

NIST MINEX Match on card Test Plan.

	const BYTE finger_position, const BYTE impression_type, const UINT16 height, const UINT16 width, UINT16 *xcenter, UINT16 *ycenter, BYTE *INCITS_378_template);	
Description	<p>This function takes a raw input image and outputs the corresponding I378 conformant template. The memory for the template is allocated before the call i.e. create_template() does not allocate memory for the result. The function returns either success (0) or failure (non zero). Failure indicates a failure to enroll the image and will nevertheless result in the output of a I378 template with zero minutia. This will be used in subsequent comparisons.</p> <p>An error shall result in a template containing only the record and finger view headers. This number of minutiae shall be set to 0, and no minutia data shall be present. The resulting template shall have length of 32 bytes (26 byte Record Header + 4 byte Finger View header + 2 bytes for the Extended Data Block length which shall be set 0x0000). All other fields in the Record and Finger View headers shall be set to their regular and accurate values.</p>	
Input Parameters	raw_image	The uncompressed raw image used for template creation.
	finger_quality	The quality of the fingerprint image (e.g. QUAL_GOOD).
	finger_position	The finger position code (e.g. FINGPOS_RI).
	impression_type	The impression type code (e.g. IMPTYPE_LP).
	height	The number of pixels indicating the height of the image.
	width	The number of pixels indicating the width of the image.
Output Parameters	xcenter	Horizontal and vertical locations of a center point suitable for pruning to be used per section 10.4.3. If this functionality is not supported, the xcenter shall be set to the input width (i.e. outside the bounds of the image).
	ycenter	
	INCITS_378_template	The output template, per Table 4
Return Value	This function returns zero on success or a documented non zero error code otherwise.	

1 **9.4.3. Minutiae matching**

2 One to one comparisons representative of single finger verification attempts will be made using the function
3 defined in Table 24.

4 **Table 24 - MINEX API match_templates function**

Prototype	INT32 match_templates(const BYTE *verification_template, const UINT16 verification_template_size, const BYTE *enrollment_template, const UINT16 enrollment_template_size, UINT16 *score);	
Description	<p>This function compares two Table 5 ISO CC compliant templates and outputs a match score. The verification_template shall be compared to the enrollment_template (in that order where the underlying matcher is order dependent).</p> <p>The returned score is an integer representing the similarity of the parent fingerprint images. It should not be artificially quantized. NIST will allocate memory for this parameter before the call. When the function is called with either or both templates containing zero minutiae (see 7.6) the function shall assign the value 0 to the score, then return a documented error code (see 9.6.3 below).</p>	
Input Parameters	verification_template	A Table 5 template from create_template() as processed by NIST according to the verification BIT.
	verification_template_size	The size, in bytes, of the input verification template $0 \leq N \leq 384$
	enrollment_template	A Table 5 template from create_template() as processed by NIST according to the enrollment BIT.
	enrollment_template_size	The size, in bytes, of the input enrollment template $0 \leq N \leq 384$
Output Parameters	score	A similarity score resulting from comparison of the templates, on the range [0,65535].

Return Value	This function returns zero on success (i.e. a valid score is produced) or a documented non zero error code on failure.
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1 **9.4.4. Implementation identifiers**

2 The implementation shall support the function of Table 25 to identify itself.

3 **Table 25 - MINEX API get_pids function**

Prototype	INT32 get_pids(UINT32 *template_generator, UINT32 *template_matcher);	
Description	<p>This function retrieves CBEFF PIDs which identify the SDK’s supported core template generator and template matcher. Both PIDs shall be four byte fields conforming to the CBEFF Product Identifier (PID) requirements of clause 6.4.4 of INCITS 378:2004. These state that</p> <ul style="list-style-type: none"> – The two most significant bytes of the field indicate the (corporate) owner. It is a hexadecimal integer assigned by the IBIA (per the requirement of clause 6.5.12.1 of ISO/IEC 19785 1:2006). – The least two significant bytes are an owner assigned version number. <p>The memory for the template generator and matcher parameters will be allocated by NIST before the call.</p> <p>If the SDK does not include a template_generator, the returned value shall be zero.</p>	
Output Parameters	template_generator template_matcher	A PID which identifies the SDK’s minutiae extractor A PID which identifies the SDK’s matcher.
Return Value	This function returns zero on success or a documented non zero error code on failure. In the latter case, both output parameters shall be set to 0.	

4 **9.5. Software and Documentation**

5 **9.5.1. SDK Library and Platform Requirements**

6 Participants shall provide NIST with binary code only (i.e. no source code) – supporting files such as header
7 (“.h”) files notwithstanding. Such files shall not contain intellectual property of the company nor any
8 material that is otherwise proprietary. It is preferred that the SDK be submitted in the form of a single static
9 library file (ie. “.LIB” for Windows or “.a” for Linux). However, dynamic/shared library files are permitted.

10 If dynamic/shared library files are submitted, it is preferred that the API interface specified by this document
11 be implemented in a single “core” library file with the base filename ‘libminex’ (for example, ‘libminex.dll’
12 for Windows or ‘libminex.so’ for Linux). Additional dynamic/shared library files may be submitted that
13 support this “core” library file (i.e. the “core” library file may have dependencies implemented in these
14 other libraries).

15 **9.5.2. Linking**

16 NIST will link the provided library file(s) to a C language test driver application (developed by NIST) using

- 17 – For windows, version 3.3.3 of the GCC compiler will be used under Cygwin;
- 18 – For RedHat Linux 7.3 platforms, version 2.96 of GCC will be used.

19 All GCC compilers use libc. The link command might be "gcc -o mintest mintest.c L. -lminex"

20 Participants are required to provide their library in a format that is linkable using GCC with the NIST test
21 driver, which is compiled with GCC. All compilation and testing will be performed on x86 platforms running
22 either Windows 2000 or Red Hat Linux 7.3 (dependent upon the operating system requirements of the SDK).
23 Thus, participants are strongly advised to verify library level compatibility with GCC (on an equivalent
24 platform) prior to submitting their software to NIST to avoid linkage problems later on (e.g. symbol name and
25 calling convention mismatches, incorrect binary file formats, etc.).

1 NOTE Dependencies on external dynamic/shared libraries such as compiler specific development
2 environment libraries are discouraged. If absolutely necessary, external libraries must be provided to NIST
3 upon prior approval by the Test Liaison.

4 **9.5.3. Installation and Usage**

5 The SDK must install easily (i.e. one installation step with no participant interaction required) to be tested,
6 and shall be executable on any number of machines without requiring additional machine specific license
7 control procedures or activation.

8 The SDK's usage shall be unlimited. The SDK shall neither implement nor enforce any usage controls or limits
9 based on licenses, execution date/time, number of executions, presence of temporary files, etc.

10 It is recommended that the SDK be installable using simple file copy methods, and not require the use of a
11 separate installation program. Contact the Test Liaison for prior approval if an installation program is
12 absolutely necessary.

13 **9.5.4. Documentation**

14 Participants shall provide complete documentation of the SDK and detail any additional functionality or
15 behavior beyond that specified here. The documentation must define all error and warning codes (see 9.6.3).

16 **9.5.5. Modes of operation**

17 Individual SDKs provided shall not include multiple "modes" of operation, or algorithm variations. No switches
18 or options will be tolerated within one library. For example, the use of two different "coders" by a minutiae
19 extractor must be split across two separate SDK libraries, and two separate submissions.

20 **9.6. Runtime behavior**

21 **9.6.1. Speed**

22 The following limits are instituted to constrain NIST's total MINEX II computational workload.

- 23 – The mean template match operation shall not exceed 10 milliseconds.
- 24 – The mean template creation operation shall not exceed 1.2 seconds (using a 2GHz Pentium IV).

25 **9.6.2. Interactive behavior**

26 The SDK will be tested in non interactive "batch" mode (i.e. without terminal support). Thus, the submitted
27 library shall not use any interactive functions such as graphical user interface (GUI) calls, or any other calls
28 which require terminal interaction e.g. reads from "standard input".

29 **9.6.3. Error codes and status messages**

30 The SDK will be tested in non interactive "batch" mode (i.e. without terminal support). Thus, the submitted
31 library shall run quietly, i.e. it should not write messages to "standard error" and shall not write to "standard
32 output". Instead, the SDK shall conform to the error notification procedures of Annex D.

33 **9.6.4. External communication**

34 Processes running on NIST hosts shall not write any data to external resource (e.g. server, file, connection, or
35 other process) other than those explicitly allowed in this document.

36 **9.6.5. Stateful behavior**

37 All components in this test shall be stateless and idempotent. No component of the test is permitted to
38 maintain state information. This applies to template generation and matching, and to on card and off card
39 activity. NIST will institute appropriate tests to detect stateful behavior in the activities mentioned in the
40 following subsections. If detected, NIST will cease evaluation and inform the provider.

1 NOTE NIST is prohibiting template adaptation, and will accordingly implement checks to detect any stateful
2 behavior and side effects. However NIST is interested in template update as a potential means of improving
3 operational performance, but it is beyond the scope of this and foreseeable testing efforts.

4 10. NIST conversion of I378 to ISO-CC templates

5 10.1. Background

6 NIST intends to maintain its use of the I378 standard as a primary format for off card storage of minutia
7 templates. NIST recognizes the advantages of ISO CC for on card storage or matching. Although the two
8 kinds of templates differ, the accuracy implications seem to be limited see the Annex A simulation of the
9 impact on matching accuracy.

10 10.2. Presence of BITs on card

11 Each submitted card shall be populated with one or two BITs per section 8.6. These shall be treated as read
12 only data. These shall be supplied in the structure given in Table 13 which leverage the BIT and BIT grouping
13 structures of ISO/IEC 7816 11:2004 (Tables 1 and 2).

14 The BITs parameterize the production of templates that a reader, or other system, should send to the
15 requesting card: For a reference template TR, a verification template TV, and a PC or card based matcher,
16 M, the test will compare BIT processed versions of the templates to produce a similarity score

$$17 \quad s = M(BR(TR), BV(TV))$$

18 where BR and BV denote the functions representing the BIT parameterization.

19 Operationally the BIT parameters (e.g. maximum number of minutiae) might be sent *as inputs* to a template
20 generator. NIST does not intend to do this because such specialization would be computationally prohibitive
21 in the context of an interoperability test¹⁶. Instead, NIST proposes to standardize the minutiae template
22 reduction process as follows.

23 10.3. Use of BITs

24 NIST will treat on card and off card matcher implementations identically. This means that the BITs read from
25 the card will be used to parameterize BOTH the conversion of templates sent to the card and to the PC based
26 match operation.

27 The conversion operation proceeds with a pruning operation (sec. 10.4.3), a sorting operation (sec. 10.5), and
28 a re encoding (sec. Annex A.1). NIST will conduct this operation using its own software which

- 29 – exists within a larger standard biometric data interchange software distribution named BioMDI,
- 30 – is entirely open source¹⁷ ISO/IEC 9899:1999 "C" code,
- 31 – is available for [download and cooperative development](#)¹⁸ in the open source model, and
- 32 – is under formal version control¹⁹.

33 **Figure 1 - Conversion of INCITS 378 to ISO-CC**

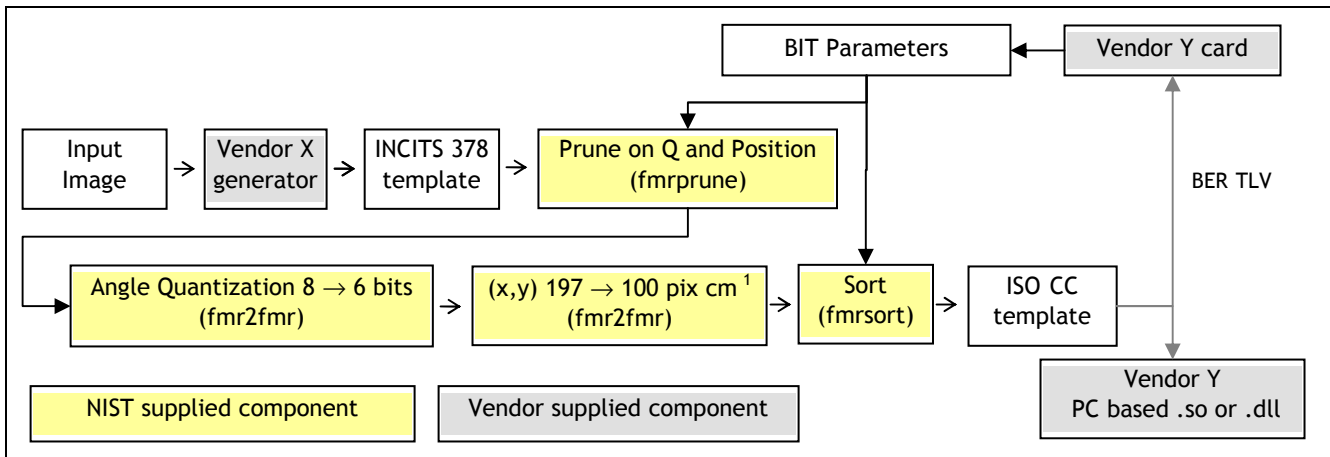
¹⁶ For example, if a test used T templates, N template generators and C cards, imposes the requirement to execute O(TNC) image to template generations.

¹⁷ See the [license](http://www.itl.nist.gov/iad/894.03/nigos/NIGOS_licdis_061906.pdf) at http://www.itl.nist.gov/iad/894.03/nigos/NIGOS_licdis_061906.pdf

¹⁸ The software is available at <http://www.itl.nist.gov/iad/894.03/nigos> and maintained using a [Perforce version control system](#), at <http://www.perforce.com/>, for which clients are freely available. While a nightly zip/tar archive is produced, users should subscribe to NIST's open source server because it automatically sends email notifications of any changes to the software.

¹⁹ Users need to [register](http://www.itl.nist.gov/iad/894.03/nigos/NIGOS_User_Registration.pdf) http://www.itl.nist.gov/iad/894.03/nigos/NIGOS_User_Registration.pdf and may then access the code branches using a client such as [P4V](#) at <http://www.perforce.com/perforce/products/p4v.html>.

NIST MINEX Match on card Test Plan.



1 The items in parentheses are the names of executables present in NIST's BioMDI distribution.

2 **10.4. Number of minutiae**

3 **10.4.1. Limits on number**

4 NIST's considers that its role is not to impose algorithmic constraints. However the minimum and maximum
5 numbers of minutia a card may accept are regulated as follows

- 6 – The one byte value implies a range of [0,255],
- 7 – Because some templates will naturally contain 0 minutia (see FTA in section 7.6), minimum values will be
8 ignored,
- 9 – NIST imposed a 128 minutia maximum in all prior MINEX trials. This is arguably too high given that MINEX
10 04, which used four large operational single index finger flat impression datasets, found that the leading
11 systems produced a median of 41 minutiae from each image with the 5% and 95% quantiles being 24 and
12 61 respectively.
- 13 – A T=0 APDU command constrains the maximum number of three byte minutia to 83. Note that T = 0 is
14 not required by NIST. 7816 command chaining will be attempted for larger templates, as necessary.
- 15 – Informative Annex D.1.1 of ISO/IEC 19794 2 recommends the minimum number of minutiae for enrollment
16 to be 16, and for verification, 12. It also recommends the maximum number of minutiae for enrollment
17 and verification is 60. NIST notes that these are recommendations only, but otherwise takes no
18 immediate position on the appropriateness of these numbers beyond the information presented in
19 Annex A.

20 **10.4.2. Effect of the BIT**

21 NIST will send single view templates to the PC based and card based matching implementations. The
22 reference and verification templates shall be parameterized by their respective BITs, as follows. If,

- 23 – the value indicated in the BIT for the minimum number of minutiae is $0 \leq N \leq 255$,
- 24 – the value indicated in the BIT for the maximum number of minutiae is $0 \leq M \leq 255$,
- 25 – the number of minutia present in a (generally third party) verification template is K, then
- 26 – the number of minutia NIST will send to the card is denoted by S where

$$S = \begin{cases} M & \text{if } K \geq M \\ K & \text{if } K < M \\ K & \text{if } K < N \end{cases}$$

1 Note that the BIT parameter N is ignored. This is necessary because some input templates will inevitably
2 have zero minutiae. The matcher shall execute successfully when either or both of the input templates
3 contains fewer than N minutiae²⁰.

4 NIST will reject cards for which $N > M$.

5 **10.4.3. Pruning mechanism**

6 When a MOC implementation indicates the capability to take no more than M minutiae, NIST proposes to
7 follow a refined version of the guidance given in the last paragraph of clause 8.3.1 of ISO/IEC 19794 2:2005:

8 If the number of minutiae exceeds the maximum number processible by a card,
truncation is necessary. The truncation is a 2 step process. At first, finger minutiae
of poor quality are eliminated. If still too many minutiae are there, then truncation
shall be made by peeling off minutiae from the convex hull of the minutiae set and
before sorting into the order required by the card.

9 Specifically NIST intends to replace the requirement to use the convex hull, with a method based on the
10 distance of a minutia from a center. This is based on the ISO/IEC 19794 2 subclause 8.3.4 guidance for polar
11 ordering.

12 Thus given a I378 template containing K minutiae and a BIT request for no more than M minutiae our software
13 will remove $K - M$ minutiae as follows.

14 Minutiae with the lowest quality value are removed first. If two or more minutia have an equal quality value,
15 then the one with the largest value of the integer quantity

$$r^2 = (x - x_c)^2 + (y - y_c)^2$$

16 is removed. Finally if those values are tied, then the ISO/IEC 19794 2:2005 polar ordering instruction to
17 prioritize small angle minutiae is applied.

18 NIST understands that the ISO/IEC 19794 2:2005 material on polar coordinates is intended for sorting, not
19 pruning, but considers the convex hull approach to be complex, and potentially harmful effects.

20 **10.4.4. Pruning center**

21 In MINEX II, all I378 template generators may additionally report the coordinates of an appropriate center
22 about which pruning should be conducted. Earlier versions of this test specification established the minutia
23 means (center of mass) for (x_c, y_c) , per the ISO/IEC 19794 2:2005 sorting guidance. However, this may be
24 particularly inappropriate when large numbers of minutia are reported in a noisy part of the image.

25 NIST will conduct pruning about

- 26 – the center coordinates from the template generator, if supplied, otherwise
- 27 – the center of mass, per the ISO standard.

28 **10.4.5. Pruning priority**

29 It is clear that a quality algorithm producing many levels of quality will cause the pruning operation to prune
30 on r^2 only occasionally. Conversely, a quality algorithm producing few levels of quality will cause r^2 pruning
31 to be more dominant. An implementer should not supply quality values that are dependent solely of r^2
32 because this contradicts the true minutia requirement of section 7.2.2.

²⁰ An appealing alternative would be to fill with N K randomly generated minutiae.

1 **10.5. Sort order of minutiae**

2 **10.5.1. Support for ordering**

3 Although template generators are likely to produce templates whose minutiae have an arbitrary order, the
4 ISO CC standard defines several geometric orderings of the minutia. The x y and y x sorting methods support
5 extension of the spatial range of a fingerprint (e.g. for rolled prints) in one dimension. The polar method
6 supports a center first sort.

7 Currently NIST intends to support at least the unsorted, Cartesian y x, Cartesian x y and polar sorting
8 methods, because the standard defines these as options. NIST published open source "C" code which is
9 maintained here <http://www.itl.nist.gov/iad/894.03/nigos/biomdi.html> and is called by our MOC application
10 here <http://www.itl.nist.gov/iad/894.03/nigos/biomapp.html>. NIST does not intend to accept commercial
11 code for this purpose, although we may institute a conformance test for implementations that do.

12 However, NIST is aware that commercial readers will need to include such software in addition to the pruning
13 software. This adds complexity and a "degree of freedom" that would better be handled as a natural property
14 of the matching algorithm. Although NIST notes the European Citizen Card specification, CEN/TS 15480 2,
15 requires implementations to accept arbitrarily sorted data, NIST prefers not to ignore the SC37/WG3 intent to
16 allow sorting. NIST does consider that the exact requirements of ISO/IEC 19794 2 clause 8 are unclear.

17 **10.5.2. Modulo sorting for large images**

18 Note that archival imagery used in all planned MINEX evaluations is at most 500 pixels in width and height,
19 and is scanned at 19.7 pixels mm¹, and therefore all possible minutiae coordinates can be encoded in 8 bits
20 without modulo sorting (or removal).

21 The ISO/IEC 19794 2:2005 standard needs modification, see Annex F.1.

22 **10.6. Ridge count, core and delta and zonal quality information**

23 The ISO/IEC 19794 2:2005 standard allows the BIT to indicate the "extended data" defined in clause 7.5 of
24 that standard. However in Table 13, the binary value 00000000b indicates that ridge count, core and delta
25 and zonal quality information are out of the scope of this test. Suppliers must adhere to the zero
26 specification here.

27 NIST is interested in possible performance improvement associated with the use of richer templates, but past
28 experience with INCITS 378 extensions (MINEX 04) has not suggested large improvements are available.
29 However NIST will, on request from any interested party, consider conducting tests of templates that include
30 extended data. Particularly, what benefits would zonal quality allow beyond that associated with a
31 (calibrated) minutia quality value.

32 **11. References**

33 [1] C. Wilson et al., "Biometric Data Specification for Personal Identity Verification," NIST Special Publication
34 800 76 1 http://csrc.nist.gov/publications/nistpubs/800_76_1/SP800_76_1_012407.pdf

35 [2] P. Grother et al., "Performance and Interoperability of the INCITS 378 Template," NIST IR 7296
36 http://fingerprint.nist.gov/minex04/minex_report.pdf

37 [3] E. Tabassi et al. "Finger Print Image Quality," NISTIR 7151 2004 (Gaithersburg, MD: National Institute of
38 Standards and Technology, August 2004) http://www.itl.nist.gov/iad/894.03/quality/reports/ir_7151.pdf

39 [4] American National Standard for Information Technology - Finger Minutiae Format for Data Interchange,
40 ANSI/INCITS 378 2004, www.incits.org

41

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2

Annex A Comparison of the INCITS 378 and ISO/IEC 19794-2 standards

3 CBEFF Format Owner = 0101 for ISO/IEC JTC 1/SC 37.
 4 CBEFF Format Type = 0005 for ridge endings encoded as valley bifurcation points, as in INCITS 378.
 5 The INCITS 378 standard's record format and the ISO/IEC 19794 2 compact card format differ syntactically
 6 and semantically. These differences are presented in the next two subsections. Thereafter we address the
 7 implications for transcoding between the standards, and the MINEX requirements.

8 A.1 Syntactic differences

9 The INCITS 378:2004 and ISO CC templates differ as follows. In ISO CC
 10 – the (x,y) coordinates are encoded in 8 bits as opposed to 14 bits,
 11 – the spatial resolution is fixed at 10 pixels per millimeter as opposed to variable resolution,
 12 – the angle is encoded in 6 bits as opposed to 8 bits, and
 13 – the minutia quality value is absent.
 14 These differences are depicted in Table 26. Note that ridge count and core and delta information is not
 15 being evaluated in this test, and therefore the BIT entry defined in ISO/IEC 19794 2 Table 14, shall be set to
 16 0, and ignored.

17 **Table 26 - Minutia encodings of the ISO-CC and INCITS 378**

	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6
ISO/IEC 19794 2 Compact Card Format	x coord.	y coord.	t	angle		
	8	8	2	6		
ISO/IEC 19794 2 Record Format and INCITS 378	t	x coord.	r	y coord	angle	quality
	2	14	2	14	8	8
	t = type		r = reserved			

18 A.2 Semantic differences

19 The abbreviated 8 bit (x,y) encodings in the ISO CC standard support "typical" single finger images by
 20 specifying a hard wired resolution of 10 pixels per millimeter (ISO/IEC 19794 2, subclause 8.2). This is
 21 approximately half of typical enrollment data gathered on 500 ppi (19.7 pixels per millimeter) optical
 22 scanners. This is summarized in Table 27. The effect would be that minutia can not extend over a region
 23 larger than $255 / 10 = 25.5$ mm. However the ISO CC standard provides for coordinate wraparound wherein
 24 the minutia coordinates are sorted such that the actual value may extend beyond the range by encoding it as
 25 $x \text{ mod } 256$. Reconstruction of the actual value is possible because sorting is applied.

26 **Table 27 - Minutia location quantization of ISO-CC and INCITS 378 templates**

Standard	Allowed values (units)	Allowed values (mm)	Allowed values (mm), at 500 ppi
INCITS 378:2004 record format	[0,16383]	Depends on the encoding resolution	[0, 0.051, 0.1015, 0.1523, ..., 831.6]
ISO/IEC 19794 2 record format			
ISO/IEC 19794 2 compact card	[0,255]	[0, 0.1, 0.2 ... 25.5]	N/A

27 As shown in Table 28, the three different angular encodings support minutia encodings of varying precision.
 28 Whether this difference materially affects performance is dependent on the sensitivity of the matching
 29 algorithm, and on how accurately template generators measure the angle.

30 **Table 28 - Minutia angle quantization of ISO-CC and INCITS 378 templates**

NIST MINEX Match on card Test Plan.

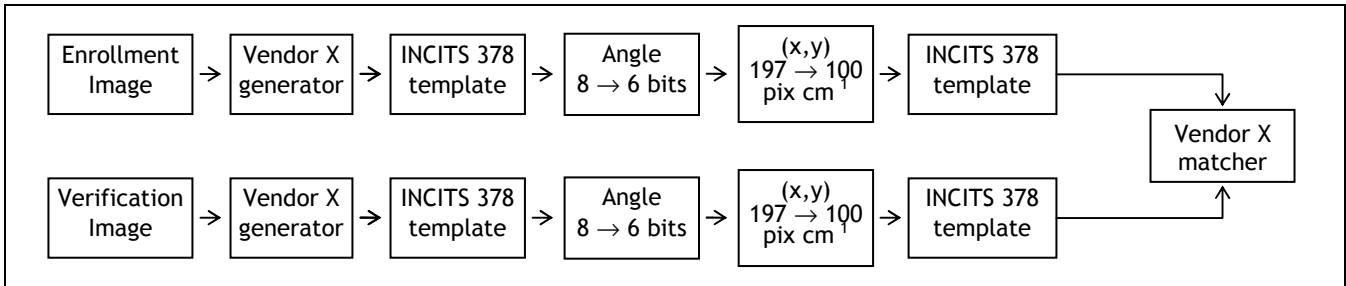
Standard	Allowed values (units)	Quantization	
		Degrees per unit	Radians per unit
INCITS 378:2004 record	[0,179]	360 / 180 = 2	2pi / 180 = 0.0349
ISO/IEC 19794 2 record	[0,255]	360 / 256 = 1.4063	2pi / 256 = 0.0245
ISO/IEC 19794 2 compact card	[0,63]	360 / 64 = 5.625	2pi / 64 = 0.0982

1

2 **A.3 Simulation protocol**

3 To quantify the effects of the ISO CC encoding vs. the INCITS 378 record format, NIST simulated the
 4 production of ISO CC templates by quantizing the coordinates and angles in sets of INCITS 378 templates
 5 produced in NIST's existing MINEX testing.

6 **Figure 2 - Use of INCITS 378 for simulation of ISO-CC accuracy**



7 The C code fragments to effect these transformations are shown in Table 29. This code is part of the
 8 "fmr2fmr" program distributed²¹ by NIST as part of a suite of libraries and applications that support various
 9 INCITS and ISO biometric data interchange standards.

10 **Table 29 - Source code for conversion of INCITS 378 to ISO-CC**

```

Angular re quantization
// The ISO minutia record has 6 bits for the angle, so
// we have 64 possible values to represent 360 degrees.
for (m = 0; m < mcount; m++) // for all minutiae
{
    const int theta = 2 * (int)fmds[m]->angle; // 378 has 2 degrees
    const double isotheta = round((64.0 / 360.0) * (double)theta); // CC has 5.625 deg
    fmds[m]->angle = (unsigned char)round(((360.0 / 64.0) * isotheta) / 2.0); // Put back in 378
}

Spatial re quantization
for (m = 0; m < mcount; m++) // for all minutiae
{
    const double x = (double)fmds[m]->x_coord; // cast from unsigned short
    const double y = (double)fmds[m]->y_coord; // cast from unsigned short

    const double xmm = 10.0 * x / (double)xres; // millimeters, because INCITS 378 resolution
    const double ymm = 10.0 * y / (double)yres; // values are in pixels per centimeter
    const double xunits = xmm / 0.1; // units of 0.1 pix per mm which is the CC
    const double yunits = ymm / 0.1; // card format's hardwired sampling freq
    const unsigned short xcc =
        (unsigned short)(0.5 + xunits); // round the value - this is what would be
    const unsigned short ycc = // stored in "typical" say 500 dpi operation
        (unsigned short)(0.5 + yunits);

    fmds[m]->x_coord = (unsigned short)((double)xcc * (double)xres * 0.01); // Now put back
    fmds[m]->y_coord = (unsigned short)((double)ycc * (double)yres * 0.01); // in 378 format
}
    
```

²¹ This is available for download; see <http://www.itl.nist.gov/iad/894.03/nigos/biomdi.html>

1 We took five vendors and applied their matchers to INCITS 378 templates derived from the outputs of that
 2 vendor's template generator. They are applied natively, that is to enrollment and verification templates
 3 from the same supplier's INCITS 378 generator. The five matching algorithms, identified in the first columns,
 4 are some of the more accurate ones assessed in the Ongoing MINEX evaluation.

5 All results apply to single finger matching using the POEBVA collection of left and right index fingers, as used
 6 in the Ongoing MINEX evaluation. The FNMR computation is conducted over 15 disjoint sets each containing
 7 16000 genuine scores. The FMR computation is likewise conducted over 15 disjoint sets each containing
 8 16000 impostor scores.

9 **A.4 Results after re-quantization of angle and position**

10 Table 30 gives the change in FNMR when the matcher operating threshold is set to achieve FMR values of 0.01
 11 on INCITS 378 templates and then reset to achieve those FMRs on ISO CC templates. This thresholding
 12 strategy is representative of the situation where thresholds can be set for the ISO CC template independently
 13 of any INCITS 378 matcher trial or calibration.

14 **Table 30 - Relative accuracy of ISO-CC and INCITS 378 templates (Fixed FMR)**

	Base FMR	Base FNMR	Change in FNMR
A1	0.01	0.0140	0.0005 +/- 0.0006 p 2e 03
A2	0.01	0.0158	0.0018 +/- 0.0007 p 3e 08
A3	0.01	0.0133	0.0007 +/- 0.0007 p 2e 03
A4	0.01	0.0183	0.0006 +/- 0.0005 p 6e 05
A5	0.01	0.0159	0.0008 +/- 0.0005 p 9e 05

15 Table 31 gives changes in FMR and FNMR when the matcher operating threshold is set to achieve FMR values
 16 of 0.01, on the unaltered INCITS 378 templates. This thresholding strategy is representative of the situation
 17 where a ISO CC template is sent, with transcoding, to an INCITS 378 matcher.

18 **Table 31 - Relative accuracy of ISO-CC and INCITS 378 templates (fixed t)**

Change in FMR and FNMR when ISO CC encoding is synthesized from instances of the INCITS 378 record format "MIN:A" templates.					
	Base FMR	Change in FMR	Base FNMR	Change in FNMR	
A1	0.01	0.0013 +/- 0.0008 p 7e 06	0.0140	0.0008 +/- 0.0008 p 5e 04	
A2	0.01	0.0008 +/- 0.0011 p 1e 02	0.0158	0.0020 +/- 0.0007 p 4e 09	
A3	0.01	0.0006 +/- 0.0008 p 6e 03	0.0133	0.0007 +/- 0.0006 p 5e 04	
A4	0.01	0.0004 +/- 0.0006 p 1e 02	0.0183	0.0007 +/- 0.0007 p 7e 04	
A5	0.01	0.0008 +/- 0.0009 p 1e 03	0.0159	0.0010 +/- 0.0008 p 1e 04	

19 Thus when going from INCITS 378 to ISO CC

- 20 – Table 30 shows small but statistically significant increases in FNMR. The worst case is A2 whose FNMR
 21 goes from 0.0158 to 0.0176 at a FMR of 0.01 corresponding to about 11% more missed matches.
- 22 – At a fixed threshold for both kinds of template, Table 31 shows small that FMR is slightly but significantly
 23 lower for ISO CC than for INCITS 378, but that FNMR is again higher.

24 The presence of an algorithm effect (some implementations are more sensitive than others, viz. A2 over A3,
 25 means that vendors should consider this issue for their implementations.

26 NOTE The change in performance for less accurate matchers and template generators has not been studied.

27 **A.5 Results after reduction in number of minutiae**

28 The plots of Figure 3 show the effect of apply the pruning operation of section 10.4.3 to raw INCITS 378 (not
 29 ISO CC) templates. The effect on accuracy is shown for the same five leading matcher providers as used
 30 above. The matchers are applied natively i.e. the matcher from provider X is applied to compare templates
 31 from X's generator. For each matcher, the threshold is set to the value that gives a FMR of 0.001 on the
 32 entire unpruned corpus. The error rates are then recomputed after removing zero or more minutia to

1 achieve a maximum of N in each template. The top graph shows the effect of retaining all minutiae in the
2 enrollment template and minutiae in the verification template. The lower graph shows the effect of pruning
3 both.

4 The conclusions are

- 5 – FNMR increases for all matchers algorithms, with approximately 60 minutia being a reasonably "lossless"
6 value. Note that the 95% percentiles for number of minutiae are 60, 65, 60, 64, and 63.
- 7 – FNMR has increased by an order of magnitude (from ~2% to ~20%) when fewer than 20 minutia are used.
- 8 – FMR values also change significantly, beginning at the same 60 minutiae breakpoint, and substantially
9 below about 20 minutiae. Some systems improve (decline in FMR) and some degrade (increase in FMR).
10 NIST is concerned that any increase in FMR associated with transactions involving small numbers of
11 minutiae is a security hazard.

12 Not shown here is distributional information on the numbers of minutiae produced by template generators.
13 NIST has observed variation in the numbers found from a single image. Also not shown are interoperable
14 results (cross vendor) and NIST suggests that an incorrect conclusion from the graphs would be that template
15 generators finding more minutiae are better performing.

16 **A.6 Conclusions**

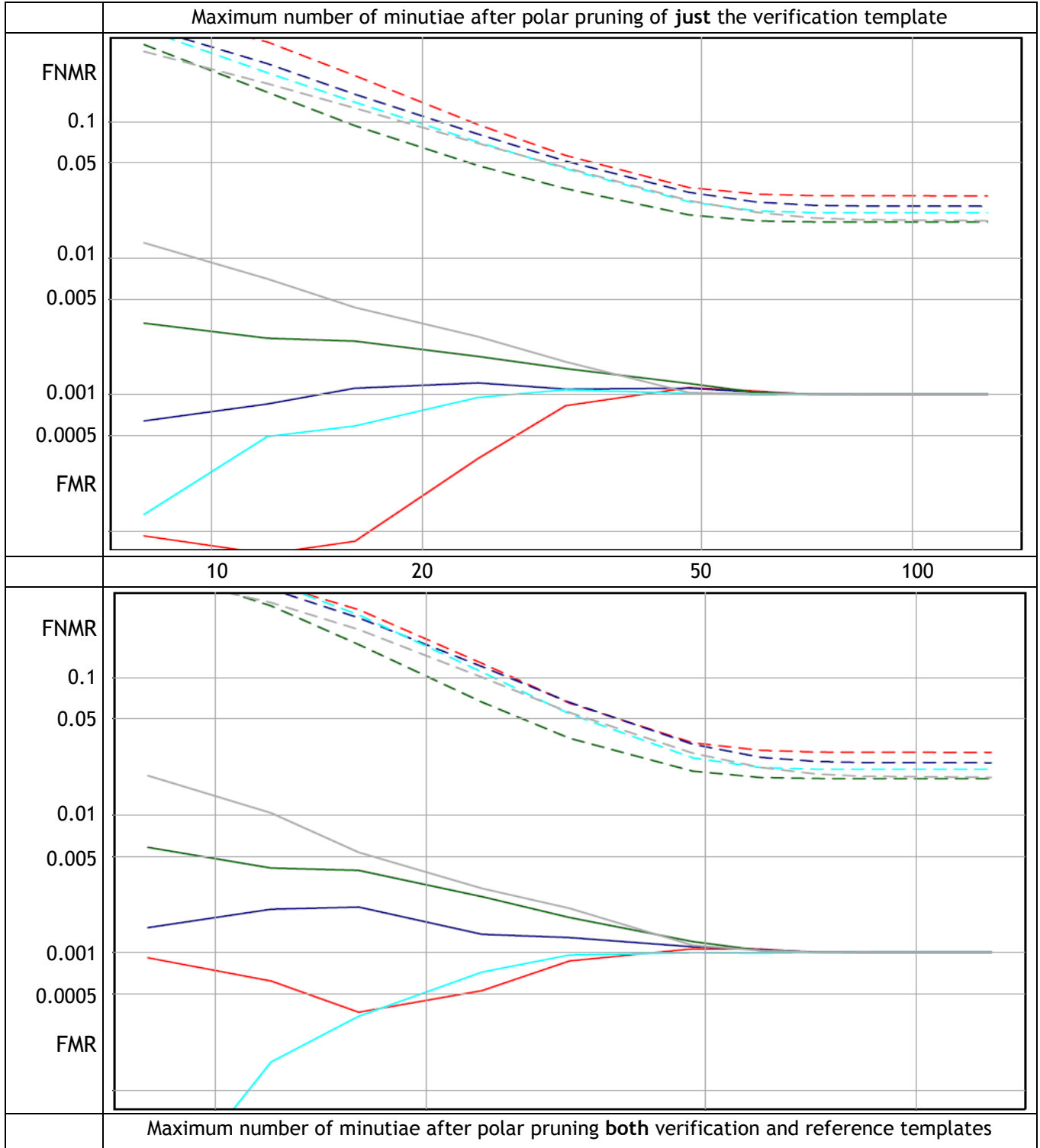
17 The ISO CC template can offer performance approaching that of the INCITS 378 template. However, some
18 implementations exhibit degraded performance. This study, however, only approximates actual ISO CC
19 performance because providers may be able to improve algorithmic functionality if they specifically know the
20 target result is ISO CC.

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Figure 3 - Effect of minutia pruning on FNMR (above) and FMR (below)



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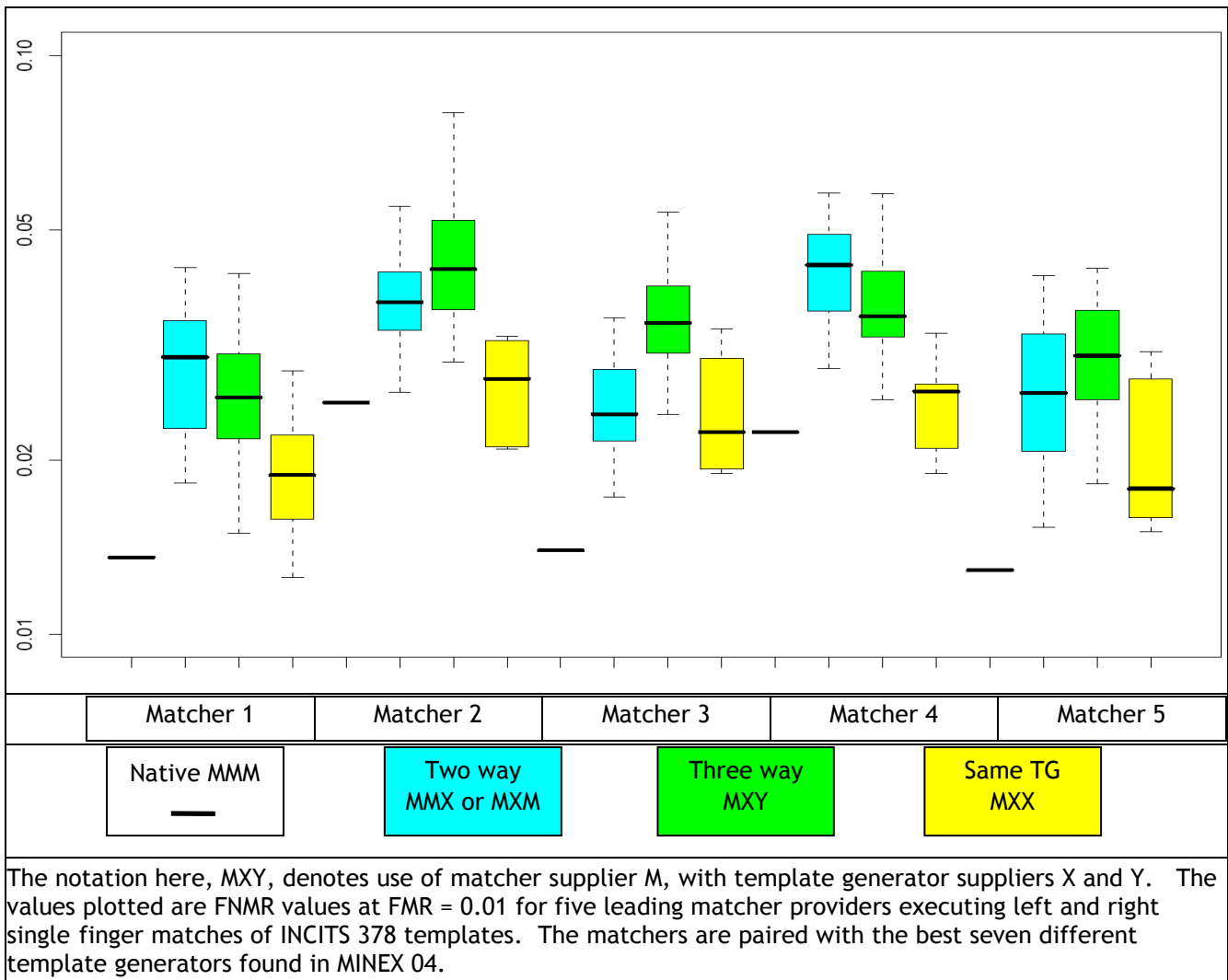
3

1 **Annex B**
 2 **Three-way interoperability**

3 NIST anticipates that some cards embed fingerprint matchers that are not accompanied by an associated
 4 template generator, and may well be used with enrollment and verification templates coming from two
 5 different sources. That is card based matcher, M, will compare a reference template produced by X with a
 6 verification template from Y. NIST will evaluate three way interoperability in this test. MINEX participants
 7 should be aware that the MINEX 04 measurements of Figure 4, show three way interoperability (green) will
 8 generally offer poorer performance

- 9 – than in two way (cyan) or native (horizontal bar) cases, and
- 10 – in situations (matchers 1 and 4) in which the provider of a matcher supplies a template generator that is
- 11 less effective than its peers.

12 **Figure 4 - Native vs. Two-way vs. Three-way Interoperability**



13 NIST acknowledges that not requiring a card/matcher provider to team with a template generator provider is
 14 inconsistent with the requirement in section 6.6 to require pairing of card and matcher combinations.
 15 However this seeming inconsistency is undertaken in light of the following:

- 16 – Cards and matching algorithms may well be bound at time of manufacture;

NIST MINEX Match on card Test Plan.

- 1 – Cards and reference templates are bound at time the card issuance or IDMS software was shipped by an
- 2 integrator;
- 3 – Although software matcher implementations (e.g. Java applets) exist (and are eligible for testing) and
- 4 these could be selected during integration or even issuance, they are reported to run significantly more
- 5 slowly.
- 6 Further NIST is motivated by a desire to improve performance, both in this evaluation and in fielded
- 7 operation. Given that NIST has demonstrated that some template generators are better than others, NIST
- 8 seeks to measure card matcher template generator compatibility.

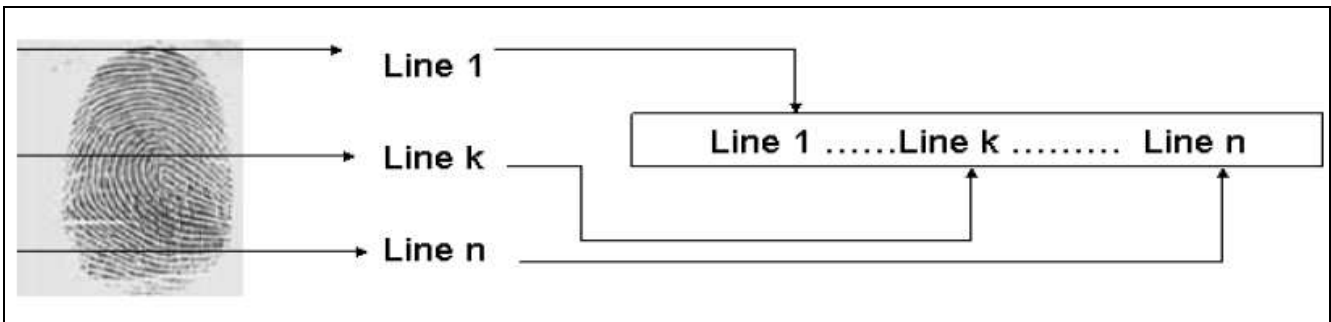
Annex C Input fingerprint image specifications

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3 C.1 Format

4 The SDK must be capable of processing fingerprint images supplied to the SDK in uncompressed raw 8 bit (one
5 byte per pixel) grayscale format. Each image shall appear to have been captured in an upright position and
6 approximately centered horizontally in the field of view. The image data shall appear to be the result of a
7 scanning of a conventional inked impression of a fingerprint. Figure 1 illustrates the recording order for the
8 scanned image. The origin is the upper left corner of the image. The x coordinate (horizontal) position shall
9 increase positively from the origin to the right side of the image. The y coordinate (vertical) position shall
10 increase positively from the origin to the bottom of the image.

11 **Figure 5 - Fingerprint image raster scan order**



12 Raw 8 bit grayscale images are canonically encoded. The minimum value that will be assigned to a "black"
13 pixel is zero. The maximum value that will be assigned to a "white" pixel is 255. Intermediate gray levels will
14 have assigned values of 1 254. The pixels are stored left to right, top to bottom, with one 8 bit byte per
15 pixel. The number of bytes in an image is equal to its height multiplied by its width as measured in pixels;
16 there is no header. The image height and width in pixels will be supplied to the SDK as supplemental
17 information.

18 C.2 Resolution and dimensions

19 All images for this test will employ 500 PPI resolution (horizontal and vertical).

20 The dimensions of the fingerprint images will vary from 150 to 812 pixels in width, and 166 to 1000 pixels in
21 height.

22 Note - the SDK must be capable of processing images with any dimensions in these specified ranges without
23 the use of separately invoked cropping or padding facilities. For example, SDKs which require cropping of
24 large images must do so internal to the operation of the create_template (see below) API call.

25 C.3 Sensor and impression types

26 All images used for testing in MINEX come from the POEBVA data set described in NISTIR 7296 [2] (see
27 Appendix B, Table 23 page 47) and thus have been obtained from live scan sensors (Smiths Heimann ACCO
28 1394 and Cross Match 300A). All images tested in MINEX are plain impression type images.

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Annex D Error Codes and Handling

3 Each participant shall provide their SDK with text documentation of all (non zero) error or warning return
4 codes (see section 9.5.4, Documentation).

5 The application should include error/exception handling so that in the case of a fatal error, the return code is
6 still provided to the calling application.

7 At minimum the return codes of Table 32 shall be used.

8 **Table 32 - MINEX API return codes**

Return code	Explanation
0	Success
1	Image size not supported
2	Failed to extract minutiae - unspecified error
3	Failed to extract minutiae - impression type not supported
4	Failed to match templates - null probe or gallery template
5	Failed to match templates - unable to parse probe template
6	Failed to match templates - unable to parse gallery template

9 All messages which convey errors, warnings or other information shall be suppressed.

Annex E Predefined SDK Constants

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E.1 Pre-defined values

The pre defined values (constants) of Table 33 are for use in specifying parameters to the MINEX testing interface:

Table 33 - MINEX API predefined values

<pre>// Finger quality values #define QUAL_POOR 20 // NFIQ value 5 #define QUAL_FAIR 40 // NFIQ value 4 #define QUAL_GOOD 60 // NFIQ value 3 #define QUAL_VGOOD 80 // NFIQ value 2 #define QUAL_EXCELLENT 100 // NFIQ value 1 // Impression type codes #define IMPTYPE_LP 0x00 // Live scan plain #define IMPTYPE_NP 0x02 // Nonlive scan plain</pre>	<pre>// Finger position codes #define FINGPOS_UK 0x00 // Unknown finger #define FINGPOS_RT 0x01 // Right thumb #define FINGPOS_RI 0x02 // Right index finger #define FINGPOS_RM 0x03 // Right middle finger #define FINGPOS_RR 0x04 // Right ring finger #define FINGPOS_RL 0x05 // Right little finger #define FINGPOS_LT 0x06 // Left thumb #define FINGPOS_LI 0x07 // Left index finger #define FINGPOS_LM 0x08 // Left middle finger #define FINGPOS_LR 0x09 // Left ring finger #define FINGPOS_LL 0x0A // Left little finger</pre>
--	--

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Note that the finger position codes differ in the fingerprint standards, and the smart card standards.

For all interactions with the card ISO/IEC 7816 11:2004 finger position codes shall be used. For all interactions with PC based implementations ISO/IEC 17994 2:2005 finger positions shall be used. NIST will transcode any values using the Table 34 associations whenever needed. The table summarizes the two base standards and is included here for informative purposes only.

Table 34 - ISO/IEC 19794-2 and ISO/IEC 7816-11 finger position codes

Finger ID Biometric subtype	ISO/IEC 19794 2:2005		ISO/IEC 7816 11:2004	
	Binary value	Hex Value	Binary value	Hex Value
No information given	00000b	00	00000b	00
right thumb	00001b	01	00101b	05
right index	00010b	02	01001b	09
right middle	00011b	03	01101b	0D
right ring	00100b	04	10001b	11
right little	00101b	05	10101b	15
left thumb	00110b	06	00110b	06
left index	00111b	07	01010b	0A
left middle	01000b	08	01110b	0E
left ring	01001b	09	10010b	12
left little	01010b	0A	10110b	16

Annex F Ambiguities in the standards

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3 **F.1 Compact card sorting**

4 The last line of ISO/IEC 19794 2:2005 clause 8.3.4 "The same construction principle may be applied also for
5 the Y coordinate" should be changed to "The same construction principle may alternatively be applied to the
6 Y coordinate. Using this construction on X and Y together is not possible."

7 Clause 8.3.4 is very long. To enable easy citation of the standard, it needs to be broken up into named (or
8 even unnamed) subparagraphs.

9 The text in ISO/IEC 19794 2:2005 Table 14 second to last line references subclause "8.33" which should be
10 "8.3.4".

11 **F.2 Unique minutia**

12 There should be a normative requirement for minutia (x,y,theta) triples to be unique. The issue of requiring
13 unique (x,y) values seems to be in conflict with the reporting of trifurcations which would have same (x,y).

14 **F.3 No support for placing reference data on the card**

15 ISO/IEC FDIS 19785 3:2007(E) establishes the CBEFF TLV encoded CEBFF patron format for the tag associated
16 with biometric subtype data (in this case finger position). This value is '82'. Neither ISO/IEC 7816 11:2004,
17 nor ISO/IEC 19794 2:2005 include normative specifications for this location. However, there is no
18 standardized mechanism for finger position information to be sent to the card when storing a reference
19 template. Indeed, none of the relevant standards advance a normative prescription for a ISO/IEC 7816
20 4:2005 command for this purpose. Yes, ISO/IEC 7816 11:2004 includes the use of a CHANGE REFERENCE DATA
21 command as an example in informative Annex B, but that text does not advance a method for passing the
22 biometric subtype to the card.

23 NIST sees the lack of a standardized command as an impediment to MINEX II (see discussion in section 8.5).

24 NIST sees the lack of a standardized mechanism for transmission of biometric subtype data to the card as an
25 inhibitor toward (future) multi finger applications.

26 NIST is interested in standardization of the transmission of reference data to the card.

27 A revision of ISO/IEC 19794 2 might usefully include definitive procedures for enrolling fingerprint minutiae
28 templates on the card. It should recommend CHANGE REFERENCE DATA or PUT DATA and particularly should
29 establish tags for finger position (biometric subtype). NIST notes that there is no support for unsegmented
30 fingerprints.

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Annex G
ISO/IEC 19794-2:2005 record profile

3 **Table 35 - MINEX II profile of ISO/IEC 19794-2:2005 standard**

	Field name and ISO/IEC 19794 2:2005 clause numbers in parentheses	Values Allowed	Informative Remarks
5.	Format Identifier (7.3.1)	0x464D5200	i.e. ASCII "FMR\0"
6.	Version Number (7.3.2)	0x20323000	i.e. ASCII " 20\0".
7.	Record Length (7.3.3)	$32 \leq L \leq 800$	26 record header + 4 view header +2 extended data length + 6K. Max K is 128
8.	Capture Equipment Certifications (7.3.4)	0	
9.	Capture Device Type ID (7.3.5)	0	
10.	Size of Scanned Image in x direction (7.3.6)	MIT	Inherited directly from input data
11.	Size of Scanned Image in y direction (7.3.7)	MIT	
12.	X (horizontal) resolution (7.3.8)	197	
13.	Y (vertical) resolution (7.3.9)	197	
14.	Number of Finger Views (7.3.10)	1	
15.	Reserved Byte (7.3.11)	0	
16.	Finger Position (7.4.1.1)	MIT	Inherited directly from input data
17.	View Number (7.4.1.2)	0	
18.	Impression Type (7.4.1.3)	0 or 2	Inherited directly from input data
19.	Finger Quality (7.4.1.4)	MIT	Inherited directly from input data
20.	Number of Minutiae (7.4.1.5)	$0 \leq K \leq 128$	K minutiae data blocks
21.	Minutiae Type (7.4.2.1)	01b, 10b, or 00b	
22.	Minutiae Position (7.4.2.2)	MIT	
23.	Minutiae Angle (7.4.2.3)	MIT	
24.	Minutiae Quality (7.4.2.4)	$0, 1 \leq Q \leq 100$	0 = unsupported
25.	Extended Data Block Length (7.5.1.1)	≥ 0	Either 0 for no extended data, or the length of a zonal quality block
26.	Extended Data Area Type Code (7.5.1.2)	0x0003	Optional, only present if (7.5.1.1) is > 0 .
27.	Zonal Q. Cell Width and Height (7.5.4.1)	$1 \leq NPIX \leq W$	Optional, only present if (7.5.1.1) is > 0 .
	Zonal Q. Cell Width and Height (7.5.4.1)	$1 \leq NPIX \leq H$	Optional, only present if (7.5.1.1) is > 0 .
28.	Zonal Q. Cell Quality Info. Depth (7.5.4.2)	1, 2, 4, 8	Optional, only present if (7.5.1.1) is > 0 . This value shall not be 0.
29.	Zonal Q. Cell Quality Data (7.5.4.3)		Optional, only present if (7.5.1.1) is > 0 .

MIT = mandatory at time of instantiation

4
5 **Table 36 - ISO/IEC 19794-2 minutiae template DO**

Tag	L	Value				
'7F2E'	L1	Biometric data template				
		Tag	L	Value		
		'81'	L2	Finger minutiae data		
				Field	Size (bits)	Valid Values
				X coordinate	8	[0,255]
				Y coordinate	8	[0,255]
				Minutiae type	2	
				Minutiae angle	6	[0,63]
		'94'	L3	Zonal Quality Data	5+var	See Table 37

S instances
1 instance

NIST MINEX Match on card Test Plan.

1 where the zonal quality block shall conform to Table 37. This data is a modified version of that inserted into
 2 ISO/IEC 19794 2:2005 by the draft Technical Corrigendum 1, SC 37 N2119.

3 **Table 37 - Zonal quality data**

	Field	Length (bytes)	Values Allowed	Informative Remarks
1	Horizontal Resolution of the Quality Map (8.4.1.1.2)	1		See Note 1 and Example 1
2	Vertical Resolution of the Quality Map (8.4.1.1.2)	1		
3	Quality Map Width (8.4.1.1.3)	1		# cells in x horizontal direction
4	Quality Map Height (8.4.1.1.3)	1		# cells in y vertical direction
5	Cell Quality Information Depth (8.4.1.1.4)	1	1, 2, 4, 8	Not 0.
6	Cell Quality Data (8.4.1.1.5)	L		Packed bits

4 NOTE 1 The first draft Technical Corrigendum 1, SC37N2119 has one field for cell quality resolution,
 5 i.e. it assumes the x y resolutions are equal. However, the ISO REC standard allows different cell resolutions
 6 in x and y. Therefore, if the ISO REC to ISO CC transcoding process is to become viable operationally, then
 7 card zonal quality data needs to support anisotropic resolutions. NIST will comment on the update of N2119
 8 (to be circulated for ballot in the latter half of 2007).

9 EXAMPLE 1 If the horizontal cell dimension in a ISO REC zonal quality block (clause 7.5.4.1 of ISO/IEC
 10 19794 2:2005) is 20 pixels, and the corresponding horizontal resolution is 197 pixels per centimeter (clause
 11 7.3.8 of ISO/IEC 19794 2:2005), then the value of the entry on line 1 of this table (i.e. the number of cells
 12 per decimeter) will be round($10 * 197 / 20$) = 99, where the rounding operator is nowhere standardized.

1 **H.6 Access to MINEX II test data**

2 The MINEX II Test Datasets are protected under the Privacy Act (5 U.S.C. 552a), and will be treated as
3 Sensitive but Unclassified and/or Law Enforcement Sensitive.

4 MINEX II Participants shall have no access to MINEX II Test Data, either before, during or after the test.
5 Information about the images data has been previously published in MINEX 04 report, [NIST IR 7296](#)²².

6 **H.7 Reporting of results**

7 **H.7.1 Reports**

8 The Government will combine appropriate results into one or more MINEX II Reports. Together these will
9 contain, at a minimum, descriptive information concerning MINEX II, descriptions of each experiment, and
10 aggregate test results. NIST will include

- 11 – DET performance metrics as the primary indicators of one to one verification accuracy,
- 12 – ISO/IEC 19795 4 interoperability matrices as the primary measures of interoperability, and
- 13 – enrollment and verification timing statistics.

14 NIST may compute and report other aggregate statistics.

15 NIST intends to release Phase 1 results to the participant only.

16 NIST intends to publish Phase 2 results in one or more NIST Interagency Reports.

17 The Phase 2 reports will:

- 18 – contain the names of Phase 1 participants,
- 19 – not contain the results from Phase 1 participants' implementations,
- 20 – contain the names of Phase 2 participants, and
- 21 – contain the results of all Phase 2 participants' implementations which will associated with the
22 participants names.

23 **H.7.2 Pre-publication review**

24 Participants will have an opportunity to review and comment on the reports. Participants' comments will be
25 either incorporated into the main body of the report (if it is decided NIST reported in error) or published as
26 an addendum. Comments will be attributed to the participant.

27 **H.7.3 Citation of the report**

28 After the release of the Phase II Final Report, Participants may decide to use the results for their own
29 purposes. Such results shall be accompanied by the following phrase: "Results shown from the Minutiae
30 Interoperability Exchange Test (MINEX II) do not constitute endorsement of any particular system by the U. S.
31 Government." Such results shall also be accompanied by the URL of the MINEX II Report on the MINEX II
32 website, <http://fingerprint.nist.gov/minexII>.

33 **H.7.4 Rights and ownership of the data**

34 Any data obtained during MINEX (excepting the submitted SDK itself), as well as any documentation required
35 by the Government from the participants, becomes the property of the Government. Participants will not
36 possess a proprietary interest in the data and/or submitted documentation.

37 **H.8 Return of the supplied materials**

38 **H.8.1 Returning software to vendors**

39 NIST will not return any supplied software, documentation, or other material to vendors.

²² MINEX Report NIST IR 7296 PDF is here: http://fingerprint.nist.gov/minex04/minex_report.pdf

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Annex I **NIST mailing address**

3 The address given below shall be used for all mail or courier delivery to NIST. This includes delivery of MINEX
4 II participation agreements and all MINEX II cards and software.
5

MINEX II Test Liaison
National Institute of Standards and Technology
Information Access Division (894)
100 Bureau Drive, Stop 8940
Gaithersburg, MD 20899 8940
USA

6 In cases where the courier needs a phone number please use NIST S+H 301 nine seven five six two nine six.
7