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DOC: M1/04-0399
Date: 28July 2004

Technical Report for M1.3

Fingerprint Standards: Overview and Comparative Analysis

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1 Introduction

This document compares and contrasts current fingerprint biometric data interchange format standards and fingerprint image compression standards used in fingerprint biometric systems. The first part of this document, Section 2, compares and contrasts "technologically similar" fingerprint data interchange specifications. Section 2.1 examines image-based data interchange formats, Section 2.2 examines formats for finger minutiae representation, and Section 2.3 examines pattern-based formats. Section 3 compares and contrast finger image compression standards.

The motivation for this report was to determine the degree of compatibility between various fingerprint data formats, for example, determining how similar or how different the US and international versions of the finger image data interchange format standard are from the Type-4 logical records of ANSI/NIST ITL 1-2000 Data Format for the Interchange of Fingerprint, Facial, & Scar Mark & Tattoo Information. Knowing the degree of compatibility between various data formats helps customer organizations to estimate the potential effort or feasibility involved in converting from one image format to another.

Table 1. Current Status of Fingerprint Image Standards Within the FBI, ANSI, and ISO

Standard	Organization	Category	Status
ANSI/EIA-538-1988 Facsimile Compression Standard	ANSI/EIA	Compression	Approved 1988
ANSI/INCITS 358-2002 BioAPI Specification, Version 1.1	ANSI/NIST	Data Interchange Format	Approved 2002
ANSI/INCITS 377-2004 Finger Pattern-Based Interchange Format	ANSI/NIST	Data Interchange Format	Approved Jan 2004
ANSI/INCITS 378-2004 Finger Minutiae Format for Data Interchange	ANSI/NIST	Data Interchange Format	Approved Mar 2004
ANSI/INCITS 381-2004 Finger Image-Based Data Interchange Format	ANSI/NIST	Data Interchange Format	Approved May 2004
ANSI/NIST-ITL 1-2000 Data Format for the Interchange of Fingerprint, Facial, & Scar Mark & Tattoo Information	ANSI/NIST	Data Interchange Format	Approved 2000
CJIS-RS-0010 (V7) Electronic Fingerprint Transmission Specification (EFTS)	FBI	Data Interchange Format	Approved 1999
IAFIS-IC-0110 (V3) Wavelet Scalar Quantization	FBI	Compression	Approved 1993
IS 10918-1 Joint Photographic Experts Group (JPEG) Standard	ISO/IEC	Compression	Approved 1994
IS 15444-1 Joint Photographic Experts Group (JPEG 2000)	ISO/IEC	Compression	Approved 2001
ISO/IEC JTC 1/SC 37 N340 Biometric Data Interchange Formats – Part 2: Finger Minutiae Data	ISO/IEC	Data Interchange Format	Committee Draft 2003
ISO/IEC JTC 1/SC 37 N341 Biometric Data Interchange Formats – Part 4: Finger Image Data	ISO/IEC	Data Interchange Format	Committee Draft 2003
ISO/IEC JTC 1/SC 37 N470 Biometric Data Interchange Formats – Part 3: Finger Pattern Spectral Data	ISO/IEC	Data Interchange Format	Committee Draft Mar 2004
ISO/IEC JTC 1/SC 37 N490 Biometric Data Interchange Formats – Part 8: Finger Pattern Skeletal Data	ISO/IEC	Data Interchange Format	Working Draft Mar 2004

2 Fingerprint Data Interchange Format Standards

This chapter describes four fingerprint image-based data interchange format standards that currently exist or are under development at the ANSI and ISO levels. It also identifies the differences among these standards.

These standards are addressed in the following order.

- Fingerprint image-based data interchange format
- Fingerprint minutiae data interchange format
- Fingerprint pattern-based data interchange format

2.1 Image-Based Data Interchange Format

Fingerprint image-based interchange format standards concern those applications that require an exchange of raw or processed fingerprint images that may be limited by data storage or transmission time constraints. These standards support exchanging

- scanned fingerprints that contain detailed image pixel information or
- processed fingerprint image data that contain limited pixels per inch and/or a low number of grayscale levels.

In this section, the specifications regarding image record format, compression algorithms, and image quality specifications are described and compared for the ANSI/NIST, CJIS, ANSI/INCITS and ISO/IEC standards.

Type-3, Type-4, Type-5, and Type-6 of ANSI/NIST-ITL 1-2000 Data Format for the Interchange of Fingerprint, Facial, & Scar Mark & Tattoo Information defines the image record formats for interchanging. CJIS-RS-0010 (v7) Electronic Fingerprint Transmission Specification (EFTS) is the FBI specification for transmitting fingerprint information across computer and telecommunications networks. The EFTS defines the special requirements for a fingerprint image to communicate with the FBI's Integrated Automated Fingerprint Identification System (IAFIS) as well.

2.1.1 Image Record Format

The image record format refers to the method and means of storing and transmitting the fingerprint image. The image may be stored and transmitted as either an EFTS or a Common Biometrics Exchange File Format (CBEFF) record type. The EFTS is the FBI's specification for transmitting fingerprint information across computer and telecommunications networks. DoD organizations that have military law enforcement responsibilities, and therefore interface with the FBI IAFIS, are required to support the EFTS specification. The CBEFF defines a common set of data elements that are necessary to support multiple biometric technologies and to promote interoperability of biometric-based application programs and systems by enabling biometric data exchange. CBEFF describes required and optional data fields, domains of use, and formats that use some combination of these standard elements. The common set of data elements described in CBEFF can exist in a single file record, or data object, used to exchange biometric information between different system components. Different biometric technologies, or

different data instantiations in a single technology, can leverage the CBEFF nested structure specified in NISTIR 6529-A to exchange biometric data.

The fingerprint image may be stored as either grayscale or binary. The difference between grayscale and binary images is in the dynamic range of the grayscale of each pixel. The value of each pixel in a grayscale image is in a range of the byte's value, which is from 0 to 255. The value of each pixel in a binary image is 0 or 1 only.

2.1.1.1 ANSI/NIST-ITL 1-2000

ANSI/NIST-ITL 1-2000 Data Format for the Interchange of Fingerprint, Facial, & Scar Mark & Tattoo Information specifies four types of fingerprint image records. Type-3 and Type-4 are specifications for grayscale fingerprint image records. Type-5 and Type-6 specify binary fingerprint image records.

Type-3 and Type-4 logical records contain and are used to exchange grayscale fingerprint image data that is scanned at no less than the minimum scanning resolution. The resultant transmitting resolution shall be within the bounds of the permissible transmitting resolutions for grayscale fingerprint images. The grayscale fingerprint image data contained in the Type-3 and Type-4 logical records may be in compressed form.

Type-5 and Type-6 logical records contain and are used to exchange binary fingerprint image data that is scanned at no less than the minimum scanning resolution. The resulting transmitting resolution will be within the bounds of the permissible transmitting resolutions for binary fingerprint images. The binary fingerprint image data contained in the Type-5 and Type-6 logical records may be in compressed form.

2.1.1.2 CJIS-RS-0010 (v7) EFTS

CJIS-RS-0010 (v7) EFTS specifies that fingerprint images must be captured and transmitted to the FBI in accordance with the ANSI/NIST-ITL 1-2000 Data Format for the Interchange of Fingerprint, Facial, and Scar Mark & Tattoo Information standard.

2.1.1.3 ANSI/INCITS 381-2004

The ANSI/INCITS 381-2004 Finger Image-Based Data Interchange Format standard specifies the data record interchange format for storing, recording, and transmitting the information from one or more finger or palm images stored within a CBEFF data structure.

2.1.1.4 ISO/IEC JTC 1/SC 37 N341 (Draft)

ISO/IEC JTC 1/SC 37 N341 Biometric Data Interchange Formats—Part 4: Finger Image Data is a draft ISO standard and is similar to the scope of the ANSI/INCITS 381-2004 Finger Image-Based Data Interchange Format standard.

2.1.1.5 Comparison of Fingerprint Image Record Specifications

Table 2 lists the differences in the fingerprint image record fields between the standards and specifications identified in Sections 2.1.1.1 thorough 2.1.1.4.

Table 2. The Differences in the Specifications for the Fingerprint Image Record Fields

Field	ANSI/NIST-ITL 1-2000 and CJIS-RS-0010 (v7)	ANSI/INCITS 381-2004 and ISO/IEC JTC 1/SC 37 N341
Pixel Depth	8-bit for Grayscale and 1-bit for Binary	1 – 16 bits
Minimum scanner resolution	500 pixels per inch/ 19.69 pixels per millimeter	125 pixels per inch/ 4.9 pixels per millimeter
Maximum scanner resolution	Not specified	1,000 pixels per inch/ 39.4 pixels per millimeter
Minimum transmitting resolution – High	500 pixels per inch/ 19.69 pixels per millimeter	Not specified
Minimum transmitting resolution – Low	250 pixels per inch/ 9.84 pixels per millimeter	Not specified
Minimum transmitting resolution – Variable	> 500 pixels per inch	Not specified
CBEFF Product Identifier	Not specified	Specified by ANSI Not specified by ISO
Capture Device ID/Scanner ID	Not specified	Capture Device ID specified by ISO Scanner ID specified by ANSI

2.1.2 Image Compression Algorithms

Image compression seeks to reduce the number of bytes used to store or transmit information. Image compression schemes can be divided into two broad classes: lossless compression minimizes the number of bytes required to represent the original image samples without any loss of information, and lossy compression minimizes the number of bytes required to represent an image with an allowable level of distortion. The Joint Photographic Experts Group (JPEG) specification is a long-standing common industry data format for compressing general image data. JPEG 2000 resulted form a standardization effort that culminated in the publication of International Standard ISO/IEC 15444 Part 1. Specifications for biometric data formats that represent captured biometric samples (e.g., fingerprints, handwriting samples, iris photographs) as images frequently cite JPEG and JPEG 2000 as references. The Wavelet Scalar Quantization (WSQ) algorithm is the FBI-specified compression standard used for the exchange of fingerprint images within the criminal justice community. The WSQ specification is a publicly available specification for representing biometric image data in a compressed image format. The JPEG, JPEG2000, and WSQ standards offer varying degrees of image compression. Implementations of the JPEG, JPEG 2000, and WSQ standards must be capable of compressing and decompressing data to the same compression ratios, but this data will have various distortion.

2.1.2.1 ANSI/NIST-ITL 1-2000

The contents of a one-byte Grayscale Compression Algorithm (GCA) in a Type-3 or Type-4 record isa binary representation for the number allocated to the particular compression technique used by the interchange parties.

ANSI/NIST-ILT 1-2000 recommends IAFIS-IC-0010 (V3) IAFIS WSQ grayscale compression algorithm for the image compression algorithm with a 15:1 nominal compression ratio. Binary one of

the Binary Compression Algorithm (BCA) byte designates the use of the ANSI/EIA-538-1988 Facsimile Compression Standard to address the lossless compression and decompression of the image data.

2.1.2.2 CJIS-RS-0010 (v7) EFTS

For the CJIS-RS-0010 (v7) EFTS, the IAFIS-IC-0010 (V3) IAFIS Wavelet Scalar Quantization (WSQ) Grayscale Fingerprint Image Compression Specification—dated 19 December 1997—provides the definitions, requirements, and guidelines for specifying the FBI's WSQ compression algorithm.

2.1.2.3 ANSI/INCITS 381-2004

The ANSI/INCITS 381-2004 standard specifies a one-byte image compression algorithm field to record the uncompressed or compressed grayscale images.

The available storage options and compression algorithms that may be used in this standard are (1) uncompressed with no bit packing, (2) uncompressed with bit packed, (3) WSQ standard, (4) JPEG standard, (5) JPEG 2000 standard, and (6) Portable Network Graphics (PNG) standard. Uncompressed image data can be recorded in an unpacked or packed form. When using the unpacked option for grayscale pixels greater than 8 bits, each pixel shall be recorded in a packed format or as a pair of bytes right justified. A certified version of the WSQ method is generally used for 8-bit, 500-ppi grayscale images and should provide a 15:1 compression ratio. This will result in an insignificant degradation to the image. The JPEG algorithm can also be used for compressing 8-bit, 500-ppi fingerprint images. Fingerprint images compressed using the JPEG baseline should be limited to a 5:1 compression ratio to ensure minimum humanly observable visual degradation of the image.

2.1.2.4 ISO/IEC JTC 1/SC 37 N341 Part 4: Finger Image Data (Draft)

The compression algorithms supported by the ISO/IEC JTC 1/SC 37 N341 Biometric Data Interchange Formats – Part 4: Finger Image Data draft standard is similar to the draft ANSI/INCITS 381-2004 Finger Image Based Data Interchange Format.

2.1.2.5 Comparison of Fingerprint Image Compression Algorithms

Table 3 lists the differences in the fingerprint image compression algorithms between the following standards and specifications.

Table 3. The Differences of the Specifications for the Fingerprint Image Compression Algorithm

Data Type	ANSI/NIST-ITL 1-2000 Standard	CJIS-RS-0010 (v7) Specification	ANSI/INCITS 381-2004 Standard	ISO/IEC JTC 1/SC 37 N340 Draft Standard
Uncompressed	No bit packing	No bit packing	Bit packing	Bit packing
Compressed – Grayscale	WSQ 2.0 IAFIS-IC-0010 (V3)	WSQ 2.0 IAFIS-IC-0010 (V3)	WSQ 2.0 IAFIS-IC-0010 (V3) JPEG JPEG 2000 PNG	WSQ 2.0 IAFIS-IC-0010 (V3) JPEG JPEG 2000 PNG

Data Type	ANSI/NIST-ITL 1-2000 Standard	CJIS-RS-0010 (v7) Specification	ANSI/INCITS 381-2004 Standard	ISO/IEC JTC 1/SC 37 N340 Draft Standard
Compressed – Binary	ANSI/EIA-538-1988 Facsimile Compression Standard	Not specified	Not specified	Not specified

2.1.3 Image Quality Specifications

Fingerprint images must be of sufficient quality to allow for:[1]

1. conclusive fingerprint comparisons (identification or non-identification decision),
2. fingerprint classification,
3. automatic feature detection, and
4. overall Automated Fingerprint Identification System (AFIS) search reliability.

2.1.3.1 ANSI/NIST-ITL 1-2000

ANSI/NIST-ITL 1-2000 does not address image quality specifications.

2.1.3.2 CJIS-RS-0010 (v7) EFTS

Appendix F of the CJIS-RS-0010 (v7) EFTS defines the requirements and guidelines for the IAFIS Image Quality Specifications.

2.1.3.3 ANSI/INCITS 381-2004

ANSI/INCITS 381-2004 Finger Image-Based Data Interchange Format standard has a reserved field that will contain an image quality metric—used to measure an image's quality—for the the scanned finger images. Until standard methods are developed for computing such a metric, this field will contain the number 254 to indicate an undefined quality measure.

2.1.3.4 ISO/IEC JTC 1/SC 37 N341 Part 4: Finger Image Data (Draft)

The quality of the scanned fingerprint image will be gauged between 0 and 100 and will be recorded in one byte. A value of 0 will represent the lowest possible quality and a value of 100 will represent the highest possible quality. The numeric values of quality will be set in accordance with the general guidelines contained in ANSI/INCITS 358-2002 BioAPI Specification, Version 1.1.

2.2 Fingerprint Minutiae Data Interchange Format

Fingerprint minutiae format for data interchange standards specify methods of representing fingerprint information using the concept of minutiae. Minutiae are key points located at the end or at the division of the ridges in a fingerprint image. By recording the location of these minutiae, a fingerprint can be represented in a compact and interoperable manner. Figure 1 illustrates minutiae-based biometric matching.

[1] CJIS-RS-0010 (v7) EFTS

Figure 1. Finger Minutiae-Based Biometric Matching

Fingerprint minutiae format for data interchange standards provide values for items such as:

- finger position codes,
- finger impression-type codes (flat or rolled),
- ridge counts,
- core values (the approximate center of a fingerprint image area), and
- delta values (the point on a ridge at or nearest to the point of divergence of two types of lines and located at or directly in front of the point of divergence).

Table 4 lists the fingerprint minutiae data interchange format standards at ANSI and ISO as well as their current status.

Table 4. ANSI and ISO Fingerprint Minutiae Data Interchange Format Standards

Version	Standard Title	Organization	Status
ANSI/NIST-ITL 1-2000	Data Format for the Interchange of Fingerprint, Facial, & Scar Mark & Tattoo Information – Type 9	ANSI/NIST	Approved 2000
ANSI/INCITS 378-2004	Finger Minutiae Format for Data Interchange	ANSI/INCITS	Approved 2002
ISO/IEC JTC 1/SC 37 N340	Biometric Data Interchange Formats – Part 2: Finger Minutiae Data	ISO	Committee Draft 7 Oct 2003

These standards are described in the following sections.

2.2.1 ANSI/NIST-ITL 1-2000

ANSI/NIST-ITL 1-2000 Data Format for the Interchange of Fingerprint, Facial, & Scar Mark & Tattoo Information defines four identifier characters used to describe minutiae for Type-9 logical records. Type-9 logical records are used to exchange geometric and topological minutiae information encoded from a finger image.

The four identifiers that characterize minutia are ridge ending, bifurcation, compound minutia (trifurcation or crossover), and undetermined. A ridge ending, which is the point where a ridge terminates, is designated as Type A. A bifurcation, which is the point where one ridge splits into two ridges, is designated as Type B. A minutia is designated as Type C (a compound type) if it is either a trifurcation or a crossover. A trifurcation is a single ridge that splits into three ridges, while a crossover results when two ridges intersect. If a minutia cannot be clearly categorized as one of the preceding three types, it will be designated as undetermined, which is Type D.

2.2.2 ANSI/INCITS 378-2004

ANSI/INCITS 378-2004 Finger Minutiae Format for Data Interchange specifies a concept and data format for representing fingerprints. The data format is generic in that it may be applied and used in a wide range of application areas where automated fingerprint recognition is involved. The standard contains definitions of relevant terms, a description of where minutiae shall be defined, a data format for containing the data, and conformance information.

This standard assumes compliance with the following:

- ANSI/INCITS 358-2002 BioAPI Specification, Version 1.1
- ANSI/NIST-ITL 1-2000 Data Format for the Interchange of Fingerprint, Facial, & Scar Mark & Tattoo Information
- NISTIR 6529-A-2003 National Institute of Standards and Technology Interagency Report (NISTR) Common Biometric Exchange Framework Format (CBEFF)

2.2.3 ISO/IEC JTC 1/SC 37 N340 Part 2: Finger Minutiae Data

The draft ISO/IEC standard, ISO/IEC JTC 1/SC 37 N340 Biometric Data Interchange Formats – Part 2: Finger Minutiae Data establishes a data interchange format for minutiae-based fingerprint capture and recognition equipment. It specifies the extraction of key points (minutiae) from fingerprint ridge patterns. It also states that the biometric data record specified in this standard shall be embedded in a CBEFF-compliant structure in the CBEFF Biometric Data Block.

2.2.4 Comparisons of Fingerprint Minutiae Data Interchange Standards

Table 5 lists the differences between Type-9 of ANSI/NIST-ITL 1-2000 Data Format for the Interchange of Fingerprint, Facial, & Scar Mark & Tattoo Information and ANSI/INCITS 378-2004 Finger Minutiae Format for Data Interchange. These differences may result in a lack of interoperability between biometric systems. ISO/IEC JTC 1/SC 37 N340 Biometric Data Interchange Formats – Part 2:

Finger Minutiae Data is not included in this table because it is almost identical to ANSI/INCITS 378-2004. The fields noted in this table are further defined in their respective standards.

Table 5. Minutiae Format Differences Between ANSI/NIST-ITL 1-2000 and ANSI/INCITS 378-2004

Field	ANSI/NIST-ITL 1-2000 Type-9	ANSI/INCITS 378-2004
Data Type	ASCII	Binary
Minutiae Type	Ridge Ending, Ridge Bifurcation, Compound, and Undetermined	Ridge Ending, Ridge Bifurcation, and Points of Interest
Minutiae Placement	Not specified for this standard	Ridge Ending, Ridge Bifurcation, and other types
Minutiae Origin	Lower left corner	Upper left corner
Minutiae Coordination System	Based upon unit of 0.01 millimeters in a Cartesian coordinate system located in Quadrant 1	Based upon pixels
Minutiae Angle	0 – 359	0 – 179
Ridge Counts Data	With each minutia	In extended data area
Impression Type	0 – 7	Same as ANSI plus 8: Swipe and 9: Live-Scan Contactless
Minutiae Quality	0 – 63 0: manually encoded 1: no method 2 – 63: decreasing levels of confidence with 2 meaning the greatest confidence	0 – 100 0: no method 1 – 100: increasing levels of confidence with 100 meaning the maximum confidence

Table 6, Table 7, and Table 8 list only the differences between ANSI/INCITS 378-2004 Finger Minutiae Format for Data Interchange and the draft Biometric Data Interchange Formats – Part 2: Finger Minutiae Data standard in their record header, finger view header, and extended data.

Table 6. Minutiae Format Differences Between ANSI/INCITS 378-2004 and ISO/IEC JTC 1/SC 37 N340 - Record Header

Record Header		
Field	**ANSI/INCITS 378-2004**	**ISO/IEC JTC1/SC 37 N340**
Length of Record	2 or 6 bytes	4 bytes
CBEFF Product Identifier	4 bytes	Not specified
Capture Equipment Certification	Not specified	4 bits
Capture Equipment Compliance	4 bits	Not specified

Table 7. Minutiae Format Differences Between ANSI/INCITS 378-2004 and ISO/IEC JTC 1/SC 37 N340 - Finger View Header

Finger View Header		
Field	**ANSI/INCITS 378-2004**	**ISO/IEC JTC1/SC 37 N340**
θ	0 – 179	0 – 255

Table 8. Minutiae Format Differences Between ANSI/INCITS 378-2004 and ISO/IEC JTC 1/SC 37 N340 - Extended Data

Extended Data		
Field	**ANSI/INCITS 378-2004**	**ISO/IEC JTC1/SC 37 N340**
Cell Width	Not specified	1 – 255 (ISO)
Cell Height	Not specified	1 – 255 (ISO)
Cell Data Length	Not specified	1 – 65536 (ISO)
Cell Quality Data	Not specified	Cell Data

2.3 Fingerprint Pattern-Based Data Interchange Format

Fingerprint Pattern-Based Data Interchange Format specifications describe a number of parameters used to generate data records, such as the size of finger pattern in the X and Y directions. This technique differs from that of the standards for finger minutiae interchanges—finger minutiae interchange specifications store minutiae points from a fingerprint whereas finger pattern specifications store angular orientation information about the ridges in the fingerprint. To determine angular orientation, the fingerprint image is divided into a grid of "sample cells," which are analyzed for the angular differences between the ridges within each cell.[2] Figure 2 illustrates this concept.

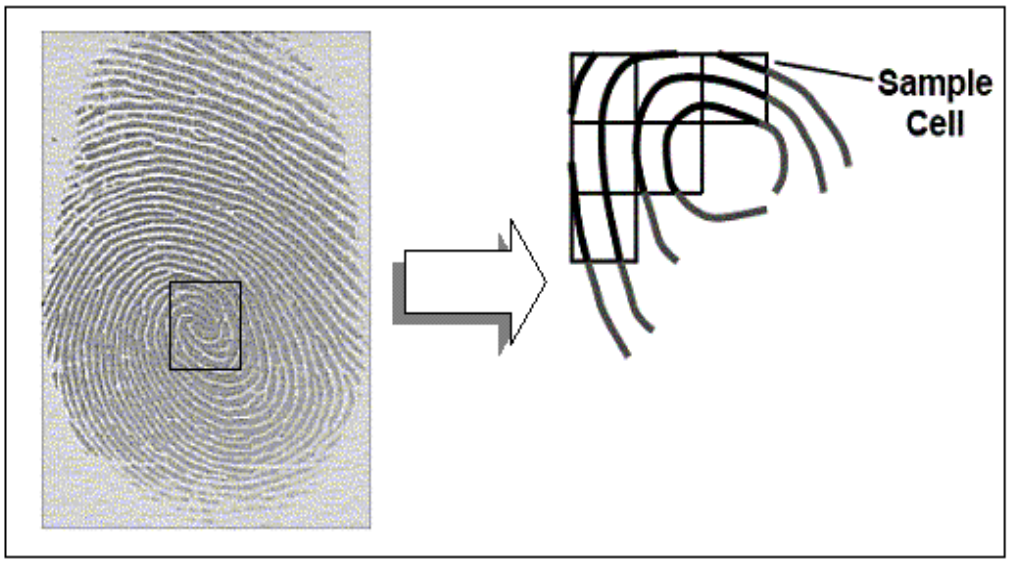

Figure 2. Finger Pattern-Based Biometric Matching[3]

Table 9 lists the fingerprint pattern-based data interchange format standards at ANSI and ISO and their current status. Note that ANSI/NIST-ITL 1-2000 Data Format for the Interchange of Fingerprint, Facial, & Scar Mark & Tattoo Information specifies no fingerprint pattern-based data interchange format.

[2] ANSI/INCITS 377-2004 Finger Pattern-Based Interchange Format

[3] ANSI/INCITS 377-2004 Finger Pattern-Based Interchange Format

Table 9. Fingerprint Pattern-Based Data Interchange Format Standards

Version	Standard	Organization	Status
ANSI/INCITS 377-2004	Finger Pattern Data Interchange Format	ANSI/INCITS	Approved
ISO/IEC JTC 1/SC 37 N 470	Biometric Data Interchange Formats – Part 3: Finger Pattern Spectral Data	ISO	Committee Draft 1 Mar 2004
ISO/IEC JTC 1/SC 37 N 490	Biometric Data Interchange Formats – Part 8: Finger Pattern Skeletal Data	ISO	Working Draft 2 Mar 2004

2.3.1 ANSI/INCITS 377-2004 Finger Pattern Data Interchange Format

ANSI/INCITS 377-2004 Finger Pattern Data Interchange Format specifies a method of creating biometric templates using fingerprint ridge patterns. It describes the conversion of a raw fingerprint image to a cropped and "down-sampled"[4] finger pattern, which is ten used to create a cellular representation of the finger pattern image to create the finger-pattern interchange data.

This standard assumes compliance with the following:

- ANSI/INCITS 358-2002 BioAPI Specification, Version 1.1
- ANSI/NIST-ITL 1-2000 Standard Data Format for the Interchange of Fingerprint, Facial, & Scar Mark & Tattoo Information
- NISTIR 6529-A-2003 National Institute of Standards and Technology Interagency Report (NISTR) Common Biometric Exchange Framework Format (CBEFF)

2.3.2 ISO/IEC JTC 1/SC 37 N470 – Part 3: Finger Patter Spectral Data

The draft ISO standard JTC 1/SC 37 N470 Biometric Data Interchange Formats – Part 3: Finger Pattern Spectral Data establishes a data interchange format for fingerprint spectral data exchange. The goal of this standard is to allow local or global spectral data derived from a fingerprint image to be exchanged without exchanging the entire image. Spectral data-based recognition algorithms process "global" sections (cells) of biometric images.

This standard assumes compliance with the following:

- ANSI/INCITS 358-2002 BioAPI Specification, Version 1.1
- ANSI/NIST-ITL 1-2000 Data Format for the Interchange of Fingerprint, Facial, & Scar Mark & Tattoo Information
- ISO/IEC CD3 19785-1.3 Common Biometric Exchange Framework Format (CBEFF)
- ISO/IEC 15408:1999 Evaluation Criteria for IT Security

[4] The term down-sampled means to reduce the resolution of an image by resampling the image. This reduces the number of pixels accordingly. The resolution-reduced image is the so-called sub-band image.

2.3.3 ISO/IEC JTC 1/SC 37 N490 – Part 8: Finger Patter Skeletal Data

The draft ISO standard Biometric Data Interchange Formats – Part 8: Finger Pattern Skeletal Data[5] is based upon the representation of a friction ridge. The ridge skeleton is computed by reducing the ridge area of the image to a single pixel line. The pattern record is the direction encoding[6] of the skeleton line elements. The start and end points of the skeleton ridgelines are marked as minutiae. The line from start to end point is encoded by successive direction changes.

This standard assumes compliance with the following:

- ISO/IEC CD3 19785-1:2003 Common Biometric Exchange Formats Framework (CBEFF) – Part 1: Data Element Specification
- ANSI/INCITS 358-2002 BioAPI Specification, Version 1.1
- ISO/IEC CD2 19784:2003 BioAPI Specification
- ANSI/NIST-ITL 1-2000 Data Format for the Interchange of Fingerprint, Facial, & Scar Mark & Tattoo Information
- ISO/IEC 15408:1999 Evaluation Criteria for IT Security

2.3.4 Comparisons of Fingerprint Pattern-Based Data Interchange Formats

ANSI/INCITS 377-2004 Finger Pattern Data Interchange Format is very similar to the ISO draft standard ISO/IEC JTC 1/SC 37 N470 Biometric Data Interchange Formats – Part 3: Finger Pattern Spectral Data. The ISO standard, however, specifies only a finger pattern spectral data format.

Table 10 and Table 11 illustrate the differences between the two standards in their specifications for record header and finger pattern / pattern spectral record header. Because ANSI/INCITS 377-2004 Finger Pattern Data Interchange Format does not provide a definition of the finger pattern skeletal data format, these tables do not include a comparison of the ISO/IEC JTC 1/SC 37 N490 ISO draft standard Biometric Data Interchange Formats – Part 8: Finger Pattern Skeletal Data. Table 12 and Table 13 summarize the finger pattern skeletal record format.

[5] As of this technical report's writing, the Biometric Data Interchange Formats – Part 8: Finger Pattern Skeletal Data was a Committee Draft and identified as ISO/IEC JTC 1/SC 37 N490.

[6] Section 5.2 of the Biometric Data Interchange Formats – Part 8: Finger Pattern Skeletal Data specifies that the line stops at an offset coordinate with the starting direction and the minutiae characteristics. The successive polygonal elements are defined by their direction change relative to the previous one.

Table 10. Part 1 – Pattern-Based Format of ANSI/INCITS 377-2004 and Draft ISO/IEC JTC 1 SC 37 N470 – Record Header

Record Header		
Field	**ANSI/INCITS 377-2004**	**ISO/IEC JTC 1/SC 37 N470**
CBEFF Product Identifier (PID)	4 bytes	Not specified
Capture Device ID	Not specified	2 bytes
Size of finger pattern in x-direction (pixels)	1 byte	Not specified
Size of finger pattern in y-direction (pixels)	1 byte	Not specified
Number of Cells in x-direction	1 byte	2 bytes
Number of Cells in y-direction	1 byte	2 bytes
Number of Pixels in Cells in x-direction	1 byte	2 bytes
Number of Pixels in Cells in y-direction	1 byte	2 bytes
Cellular x-offset	1 byte	2 bytes
Cellular y-offset	1 byte	2 bytes
Number of Pixels between Cell Centers in x-direction	Not specified	2 bytes
Number of Pixels between Cell Centers in y-direction	Not specified	2 bytes
Number of components extracted from each cell	Not specified	2 bytes
Type of window and parameter	Not specified	2 bytes
Wavelength and angle generating mechanism for filters	Not specified	1 bytes
Method of selecting retained components	Not specified	1 bytes
Naming and ordering of retained components	Not specified	1 bytes

Table 11. Part 2 – Pattern-Based Format of ANSI/INCITS 377-2004 and Draft ISO/IEC JTC 1 SC 37 N470 – Finger Pattern / Pattern Spectral Record Header

Finger Pattern / Pattern Spectral Record Header		
Field	**ANSI/INCITS 377-2004**	**ISO/IEC JTC 1/SC 37 N470**
Extended Data Block Length	N/A	2 bytes

Table 12. Summary (Record Header) of the Draft ISO/IEC JTC 1 SC 37 N490 Standard

Record Header		
Field	**Size**	**Valid Values**
Format Identifier	4 bytes	0x46505200
Version Number	4 bytes	
Length of Record	4 bytes	
Capture Device ID	2 bytes	
Number of Finger Patterns in Record	1 byte	1 – 255
Resolution of Finger Pattern (ppcm)	1 byte	1 – 255
Bit-depth of Direction Code Start and Stop Point in X	1 byte	8 – 16

Record Header		
Field	**Size**	**Valid Values**
Bit-depth of Direction Code Start and Stop Point in Y	1 byte	8 – 16
Bit-depth of Direction Code Start and Stop Direction	1 byte	4 – 8
Bit-depth of Direction in Direction Code	1 byte	3 – 8
Step size of Direction Code	1 byte	1 – 255
Bit-depth of Quality Map	1 byte	0 – 8
Granularity of Quality Map	1 byte	1 – 255
Reserved byte	1 byte	

Table 13. Summary (Single-Finger Record Format) of the Draft ISO/IEC JTC 1 SC 37 N490 Standard

Single-Finger Record Format		
Field	**Size**	**Valid Values**
View Number	1 byte	0 – 15
Finger Position	1 byte	0 – 11
Impression Type	1 byte	0 – 3 or 8
Finger Quality	1 byte	0 – 100
Skeleton Image Size in X	2 bytes	
Skeleton Image Size in Y	2 bytes	
Length of Pattern Data Block	2 bytes	
Pattern Data	Data	
Length of Quality Map Block	2 bytes	
Quality Map	Data	
Extended Data Block Length	2 bytes	
Extended Data Area	Data	

3 Finger Image Compression Standards

This chapter describes and compares established fingerprint image compression. The primary purpose of image data compression is to represent images with less data in order to save storage and transmission time and costs. This chapter discusses three image compression standards that impact how data may be or is compressed.

- IS 10918-1 Joint Photographic Experts Group (JPEG) Standard
- IS 15444-1 JPEG 2000
- IAFIS-IC-0110 (v3) Wavelet Scalar Quantization

3.1 IS 10918-1 JPEG Standard

In the late 1970s and early 1980s, two standardization groups – the International Telegraph and Telephone Consultative Committee (CCITT) and the ISO – worked closely to create the Joint Photographic Experts Group (JPEG) standard. The JPEG standard includes both lossless[7] and lossy[8] encoding.

3.1.1 JPEG Lossy Compression Algorithm

Figure 3 illustrates the JPEG lossy compression algorithm, which operates in three successive stages.

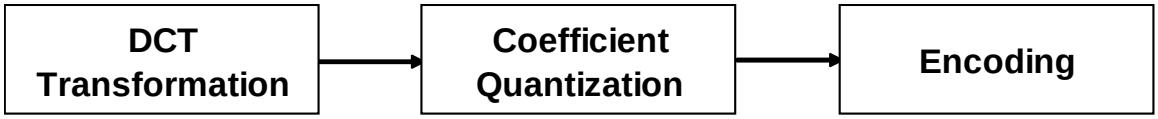

Figure 3. JPEG Lossy Compression Algorithm

The Discrete Cosine Transform (DCT)—which helps separate an image into parts (or spectral sub-bands[9]) of differing importance—takes each 8 pixel x 8 pixel block of image data and transforms the blocks from the original grayscale values to the cosine coefficients; then, it applies a quantization matrix on the coefficients. A "lossy" result occurs at this stage. The JPEG standard allows any number of quantization matrices to be used; however, ISO has developed a standard set of quantization values supplied for use by implementers of JPEG code. The final stage in the JPEG process is coding the quantized coefficients.

[7] The lossless compression minimizes the number of bytes required to represent the original image samples without any loss of information. Lossless compression usually only provides a very low compression ratio of around 5:1.

[8] The lossy compression minimizes the number of bytes required to represent an image.

[9] See Footnote 5.

The following are the four coding techniques that the compression standard uses.[10]

- Since adjacent blocks in an image exhibit a high degree of correlation, the Run-Length Encoding (RLE) technique is used to code the first coefficient (referred to as the DC element). The RLE is a simple technique used to compress runs of identical DC values in a sequence stream.

- The entropy-encoding technique is used to code of other coefficients (so-called AC elements). The Advanced Huffman Coding and the Arithmetic Coding Algorithm techniques are the most frequently used in entropy-encoding techniques.

- Huffman coding is a method of encoding coefficients that varies the length of the bits in proportion to their value content. Coefficients with a low probability of appearance are encoded with a code that uses more bits. Coefficients with a high probability of appearance are represented with a code that uses fewer bits.

- Arithmetic coding takes entire coefficients and encodes them as a single floating point number that is less than 1 and greater than or equal to 0. It can more efficiently encode coefficients by eliminating the quantization effects of other coding techniques.

3.1.2 JPEG Advantages and Disadvantages

The JPEG compression standard can reduce the size of an image to less than 10 percent of the original with only an insignificant loss of resolution. However, since the encoding process is performed upon individual 8 x 8 pixel blocks one after the other (rather than the image as a whole), distortion in continuity occurs between adjacent but non-sequential blocks. This distortion causes blocking artifacts. Blocking artifacts could destroy the essential characteristics of the finger image for both automatic pattern matching and fingerprint identification by human examiners.

3.2 IS 15444-1 JPEG 2000

JPEG 2000 is a wavelet-based image compression standard developed as the next generation of the JPEG standard.[11] In 2000, the core JPEG 2000 algorithm was completed and is defined in the ISO 15444-1 JPEG 2000 standard.[12]

3.2.1 JPEG 2000 Part 1 Algorithm

JPEG 2000 Part 1 is based upon the two-dimensional Discrete Wavelet Transform (DWT), which transforms an image into frequency components. Unlike the DCT process in the JPEG standard, DWT performs this process on an entire image rather than working on smaller pieces of the desired data.

[10] Mitchelle, Joan and Pennebaker, William, *JPEG Still Image Data Compressed Standards*, 1993.

[11] The JPEG committee identified as ISO/IEC JTC1 SC29/WG1 created JPEG 2000.

[12] JPEG 2000 Part 1 is identified as ISO 15444-1.

As Figure 4 illustrates, the JPEG 2000 compression algorithm operates in three successive stages. The DWT decomposes finger image data down to sub-bands based upon scale or resolution, rather than the frequency content-based decomposition resulting from the DCT used in a JPEG algorithm.

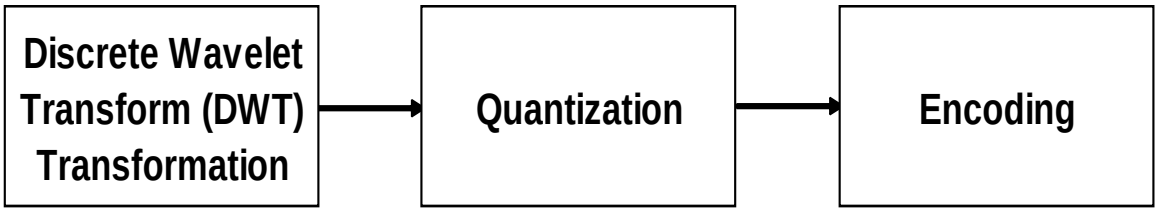

Figure 4. JPEG 2000 Compression Algorithm

Figure 5 illustrates the steps involved in decomposing image data.

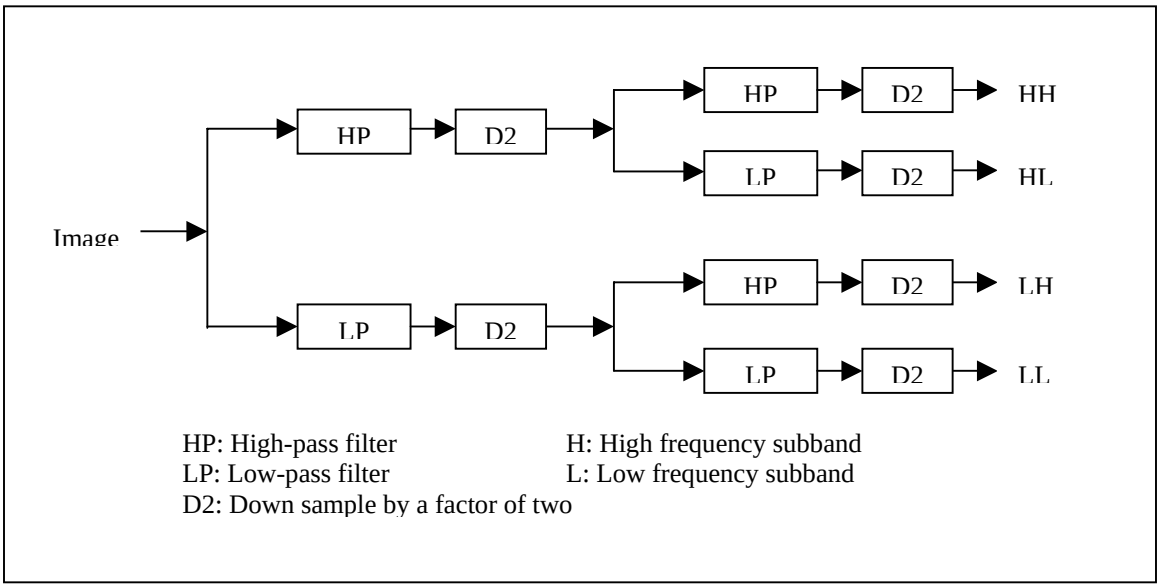

Figure 5. Wavelet Decomposition Process[13]

The decomposition process can be repeated recursively on the low-resolution image to create a series of reduced resolution sub-bands. Figure 6 illustrates the Mallat tree, which is graphical representation for multiple-level wavelet decomposition.

[13] Hopper, Thomas, *FBI Compression of Grayscale Fingerprint*, September 1994.

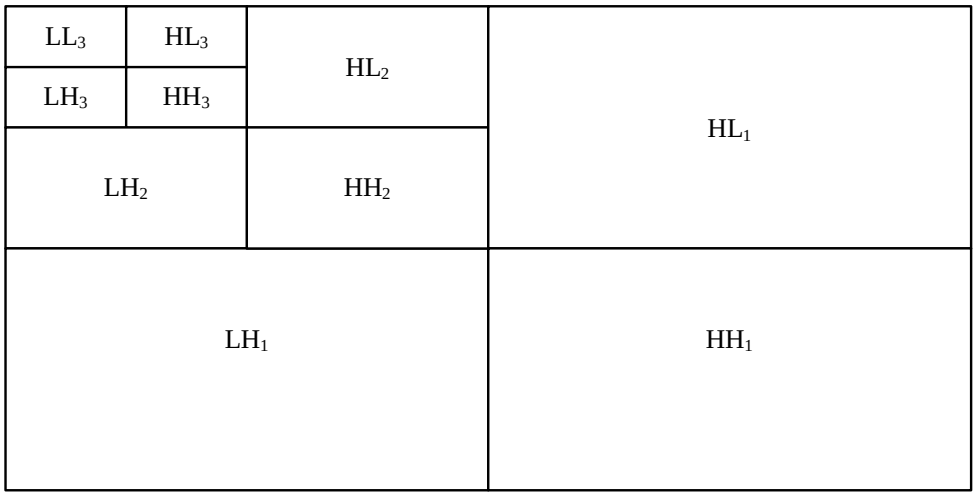

Figure 6. Multiple-Level Wavelet Decomposition Tree[14]

After transformation, all wavelet coefficients undergo uniform scalar quantization that employs a fixed dead-zone about the origin. This is accomplished by dividing the magnitude of each coefficient by a quantization step size and rounding down. One quantization step size is allowed per sub-band.

After quantization, each sub-band undergoes a packet partition. This packet partition divides each sub-band into regular[15] non-overlapping rectangles for the purpose of memory-efficient implementations, streaming, and random access to the bitstream. These regular, non-overlapping rectangles are then coded by the Arithmetic Coding Algorithm[16] with run-length entropy encoding.

3.2.2 JPEG 2000 Part 1 Features

Comparing the JPEG and JPEG 2000 standards, JPEG 2000 has superior rate-distortion and subjective image quality performance. The following JPEG 2000 features support this conclusion (JPEG does not offer these features).

[14] JPEG 2000 and WSQ Image Compression Interoperability, MITRE Technical Report, February 2001

[15] The algorithm will define the "regular" non-overlapping rectangle size when doing the coding.

[16] The Arithmetic Coding Algorithm produces a code for an entire message. Each symbol added to the message incrementally modifies the output code. It replaces a stream of input symbols with a single floating-point output number.

- Progressive transmission[17] by pixel accuracy and resolution
- Region-of-Interest coding
- Maintain image quality compression
- Lossless and lossy compression
- Continuous-tone and bi-level compression
- Support for different color spaces

3.3 IAFIS-IC-0110 (v3) Wavelet Scalar Quantization

The Wavelet Scalar Quantization (WSQ) is the FBI-specified fingerprint compression standard used nationally and internationally. This standard specifies how to represent biometric image data in a compressed image format. Additionally, ANSI/NIST ITL 1-2000 Data Format for the Interchange of Fingerprint, Facial, & Scar Mark & Tattoo Information standard assumes compliance with the WSQ.

3.3.1 WSQ Algorithm

Similar to JPEG 2000, the FBI's WSQ specification is based upon the two-dimensional DWT. For this specification, Figure 7 illustrates the FBI-specified multiple level wavelet decomposition tree.[18]

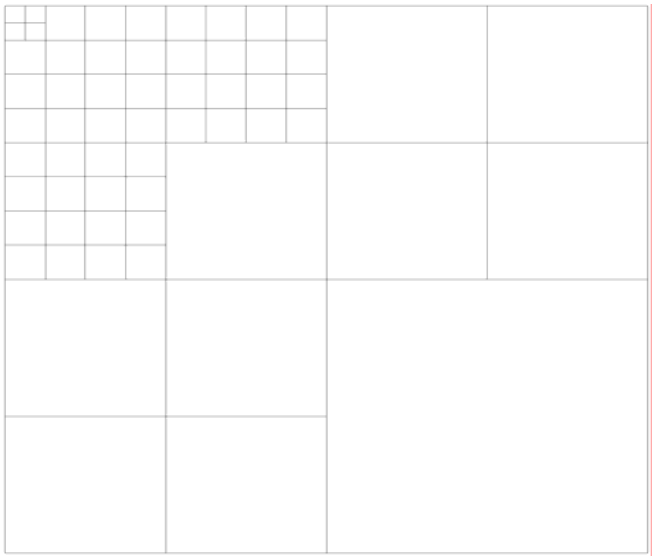

Figure 7. The FBI Decomposition Tree

The WSQ specification opted for sub-band adaptive scalar quantization. The quantizer of each sub-band is almost a uniform quantizer. All intervals are of the same length except for the middle interval centered at 0, which is 40 percent larger than the other intervals. The reconstruction values are all near the middle points of their intervals. Those quantizers are sub-band adaptive in that the length of most of

[17] IS 15444-1 JPEG 2000 Standard.

[18] See figure from the IAFIS-IC-0110 (V3) Standard.

the intervals is inversely proportional to the logarithm of the variance of the sub-band. The length of the intervals also depends upon a scalar multiplicative value, which is set depending upon the desired compression ratio – smaller factors for higher compression ratios.

In the WSQ specification, each quantized sub-band is turned into a one-dimensional sequence; next, Run Length Encoding is applied to code runs of zeros; and, last, the run lengths and other remaining data are coded with Huffman coding.

3.4 Comparison Between WSQ and JPEG 2000 Part 1 Standards

In 2001, the FBI studied[19] the compatibility between the WSQ and JPEG 2000 Part 1 standards, which involved tests that were performed on a small set of fingerprint images. The resulting report of this study showed that JPEG 2000 Part 1 differs in three major areas:

1. the image offset,
2. the FBI-decomposition tree, and
3. the scalar quantizer.

At present, these areas allow compressed files to be easily interchanged from one format to the other with minimal loss in image content. During this study, it also was noted that a visual inspection showed that JPEG 2000 Part 1 tends to be somewhat blurrier than WSQ when applied to fingerprints. However, the identification and matching capability of the images did not seem to change significantly due to this blurriness.

[19] JPEG 2000 and WSQ Image Compression Interoperability, MITRE Technical Report, February 2001

4 Conclusion

This technical report is a comparative analysis of finger image/template interchange formats and image compression standards developed by the FBI, ANSI, and ISO. This analysis resulted in identifying several differences between these standards that indicate there are incompatibilities that hinder interoperability between the formats reviewed. Table 14 summarizes the difference between these standards.

Table 14. Comparative Analysis Findings

Comparative Analysis Findings	
Fingerprint Image Record	
1	ANSI/NIST-ITL 1-2000 and CJIS-RS-0010 (v7) EFTS are identical. ANSI/INCITS 381-2004 and ISO/IEC JTC 1/SC 37 N340 are identical in most fields except CBEFF product ID and capture device ID.
2	ANSI/NIST-ITL 1-2000 specifies a minimum scanner resolution of 500 ppi. ANSI/INCITS 381-2004 specifies a minimum scanner resolution of 125 ppi.
3	ANSI/INCITS 381-2004 specifies a maximum scanner resolution of 1,000 ppi. ANSI/NIST-ITL 1-2000 does not specify a maximum scanner resolution.
4	ANSI/NIST-ITL 1-2000 specifies a minimum transmitting with high, low, and variable resolutions. ANSI/INCITS 381-2004 does not specify a minimum transmitting.
5	ANSI/INCITS 381-2004 specifies the CBEFF product identifier, however other standards do not.
6	ANSI/INCITS 381-2004 specifies the Scanner ID. ISO/IEC JTC 1/SC 37 N340 specifies the capture device ID.
Fingerprint Image Compression	
7	ANSI/NIST-ITL 1-2000 and EFTS specify the WSQ algorithm for grayscale image compression. ANSI/INCITS 381-2004 and ISO/IEC JTC 1/SC 37 N341 specify WSQ, JPEG, JPEG2000, and PNG algorithms.
8	WSQ compression algorithm is designed specifically for fingerprint images with a scanning resolution of 500 ppi.
Fingerprint Image Quality	
9	EFTS provides details for image quality specifications. ANSI/INCITS 381-2004 and ISO/IEC JTC 1/SC 37 N341 set the value of quality in accordance with the general guidelines contained in the ANSI/INCITS 358-2002 BioAPI specification, version 1.1.
Finger Minutiae	
10	The specification of ANSI/NIST – ITL 1-2000 Type-9 is incompatible with ANSI/INCITS 378-2004.
Finger Pattern	
11	ANSI/INCITS 377-2004 Finger Pattern Data Interchange Format is very similar to the ISO draft standard ISO/IEC JTC 1/SC 37 N470 Biometric Data Interchange Formats – Part 3: Finger Pattern Spectral Data, except that the latter only specifies a finger pattern spectral data format. ISO/IEC JTC 1/SC 37 N490 Biometric Data Interchange Formats – Part 8: Finger Pattern Skeletal Data specifies finger pattern skeletal data format.

As detailed in Table 14, several standards currently in use are not interoperable with one another due to incompatible specifications. These standards are well established at the national and international levels. As a result, it is unlikely that a single standard for fingerprint image records can be deployed in the current environment. Therefore, it is suggested that the biometric standards community and stakeholders develop transcoder software utilities to convert biometric fingerprint image/template data between the various formats described in this report, since a commercial off-the-shelf (COTS) market for such software does not currently exist.

Appendix A: List of Acronyms and Abbreviations

Acronym	Definitions
AC element	High frequency element
AFIS	Automated Fingerprint Identification System
ANSI	American National Standards Institute
API	Application Programming Interface
BCA	Binary Compression Algorithm
BFC	Biometrics Fusion Center
BioAPI	Biometrics Application Programming Interface Standard
BMO	Biometrics Management Office
CBEFF	Common Biometric Exchange File Format
CCITT	International Telegraph and Telephone Consultative Committee
CIO	Chief Information Officer
CJIS	Criminal Justice Information Services
DC element	The Lowest frequency element
DCT	Discrete Cosine Transform
DoD	Department of Defense
DWT	Discrete Wavelet Transform
EFTS	Electronic Fingerprint Transmission Specification
FBI	Federal Bureau of Investigation
GCA	Grayscale Compression Algorithm
IAFIS	Integrated Automated Fingerprint Identification System
IEC	International Electrotechnical Commission
INCITS	International Committee for Information Technology Standards
ISO	International Organization for Standardization
ITL	Information Technology Laboratory
JPEG	Joint Photographic Experts Group
JTA	Joint Technical Architecture
JTC 1	Joint Technical Committee
NIST	National Institute of Standards and Technology
PNG	Portable Network Graphics
Ppi	Pixels per inch
RLE	Run-Length Encoding
SC 37	Subcommittee 37 of ISO/IEC JTC 1
SMT	Scar Mark & Tattoo

Acronym	Definitions
SPI	Service Provider Interface
TAG	Technical Advisory Group
WG	Working Group
WSQ	Wavelet Scalar Quantization

Appendix B: References

1. ANSI/EIA-538-1988 Facsimile Compression Standard
2. ANSI/INCITS 377-2004 Finger Pattern-Based Interchange Format
3. ANSI/INCITS 378-2004 Finger Minutiae Format for Data Interchange
4. ANSI/INCITS 381-2004 Finger Image-Based Data Interchange Format
5. ANSI/NCITS 358-2002 BioAPI Specification, Version 1.1
6. ANSI/NIST-ITL 1-2000 Data Format for the Interchange of Fingerprint, Facial, & Scar Mark & Tattoo Information
7. CJIS-RS-0010 (v7) Electronic Fingerprint Transmission Specification
8. DoD Biometrics Management Office, Biometrics Standards Development Recommended Approach, 16 Jan 2004.
9. Hopper, Thomas, FBI Compression of Grayscale Fingerprint, September 1994.
10. IAFIS-IC-0110 (v3) Wavelet Scalar Quantization
11. Interoperability Standards For Fingerprint Information, R. M. McCabe, 29 January 2003
12. IS 10918-1 Joint Photographic Experts Group Standard
13. IS 15444-1 JPEG 2000
14. ISO 15444-1 Joint Photographic Experts Group 2000 Standard
15. ISO IEC 15948:2003 Portable Network Graphics (PNG) Specification
16. ISO/IEC 15408:1999 Evaluation Criteria for IT Security
17. ISO/IEC CD2 19784:2003 BioAPI Specification
18. ISO/IEC CD3 19785-1:2003 Common Biometric Exchange Formats Framework (CBEFF) – Part 1: Data Element Specification
19. ISO/IEC JTC 1/SC 37 N340 Biometric Data Interchange Formats – Part 2: Finger Minutiae Data
20. ISO/IEC JTC 1/SC 37 N341 Biometric Data Interchange Formats – Part 4: Finger Image Data
21. ISO/IEC JTC 1/SC 37 N470 Biometric Data Interchange Formats – Part 3: Finger Pattern Spectral Data
22. ISO/IEC JTC 1/SC 37 N490 Biometric Data Interchange Formats – Part 8: Finger Pattern Skeletal Data
23. JPEG 2000 and WSQ Image Compression Interoperability, MITRE Technical Report, February 2001

24. Mitchelle, Joan and Pennebaker, William, *JPEG Still Image Data Compressed Standards*, VanNortrand and Reinhold, 1993.

25. NISTIR 6529-A-2003 National Institute of Standards and Technology Interagency Report (NISTR) Common Biometric Exchange Framework Format (CBEFF)