NIST Special Publication
NIST SP 500-339

Specification for Certification Testing of Contactless Fingerprint Acquisition Devices, v1.0

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This publication is available free of charge from:
https://doi.org/10.6028/NIST.SP.500-339

NIST NATIONAL INSTITUTE OF STANDARDS AND TECHNOLOGY
U.S. DEPARTMENT OF COMMERCE

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April 2023

U.S. Department of Commerce
Gina M. Raimondo, Secretary

National Institute of Standards and Technology
Laurie E. Locascio, NIST Director and Under Secretary of Commerce for Standards and Technology

NIST SP 500-339
April 2023

NIST Technical Series Policies

Publication History

Approved by the NIST Editorial Review Board on 2023-03-30.

How to Cite this NIST Technical Series Publication

Orandi S, Libert J, Grantham J, Ko K, Bandini B, Watson C (2023). Specification for Certification Testing of Contactless Fingerprint Acquisition Devices, v1.0. (National Institute of Standards and Technology, Gaithersburg, MD), NIST Special Publication (SP) NIST SP 500-339. https://doi.org/10.6028/NIST.SP.500-339

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Abstract

This specification builds upon the protocols and metrics established in NIST Special Publication 500-336 and defines procedures for the evaluation and certification of contactless fingerprint acquisition devices with respect to certified legacy contact fingerprint collection devices. This protocol allows contactless fingerprint developers seeking certification of their devices to perform self-testing of their device using the NIST Fingerprint Registration and Comparison Tool (NFRaCT). NFRaCT will then enable interested parties to provide results of the self-testing to the certifying authority for verification and acceptance.

Keywords

Contactless fingerprint; image comparison; interoperability.

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Acknowledgments

This special publication would not have been possible without time and assistance from the many people who helped make it a success.

We would first like to thank Jack B. Prothero and William F. Guthrie of NIST's Statistical Engineering Division for their advice and insight on the analysis methods used for this special publication as well as Nune Atyan and everyone in NIST's Research Library for their steadfast support on the background research.

Next, our gratitude goes to Gregory P. Fiumara, R. Michael McCabe, John M. Splain, Amy N. Yates for their time, advice, and candor in reviewing the contents of this special publication and providing many meaningful suggestions to help make this a better report.

We would also like to thank our colleagues at the FBI for all their support in this effort without which this special publication would not be possible.

Executive Summary

This specification provides a set of protocols for testing and certification of contactless fingerprint acquisition devices.

In providing the basis for certification, we examined the performance of several measurands with respect to real world commercial fingerprint matcher performance. In doing so, we established a linear regression model that will be used to predict matcher performance of the contactless device under test to help establish fitness of use in the context of a modern fingerprint matching system.

This specification provides a basis for a certification pathway for these emerging devices along with a comprehensive measurement of their imaging characteristics. Results for devices that have been tested according to the protocols defined in this specification can be used by stakeholders in formulating decisions for the inclusion of these new devices into their systems.

In the initial release of this specification, application of the certification pathway has been defined for various operational use cases with the notable exception of the enrollment of contactless fingerprint imagery on systems that utilize a reference database of contact collected images. The guidance for this exception case will be provided later in a revision or amendment to this specification. This specification does however provide a certification pathway for contactless enrollment on systems that solely utilize contactless imagery (for both search and reference database).

1. Introduction

1.1. Overview

Contactless acquisition of fingerprints presents a fundamental departure from legacy contact-based capture technologies. The friction ridge surface that comprises a fingerprint is a three-dimensional (3D) topography present on a three-dimensional pseudo-cylindrical surface of a finger.

This specification provides a set of protocols for testing and certification of contactless fingerprint acquisition devices. This specification forms the basis for a certification pathway for these emerging devices and will provide a comprehensive measurement of the imaging characteristics of such devices. Results for devices that have been tested according to the protocols defined in this specification can be used by stakeholders in formulating decisions for the inclusion of these new devices into their systems.

1.2. Background

For nearly 100 years, inked fingerprint cards were accepted within the criminal justice community as the standard means for recording and storing fingerprint identification data. As electronic systems emerged to help process these inked fingerprint cards, so did the potential for differences between such systems, even if slight, to negatively impact how these fingerprints are processed and perform for their intended use of establishing identity. Because of this need to establish consistency, devices in the capture chain of custody currently undergo rigorous examination of performance characteristics prior to being certified by the Federal Bureau of Investigation (FBI) under the Electronic Biometric Transmission Specification (EBTS) Appendix F[1] test protocol to ensure that the images are fit for use. As such systems slowly transitioned from inked fingerprint cards to modern optical livescan devices so did the test protocols to validate and incorporate these new devices into the ecosystem.

As a new generation of devices emerged allowing for the collection of fingerprints without physical contact, testing and analysis of the capabilities of these emerging contactless fingerprint capture devices in [7][8] showed that these devices are fundamentally different than the previous generation of contact fingerprint collection devices that were certified under the EBTS Appendix F testing protocol. New tools and protocols were needed to measure and quantify their capabilities. This specification serves as a set of protocols along with associated metrics and tools needed to test such devices.

2. The Purpose of This Specification

i. This specification defines a protocol and associated metrics for measuring fitness of use for a candidate contactless fingerprint capture device. The candidate contactless fingerprint capture device is referred to as the Device Under Test (DUT).

ii. Tests conducted on the DUT are made in comparison to a contact collection Reference Device (RD).

iii. Tests in this specification are developed to ensure fitness of use for a DUT collecting contactless fingerprint images to use in the following defined use cases:

   a. Collection and use of contactless images for search-only transactions on systems that utilize a contact-only reference database, and implicitly allow contactless transactions.

   b. Collection and use of contactless images for search and/or enrollment on systems that utilize a contactless reference database.

iv. Tests defined in this document are not intended to replace existing certification protocols for contact collection devices (e.g., RD).

v. The tests in this specification are defined using steps, procedures, and software apparatus defined in NIST Special Publication 500-336 [5]. The measurands used are also defined in [5].

vi. While this specification defines tests that are used to ensure fitness of use for a contactless collection device, allowing contactless imagery from any device is the system operator's decision who will choose to adopt the testing and certification defined in this specification if they deem it acceptable.

vii. This specification's purpose is to define a protocol for testing images from the DUT, and not the larger system implementation, which can include (but is not limited to) other system components beyond the fingerprint capture apparatus such as segmentation, minutiae detection, or matching components.

3. Assessment Criteria

3.1. Identification of Measurands

The protocols in this specification were established based on data collected in [7] and [8], along with analysis performed in [5], to identify relevant measurands in contactless fingerprint imagery. Of the measurands identified in [5], several were classified as single-image criteria that are applicable to either the contactless image from the DUT or the reference image from the RD while others are intended for application to a pair of images consisting of a contactless image from the DUT and a reference image from the RD. A comprehensive discussion of these measurands can be found in Section 5 of [5]. Furthermore, in establishing fitness for use given these signal measurands, we also processed the image pairs collected in [7] and [8] through two different configurations of a commercial law-enforcement-grade fingerprint matcher, a commercial civilian-grade fingerprint matcher, and an open-source matcher. Next, we performed a correlation analysis between the signal measures and match scores from these matchers. The commercial matchers were from two different vendors and utilize markedly different approaches in operation.

The measurands utilized in the fitness of use analysis are provided in Table 1.

Table 1 - List of Measurands Used in Analysis

Measurand	Single or Pair Image(s)
Image Entropy	Single
Blind Signal to Noise Ratio (BSNR)	Single
Inverse RMS Difference of SIVV Signals	Pair
Correlation of SIVV Signals	Pair
Computation of Scale Factor	Pair
Correlation of Ridge Orientation Maps	Pair
Structural Similarity Index	Pair
NIST Fingerprint Image Quality (NFIQ) 2	Single
Corresponding Minutiae (Count)	Pair
Mean Displacement of Corresponding Minutiae	Pair
Law-Enforcement(LE)-Grade Matcher v1	Pair
Law-Enforcement(LE)-Grade Matcher v2	Pair
Civilian-Grade (CIV) Matcher	Pair
Open-Source (OS) Matcher	Pair

3.2. Measurand Normality Tests

In order to select which types of tests to use in conducting our analysis, we next performed normality tests on the measurands using the Shapiro-Wilk test for normality [9]. The null hypothesis of the Shapiro-Wilk test states that the population is normally distributed, while the alternate hypothesis states the population does not follow a normal distribution. A total of 17 normality tests were performed, and a Bonferroni adjusted alpha was utilized.

Given that the *p*-values for all measurand distributions is less than the adjusted alpha level of 0.0029 (see Table 2), the null hypothesis is rejected, and we accept the alternative hypothesis that the data from all measurands does not follow a normal distribution.

Table 2 - Shapiro-Wilk Test of Normality for Measurand Data

Variable	Shapiro-Wilk Test, p-value
Entropy-RD	**<0.0001**
Entropy-DUT	**<0.0001**
BSNR-RD	**<0.0001**
BSNR-DUT	**<0.0001**
SIVV RMSD	**<0.0001**
SIVV Correlation	**<0.0001**
Scale Factor	**<0.0001**
Structural Similarity	**<0.0001**
Ridge Orientation	**<0.0001**
NFIQ2-RD	**<0.0001**
NFIQ2-DUT	**<0.0001**
Corresponding Minutiae	**<0.0001**
Mean Displacement	**<0.0001**
Law-Enforcement (LE)-Grade Matcher 1 v1	**<0.0001**
Law-Enforcement (LE)-Grade Matcher 1 v2	**<0.0001**
Civilian-Grade (CIV) Matcher	**<0.0001**
Open Source (OS) Matcher	**<0.0001**

3.3. Measurand Summary Statistics

The protocols in this specification were established based on data collected in [7] and [8] utilizing several contactless fingerprint capture devices as well as their contact collected reference captures which provided *n*=10737 observations. Summary statistics for these observations are provided in Table 3.

Table 3 - Summary Statistics for Observed Data

Variable	Minimum	Maximum	Mean	σ
Entropy-RD	3.15	7.78	5.99	0.75
Entropy-DUT	0.66	7.99	6.71	1.12
BSNR-RD	3.16	34.05	26.43	3.79
BSNR-DUT	-45.86	43.44	20.18	9.24
SIVV RMSD	0.80	0.99	0.95	0.02
SIVV Correlation	0.89	1.00	0.98	0.01
Scale Factor	0.27	4.19	1.09	0.25
Structural Sim.	-0.03	0.70	0.11	0.09
Ridge Orient.	-0.56	0.97	0.54	0.23
NFIQ2-RD	0	97	46.04	31.05
NFIQ2-DUT	0	94	35.33	62.07
Corresponding Minutiae	0	57	13.88	10.16
Mean Displacement	0	444.30	16.16	24.94
OS Matcher	0	475.85	57.08	69.78

3.4. Measurand Correlation to Match Scores

Biometric quality estimation can serve as an important predictor for the capability of a fingerprint matcher to match a pair of fingerprints from the same person. However, the ultimate gauge of this quality estimation is the actual similarity score obtained from a match comparison. The ability for a matcher to use a pair of biometric samples to quantify their similarity is the end goal for the question of the fitness of use for the samples provided to the matcher.

In determining fitness of use for a given device, the fingerprints collected in [7] and [8] were processed by two independent versions of a commercial law-enforcement-grade fingerprint matching systems (with one version optimized specifically for Mobile ID caseloads), a commercial civilian grade matching system, and an open-source matching system. Match scores were obtained for a given pair of fingerprints from the same person. Next, using measurands identified in [5], the fingerprints collected in [7] and [8] were processed and results for all measurands were calculated. Next, multivariate correlation analysis was performed on these measurands, and Kendall's rank correlation coefficients (Kendall's τ) were calculated (see Table 4). Kendall's measure was used because it is non-parametric and does not rely on the assumptions of normality for the measurands, nor continuous data.

Given calculations of Kendall's τ, Table 4 shows correlation between measurands, including notably a correlation between all the matchers used. While correlation between all tested matchers cannot serve as a guarantee for fitness of use for every matcher in existence, it provides evidence for the assertion that the results of this study do correlate across multiple matchers from various sources.

Table 4 - Correlation Matrix for Measurands

Kendall's tau	Entropy-RD	Entropy-DUT	BSNR-RD	BSNR-DUT	SIVV RMSD	SIVV Correlation	Scale Factor	Structural Sim.	Ridge Orient.	NFIQ2-RD	NFIQ2-DUT	Corresponding Minutiae	Mean Displacement	LE Matcher v1	LE Matcher v2	Civ Matcher	OS Matcher
Entropy-RD	-	-0.071	-0.620	0.098	-0.040	0.002	-0.005	-0.070	-0.032	-0.047	-0.075	-0.022	-0.014	-0.040	-0.046	-0.049	-0.030
Entropy-DUT	-0.071	-	0.114	-0.685	0.169	-0.019	-0.016	-0.114	-0.002	0.038	-0.001	0.017	0.020	0.023	0.038	-0.020	-0.006
BSNR-RD	-0.620	0.114	-	-0.132	0.094	0.035	0.009	0.106	0.058	0.140	0.134	0.080	0.027	0.095	0.100	0.099	0.087
BSNR-DUT	0.098	-0.685	-0.132	-	-0.173	0.019	-0.006	0.085	-0.085	-0.059	-0.064	-0.079	0.021	-0.096	-0.109	-0.056	-0.058
SIVV RMSD	-0.040	0.169	0.094	-0.173	-	0.306	0.014	-0.062	-0.134	0.061	-0.005	-0.031	0.091	-0.060	-0.057	-0.065	-0.049
SIVV Correlation	0.002	-0.019	0.035	0.019	0.306	-	-0.103	0.137	0.034	0.020	-0.012	0.076	-0.111	0.092	0.085	0.105	0.084
Scale Factor	-0.005	-0.016	0.009	-0.006	0.014	-0.103	-	-0.071	-0.123	-0.059	-0.018	-0.142	0.252	-0.178	-0.182	-0.174	-0.141
Structural Sim.	-0.070	-0.114	0.106	0.085	-0.062	0.137	-0.071	-	0.289	0.133	0.169	0.322	-0.218	0.390	0.381	0.384	0.342
Ridge Orient.	-0.032	-0.002	0.058	-0.085	-0.134	0.034	-0.123	0.289	-	0.257	0.335	0.421	-0.277	0.452	0.456	0.470	0.441
NFIQ2-RD	-0.047	0.038	0.140	-0.059	0.061	0.020	-0.059	0.133	0.257	-	0.412	0.387	-0.012	0.366	0.372	0.356	0.377
NFIQ2-DUT	-0.075	-0.001	0.134	-0.064	-0.005	-0.012	-0.018	0.169	0.335	0.412	-	0.428	-0.028	0.392	0.399	0.425	0.437
Corresponding Minutiae	-0.022	0.017	0.080	-0.079	-0.031	0.076	-0.142	0.322	0.421	0.387	0.428	-	-0.196	0.669	0.659	0.640	0.884
Mean Displacement	-0.014	0.020	0.027	0.021	0.091	-0.111	0.252	-0.218	-0.277	-0.012	-0.028	-0.196	-	-0.255	-0.253	-0.269	-0.216
LE Matcher v1	-0.040	0.023	0.095	-0.096	-0.060	0.092	-0.178	0.390	0.452	0.366	0.392	0.669	-0.255	-	0.885	0.723	0.673
LE Matcher v2	-0.046	0.038	0.100	-0.109	-0.057	0.085	-0.182	0.381	0.456	0.372	0.399	0.659	-0.253	0.885	-	0.715	0.661
Civ Matcher	-0.049	-0.020	0.099	-0.056	-0.065	0.105	-0.174	0.384	0.470	0.356	0.425	0.640	-0.269	0.723	0.715	-	0.662
OS Matcher	-0.030	-0.006	0.087	-0.058	-0.049	0.084	-0.141	0.342	0.441	0.377	0.437	0.884	-0.216	0.673	0.661	0.662	-

Some correlations were very strong (e.g., Corresponding Minutiae with good correlation to multiple measurands), while others were weaker. All measurands were deemed of analytical value in supporting the creation of a predictive model for fitness of use. This includes measurands related to the reference image only. This may be counterintuitive at first, but it has been shown that characteristics of the reference (contact-collected) image can have an impact on a matcher's ability to establish a similarity score when using a pair of images, one of which is from the RD [10].

It should be noted that NFIQ2's use as a monadic quality measure for contactless collected images is not advised at this time due to insufficient testing and training of the algorithm for this nascent use case. NFIQ2's use in the scope of this analysis does provide a strong correlation and utility as a measurand that can support the model as seen in section 3.5 when utilized as a dyad for RD and DUT respectively.

Based on the correlation analysis in this section, as well as the findings in [9], the Mobile ID optimized version of the law-enforcement-grade matcher (LE Matcher v2) showed resiliency to contactless imagery; therefore, LE Matcher v2 was selected as the dependent variable in the analysis that follows.

3.5. Selection of a System Performance Model

In establishing a model for predicting fitness of use, we conducted a regression analysis on the measurands (explanatory variables) with respect to the law-enforcement-grade matcher's scores (LE Matcher v2, or the dependent variable).

There are many approaches at data modelling, so we conducted an exploratory analysis of several models which included non-linear and non-parametric cases.

This exploratory analysis helped narrow our scope for a suitable model for the selection of a regression model.

Analysis showed that a 3rd order polynomial non-linear model provides the best fit (Figure 1) according to Akaike Information Criterion (AIC). While the 3rd order polynomial non-linear model showed best fit, the simpler linear regression model emerged similar in predictive value and provides a far simpler approach given a similarly useful model even though not one with the absolute best observed AIC measure[11].

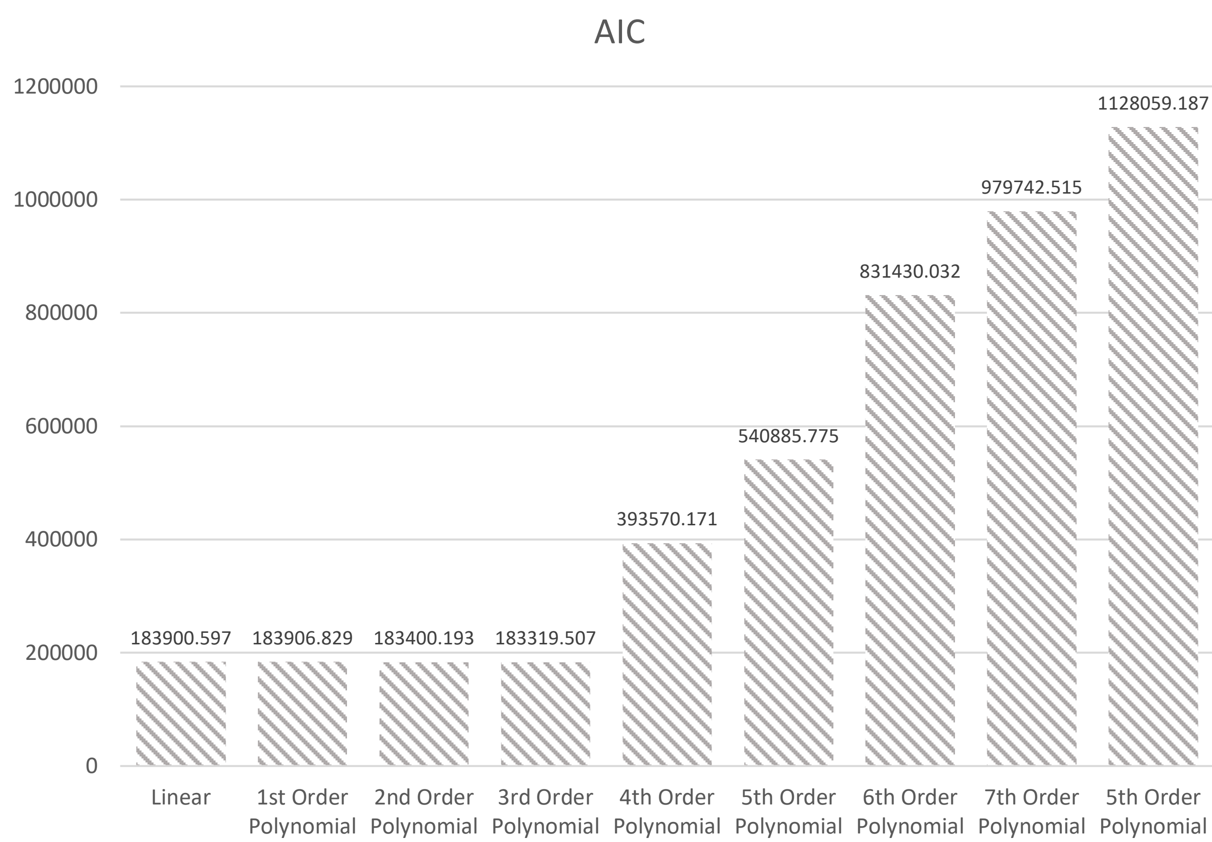

Figure 1 - Comparison of various linear and non-linear regression models

Multiple linear regression allows for the reduction of the explanatory variables from our model if the model can offer acceptable predictive strength with fewer variables. Based on this analysis (Table 5 and Table 6), we observe that measurands Entropy-RD, BSNR-RD and Mean Displacement data do not contribute significantly to the model in explaining the variance of the dependent variable, and therefore we can reduce the number of measurands in our model by eliminating these three measurands. The resulting 11 variables can effectively explain the same variance that 14 variables did (Table 6).

Table 5 - Variable Selection Summary

# of Model Variables	Variables	MSE	R²	Adjusted R²	Mallows' Cp	Akaike's AIC	Schwarz's SBC	Amemiya's PC
1	OS Matcher	31424662.689	0.774	0.774	1570.331	185355.943	185370.506	0.226
2	Structural Sim. / OS Matcher	29686272.748	0.786	0.786	890.637	184745.919	184767.763	0.214
3	Structural Sim. / Corresponding Minutiae / OS Matcher	28890779.856	0.792	0.792	580.162	184455.277	184484.403	0.208
4	BSNR-DUT / Structural Sim. / Corresponding Minutiae / OS Matcher	28355359.353	0.796	0.796	371.540	184255.426	184291.833	0.204
5	Entropy-DUT / Structural Sim. / Ridge Orient. / Corresponding Minutiae / OS Matcher	27971959.261	0.799	0.798	222.453	184110.257	184153.946	0.202
6	Entropy-DUT / Scale Factor / Structural Sim. / Ridge Orient. / Corresponding Minutiae / OS Matcher	27773773.340	0.800	0.800	145.876	184034.912	184085.882	0.200
7	Entropy-DUT / SIVV RMSD / Scale Factor / Structural Sim. / Ridge Orient. / Corresponding Minutiae / OS Matcher	27670620.127	0.801	0.801	106.499	183995.960	184054.211	0.200
8	Entropy-DUT / SIVV RMSD / Scale Factor / Structural Sim. / Ridge Orient. / NFIQ2-RD / Corresponding Minutiae / OS Matcher	27554601.247	0.802	0.801	62.096	183951.845	184017.378	0.199
9	Entropy-DUT / SIVV RMSD / Scale Factor / Structural Sim. / Ridge Orient. / NFIQ2-RD / NFIQ2-DUT / Corresponding Minutiae / OS Matcher	27498181.382	0.802	0.802	41.018	183930.837	184003.652	0.198
10	Entropy-DUT / BSNR-DUT / SIVV RMSD / SIVV Correlation / Scale Factor / Structural Sim. / Ridge Orient. / NFIQ2-RD / Corresponding Minutiae / OS Matcher	27452208.536	0.802	0.802	24.031	183913.871	183993.967	0.198
11	Entropy-DUT / BSNR-DUT / SIVV RMSD / SIVV Correlation / Scale Factor / Structural Sim. / Ridge Orient. / NFIQ2-RD / NFIQ2-DUT / Corresponding Minutiae / OS Matcher	27415740.658	0.803	**0.802**	10.766	183900.597	183987.974	0.198
12	Entropy-RD / Entropy-DUT / BSNR-DUT / SIVV RMSD / SIVV Correlation / Scale Factor / Structural Sim. / Ridge Orient. / NFIQ2-RD / NFIQ2-DUT / Corresponding Minutiae / OS Matcher	27417723.896	0.803	0.802	12.541	183902.372	183997.031	0.198
13	Entropy-RD / Entropy-DUT / BSNR-RD / BSNR-DUT / SIVV RMSD / SIVV Correlation / Scale Factor / Structural Sim. / Ridge Orient. / NFIQ2-RD / NFIQ2-DUT / Corresponding Minutiae / OS Matcher	27416369.850	0.803	0.802	13.012	183902.841	184004.781	0.198
14	Entropy-RD / Entropy-DUT / BSNR-RD / BSNR-DUT / SIVV RMSD / SIVV Correlation / Scale Factor / Structural Sim. / Ridge Orient. / NFIQ2-RD / NFIQ2-DUT / Corresponding Minutiae / Mean Displacement / OS Matcher	27418896.561	0.803	0.802	15.000	183904.829	184014.051	0.198

Table 6 - Calculated Model Parameters

Source	Value	Standard error	t	Pr > |t|	Lower bound (95%)	Upper bound (95%)
Intercept	-2541.372	4418.761	-0.575	0.565	-11202.962	6120.219
Entropy-DUT	552.241	78.997	6.991	**<0.0001**	397.393	707.089
BSNR-DUT	-37.949	9.574	-3.964	**<0.0001**	-56.715	-19.183
SIVV RMSD	-24839.225	2806.581	-8.850	**<0.0001**	-30340.645	-19337.806
SIVV Correlation	24065.082	5184.368	4.642	**<0.0001**	13902.761	34227.402
Scale Factor	-1895.521	220.974	-8.578	**<0.0001**	-2328.670	-1462.372
Structural Sim.	19779.104	777.690	25.433	**<0.0001**	18254.688	21303.520
Ridge Orient.	2271.638	289.236	7.854	**<0.0001**	1704.681	2838.595
NFIQ2-RD	15.864	1.937	8.189	**<0.0001**	12.067	19.662
NFIQ2-DUT	-3.673	0.940	-3.907	**<0.0001**	-5.516	-1.830
Corresponding Minutiae	205.225	16.185	12.680	**<0.0001**	173.499	236.952
OS Matcher	95.225	2.494	38.187	**<0.0001**	90.337	100.113

Given the parameters in Table 6, and reducing the number of descriptive variables from 14 to 11 (Entropy-RD, BSNR-DUT, SIVV RMSD, SIVV Correlation, Scale Factor, Structural Similarity, Ridge Orientation, NFIQ2-RD, NFIQ2-DUT, Corresponding Minutiae count and OS Matcher scores), the following equation will be used to model matcher (LE Matcher v2) behavior in determining fitness of use:

$$
\begin{aligned}
\text{Predicted Matcher Score} = & -(2\,541.372) \\
& +(552.241 \times \text{Entropy-DUT}) \\
& -(37.949 \times \text{BSNR-DUT}) \\
& -(24\,839.225 \times \text{SIVV RMSD}) \\
& +(24\,065.082 \times \text{SIVV Correlation}) \\
& -(1\,895.521 \times \text{Scale Factor}) \\
& +(19\,779.104 \times \text{Structural Similarity}) \\
& +(2\,271.638 \times \text{Ridge Orientation}) \\
& +(15.864 \times \text{NFIQ2-RD}) \\
& -(3.673 \times \text{NFIQ2-DUT}) \\
& +(205.225 \times \text{Corresponding Minutiae}) \\
& +(95.225 \times \text{OS Matcher})
\end{aligned}
$$

3.6. Pass/Fail Criteria

Based on the aforementioned analysis, and operational matching thresholds from [8] and [1], pass/fail criteria have been defined for testing of contactless devices using the score prediction model from 3.5. The DUT's performance as measured by NFRaCT shall satisfy the measurand thresholds presented in Table 7 below for the operational cases of interest as defined by the system operators/stakeholders utilizing this specification.

The certification pathway in the initial release of this specification is **not** applicable to the operational case of enrolling contactless imagery into systems that utilize a reference database of contact collected fingerprint images. Data obtained from the application of the initial release of this specification will be key to assessing and validating the model prior to expansion of the specification to include enrollment on such systems in a future release of this specification.

Table 7 - Pass/Fail Criteria by Operational Use Case

Operational Case	Reference Database	Submission Image	Measurand	Minimum, Maximum
Search-only	Contact	Contactless	Predicted Match Score	**[15 000 , ∞)**
			Scale Factor	**[0.94 , 1.06]**
Search-only	Contactless	Contactless	Predicted Match Score	**[8 500 , ∞)**
			Scale Factor	**[0.94 , 1.06]**
Search/Enroll	Contact	Contactless	**Not Supported at This Time**	**NA**
Search/Enroll	Contactless	Contactless	Predicted Match Score	**[15 000 , ∞)**
			Scale Factor	**[0.95 , 1.05]**

4. Test Procedures

This section defines the procedures to perform interoperability testing of the DUT. Interoperability testing will be facilitated by the NFRaCT tool. Interoperability testing can be performed at the DUT facilitator's site. Results of the interoperability tests will be packaged for transmittal back to the requesting party to validate fitness of use.

4.1. Materials

This section defines the materials needed to conduct the interoperability testing defined in this specification.

The RD must be an optical live capture device selected from the FBI Certified Product List[1] operating at 500 pixels per inch (ppi).

The stakeholder, certifying authority or agency (such as the FBI, for example) referencing this specification may reference and tailor this specification to change allowable test apparatus (live fingers or artifacts) necessary for their certification of a DUT, as well as the number of samples to be acquired from each.

4.2. Test Prerequisites and Procedures

The test prerequisites and procedures needed for the certification of a candidate contactless fingerprint capture device's fitness of use are described below.

It should be noted that a certifying authority or agency may specify further procedures and/or tailor this specification for their use cases including number of impressions, number of individuals providing biometric impressions for testing, specific impression type(s) (for example, only rolled equivalent, only FAP10[4], only plain, etc.), the number of fingerprints to test, or other specific factors.

[1] https://fbibiospecs.fbi.gov/certifications-1/cpl

4.3. Test Devices

4.3.1. Reference Device

For the scope of this specification, the offeror must select and obtain a Reference Device that is currently on the FBI Certified Product List and meet the following requirements:

- The RD shall be of optical-Frustrated Total Internal Reflection (FTIR) design.
- The RD shall capture rolled fingerprints.
- The RD shall capture fingerprints at a resolution of 500ppi[2] (19.7 pixels per millimeter, ppmm) at 8-bits per pixel in grayscale format.
- The RD shall save captured reference images in a lossless format supported by NFRaCT, and the images shall not be subjected to any lossy compression prior to saving in a lossless format.

It should be noted that while certification testing requires an optical-FTIR device as the RD, it does not imply that another type of certified device would be unusable. The methodology and analysis in this special publication were only performed using an optical-FTIR and other device methodologies have not tested as the RD and may have unforeseen impact on the result measurements.

[2] Resolution values for fingerprint imagery are specified in pixels per inch (ppi) throughout this document. This is based on widely used specification guidelines for such imagery and is accepted as common nomenclature within the industry. SI units for these will be presented only once.

4.3.2. Device Under Test

The DUT shall meet the following requirements:

- The DUT shall capture fingerprints at the EBTS specified maximum dimensions for a rolled fingerprint (EBTS P-2, 1.6” x 1.5” at 500ppi).
- The DUT shall capture as much of the friction ridge surface of the finger as possible, up to that of a rolled fingerprint (nail-to-nail capture, or 180 degrees angle of deflection relative to the finger axis)
- If the DUT is only able to capture multi-finger, the multi-finger image shall be segmented into individual fingers for the purpose of conducting the tests outlined in this specification.
- The DUT shall operate at a target resolution of 500ppi, and shall be capable of capturing and saving images at 8-bits per pixel grayscale.
- The DUT images shall be saved in a lossless format supported by NFRaCT, and the images shall not be subjected to any lossy compression prior to saving in a lossless format.

4.4. What to Capture

The test operator shall capture all ten fingers from each of the 2 distinct volunteers at the offeror's facility yielding a total of 20 fingerprint images using the RD and 20 fingerprint images from the DUT. The volunteers may include the test operator. The volunteers selected must have all ten fingers, and the fingers shall not be bandaged or otherwise rendered non-capturable.

This specification requires all ten fingers to be captured and numbered according to the Henry classification system [13].

The collection of fingerprints from both the DUT and RD shall be performed on the same day at the offeror's facility. This will minimize any longitudinal effects that may impact the comparative analysis performed by NFRaCT.

All fingerprint image files must be properly coded at the offeror's facility so that they can be compared accordingly. The method for marking image files as follows:

Person-[volunteer number]-finger-[finger number]-[DUT or RD]

For example:

Person-1-finger-01-DUT.png

Person-2-finger-07-RD.png

4.5. Image Life Cycle Management

Image acquisitions shall be performed by each respective DUT and RD at the offeror's facility.

The offeror is responsible for ensuring proper collection, safeguarding, and privacy for the images collected as well as informed consent of the volunteers.

NFRaCT will analyze these images (at the offeror's facility) and will generate a summary digest of its analysis for transmission in an encrypted package to prevent tampering with the results.

4.6. Test Cases

The offeror shall obtain the latest version of NFRaCT ([5] Appendix A) from NIST.

According to the procedures specified in [5], the offeror shall load and register each image pair as defined below in Table 8 to generate test results for each pair.

Table 8 - Image Pairing for NFRaCT Comparisons

Image Pair	Comparison Image 1	Comparison Image 2
1	Person-1-finger-01-DUT	Person-1-finger-01-RD
2	Person-1-finger-02-DUT	Person-1-finger-02-RD
3	Person-1-finger-03-DUT	Person-1-finger-03-RD
4	Person-1-finger-04-DUT	Person-1-finger-04-RD
5	Person-1-finger-05-DUT	Person-1-finger-05-RD
6	Person-1-finger-06-DUT	Person-1-finger-06-RD
7	Person-1-finger-07-DUT	Person-1-finger-07-RD
8	Person-1-finger-08-DUT	Person-1-finger-08-RD
9	Person-1-finger-09-DUT	Person-1-finger-09-RD
10	Person-1-finger-10-DUT	Person-1-finger-10-RD
11	Person-2-finger-01-DUT	Person-2-finger-01-RD
12	Person-2-finger-02-DUT	Person-2-finger-02-RD
13	Person-2-finger-03-DUT	Person-2-finger-03-RD
14	Person-2-finger-04-DUT	Person-2-finger-04-RD
15	Person-2-finger-05-DUT	Person-2-finger-05-RD
16	Person-2-finger-06-DUT	Person-2-finger-06-RD
17	Person-2-finger-07-DUT	Person-2-finger-07-RD
18	Person-2-finger-08-DUT	Person-2-finger-08-RD
19	Person-2-finger-09-DUT	Person-2-finger-09-RD
20	Person-2-finger-10-DUT	Person-2-finger-10-RD

Using NFRaCT, each set of the 20 pairs of images shall be loaded into software and registered.

Once registration is completed, the test operator can select a local directory to save NFRaCT results.

Two files will be saved by NFRaCT: one with an .XML extension and one with an .ENC extension. The XML file is readable by the offeror and may be kept for reference. The ENC file has the same contents as the XML file but is an encrypted version and thus will not be readable by the operator. The encrypted file does not contain any PII or imagery and will be submitted for scoring (See 4.7).

4.7. Naming Convention for Results Files

The encrypted files (.ENC) shall be re-named by the offeror according to the following format:

Person-[Person code]-Finger-[finger number, zero padded, 01 to 10].ENC

For example:
Person-A-Finger-01.ENC

At the conclusion of this stage in testing, there will be 20 uniquely named encrypted files each corresponding to an image pair.

4.8. Submission File

A text file named SUB.TXT shall be created by the test operator for inclusion in the score submission package containing the following information:

MAKE:	[DUT Make information, up to 49 characters]
MODEL:	[DUT Model information, up to 49 characters]
SERIAL:	[DUT Serial number, up to 49 characters]
FSV:	[DUT Firmware, or software version number up to 49 characters]
DMO:	[If DUT is a mobile device, Y, if not N]
DCT:	[If underlying DUT is COTS, Y, if not N]
REF MAKE:	[RD make information, up to 49 characters]
REF MODEL:	[RD Model information, up to 49 characters]
REF SERIAL:	[RD serial number, up to 49 characters]
REQC:	[Company name of the offeror]
REQA:	[Address of the offeror]
REQP:	[POC name at the offeror]
REQE:	[POC email at the offeror]
REQP:	[POC phone number at the offeror]

The SUB.TXT file along with the 20 encrypted score files shall be compressed into a single ZIP compatible archive.

The ZIP file shall be named according to the following convention:
[yyyymmddThhmm][3]-[REQC[4]]-[Submission Number]-Submission.ZIP

For example: 20230314T1358-Acme_Inc-01-Submission.ZIP

Submission file(s) shall then be sent to the certification authority according to their procedures for further processing and validation.

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[3] Time and date of submission package creation in UTC format, following ISO-8601-2004 convention[14], with no delimiters other than “T” separating date and time.
[4] Spaces and punctuation characters must be replaced with an underscore (“_”) to create a valid filename on the offeror’s system.

5. Response

Once the zip file has been opened and its integrity checked, the certification authority will send an initial response for the receipt of the submission package to the offeror.

Next, submitted results will be examined by the certification authority according to the criteria described in 3.6.

The pass/fail criteria will be applied to all submitted image pairs, and the DUT must pass for all image pairs submitted.

A response on the disposition of the test will then be sent from the certification authority after the submission has been processed.

This response may include a certification code (Field "CRT" as defined by [6]) assigned by the certification authority if the device meets interoperability requirements.

A certifying authority reserves the right to request that the device be sent to their facility for further testing, validation and verification prior to certification.

6. Conclusion and Future Work

The approach established in this study allows for the creation of a formal certification protocol for contactless capture devices with the goal of ensuring both interoperability with legacy contact collection devices as well as other contactless fingerprint capture devices. It does so by establishing measurement criteria using an already certified and acceptable device as a reference. While this guidance relies heavily on multiple other objective research efforts to provide a complete guidance for the inclusion of contactless fingerprint capture devices, the nascent nature of contactless technology may invariably result in a re-examination and revision of this guidance to ensure both continued fidelity to legacy devices, as well as potentially including new technology advances as they emerge.

References

[1] FBI/CJIS, "Electronic Biometric Transmission Specification (EBTS) Technical and Operational Update (TOU) 11", Federal Bureau of Information Criminal Justice Information Systems, Clarksburg, WV, April 16, 2021, https://www.fbibiospecs.cjis.gov/Document/Get?fileName=Master%20EBTS%20v11.0.pdf . Retrieved 10/08/2021

[2] Personal Identity Verification (PIV) Image Quality Specifications for Single Finger Capture Devices, FBI/CJIS Biometric Specifications, 10 July 2006, https://www.fbibiospecs.cjis.gov/Document/Get?fileName=pivspec.pdf. Retrieved 04/18/2019.

[3] Libert J, Grantham J, Bandini B, Wood S, Garris M, Ko K, Byers F, Watson C (2018) Guidance for Evaluating Contactless Fingerprint Acquisition Devices, NIST Special Publication 500-305, National Institute of Standards and Technology, Gaithersburg, MD. https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.500-305.pdf . Retrieved 01/29/2021.

[4] Special Publication (NIST SP) - 500-290e3: "American National Standard for Information Systems — Data Format for the Interchange of Fingerprint, Facial & Other Biometric Information, ANSI/NIST-ITL 1-2011 NIST Special Publication 500-290 Edition 3. August 22, 2016. http://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.500-290e3.pdf

[5] Special Publication (NIST SP) - 500-336: "Specification for Interoperability Testing of Contactless Fingerprint Acquisition Devices". June 2022. https://nvlpubs.nist.gov/nistpubs/SpecialPublications/NIST.SP.500-336.pdf

[6] Special Publication (NIST SP) - 500-334: " Contactless Fingerprint Capture and Data Interchange Best Practice Recommendation". March 2021.

[7] Libert, J, Grantham, J, Bandini, B, Ko, K, Orandi, S, Watson, C, Interoperability Assessment 2019:Contactless-to-Contact Fingerprint Capture, NIST IR 8307, National Institute of Standards and Technology, Gaithersburg, MD, May 2020. https://nvlpubs.nist.gov/nistpubs/ir/2020/NIST.IR.8307.pdf , Retrieved 1/29/2021.

[8] Orandi, S, Libert, J, Grantham, J, Bandini, B, Ko, K, Watson, C, Evaluating the Operational Impact of Contactless Fingerprint Imagery on Matcher Performance, NIST IR 8315, National Institute of Standards and Technology, Gaithersburg, MD, September 2020.

[9] https://nvlpubs.nist.gov/nistpubs/ir/2020/NIST.IR.8315.pdf . Retrieved 01/29/2021.

[10] Shapiro S. S. and Wilk M. B. (1965). An analysis of variance test for normality (complete samples). Biometrika, 52, 3 and 4, 591-611.

[11] Tabassi, E., Wilson, C., Watson, C.: Fingerprint Image Quality. NIST research report NISTIR7151. August, 2004. https://doi.org/10.6028/NIST.IR.7151. Retrieved 8/10/2022.

[12] Duong, Q. P. (1984). On The Choice of The Order of Autoregressive Models: A Ranking and Selection Approach. Journal of Time Series Analysis, 5(3), 145-157.

[13] "The Science of Fingerprints," Rev. 12-84, U.S. Department of Justice, Federal Bureau of Investigation. Available from U.S. Government Printing Office, Washington D.C. 20402.

[14] International Organization for Standardization, "Data elements and interchange formats - Information interchange - Representation of dates and times", ISO Standard 8601, December 2004.

Appendix A. List of Symbols, Abbreviations, and Acronyms

AIC
Akaike Information Criterion, an estimator of the quality of an information model

ANSI
American National Standards Institute

BSNR
Blind Signal to Noise Ratio

DUT(s)
Device(s) Under Test - where "device" is a specific combination of hardware and software comprising an acquisition system

FTIR
Frustrated Total Internal Reflection - optical principal employed by some fingerprint acquisition devices

NFRaCT
NIST Fingerprint Registration and Comparison Tool (software)

NIST
National Institute of Standards and Technology

ppi
Pixels per inch (the customary unit of sampling for digital fingerprints)

ppmm
Pixels per millimeter

RD
Reference Device - where "device" is a specific combination of hardware and software comprising an acquisition system that has already been certified and approved.

RMSD
Root-Mean-Squared Deviation (or Difference)

SIVV
Spectral Image Validation Verification