format Identifier	4 bytes	"FMR " – finger minutiae record
	Version Number	4 bytes	For standard
	Length of total record	2 bytes	In bytes
	Impression Type	1 byte	
	Scan System		
	Engine ID	4 bytes	Registration authority controlled
	Feature Extraction SW Version	4 bytes	Vendor specified
	Scanner ID	4 bytes	Vendor specified
	Pixel Aspect Ratio	2 bytes	ratio; byte1 / byte2[1]
	Sensor X Resolution	2 bytes	in pixels per inch
	Number of Fingers	1 byte	
One per finger	Finger Position	1 byte	
	Finger Quality	1 byte	0 to 100 [2]
	Number of Minutiae	1 byte	
One per minutia	Minutiae		
	X	2 byte	Expressed in image pixels
	Y	2 byte	Expressed in image pixels
	θ	1 byte	Resolution is 2 degrees
One per finger	Type Code for Private Area	2 bytes	"0000" = no private area
	Length of private feature area	2 bytes	
	Private feature area	Specified in previous field	
	Size Total for 2 fingers, 32 minutia each, no private data	27 + 3*f + 5*m 353 bytes	

[1] Pixel Aspect Ratio is the ratio of the size of a pixel in the vertical, to the size of a pixel in the horizontal. More formally, it is the ratio of the distance (in the image plane) between the center of a pixel and the center of the pixel immediately above, to the distance between the center of a pixel and the center of the pixel to the immediate right.

[2] This quality number is an overall expression of the quality of the finger record, and represents quality of the original image, of the minutia extraction and any additional operations that may affect the minutia record.

1. Interoperable Matcher Performance

< insert addition requirements to ensure matcher interoperability >



2. Compliance Testing

Interoperability of one-to-one matching relies on each matcher to adhere within a tolerance to the determination of the minutiae. To test compliance a standardized finger image data set shall be used, the following test shall be ~~executed~~executed, and the results shall be within the stated tolerances.

~~2.1.~~Record format compliance

The software shall be tested to verify compliance with this standard from a perspective of layout. Testing shall employ provision of records to be formatted and returned. The challenge is in that these are all binary records and as such can not just be printed out and checked.

2.1. Finger Minutiae Extraction

Images of known quality will be processed to determine the accuracy of extraction to a certain TBD tolerance level for each parameter. See following table. The approach would be to generate curves of behavior for each of the four quality bands of images. Then "digitize" these by size of error (e.g., 2 pixels in error in Y then 4 pixels in error, etc.)

< describe tests used to ensure that each matcher finds the same minutiae within some tolerance. >

2.2. Finger Quality Assessment

Images of known quality will be processed to determine the accuracy of Finger Quality to a certain TBD tolerance level for each finger.

< describe tests used to ensure that each matcher assesses the finger quality within a tolerance >

We got off into a methods and metrics discussion. Mike G. from NIST has lots of ideas.

There was a discussion of whether we should test readers or just writers. No conclusion was reached.