NIST Technical Note 2002

NIST Special Database 301

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National Institute of
Standards and Technology
U.S. Department of Commerce

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Walter Copan, NIST Director and Under Secretary of Commerce for Standards and Technology

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Abstract

In April 2017, the Intelligence Advanced Research Projects Activity (IARPA) held a dry run for the data collection portion of its *Nail to Nail (N2N) Fingerprint Challenge*. This data collection event was designed to ensure that the real data collection event held in September 2017 would be successful. To this end, real biometric data from unhabituated individuals needed to be collected. The National Institute of Standards and Technology (NIST), on behalf of IARPA, has released a dataset of the biometric images obtained during the N2N Fingerprint Challenge dry run data collection. The image distribution, entitled *Special Database 301 (SD 301)*, can be freely downloaded from the NIST website.

Key words

biometrics; data; devices; face; fingerprints; images; iris; latent.

Human Subjects Research

The National Institute of Standards and Technology Institutional Review Board reviewed and approved the protocol for this project and all subjects provided informed consent.

Acknowledgments

Data collections require the coordination and cooperation of countless individuals. Without each and every one of these people, this dataset would not have been possible.

- Thank you to the Intelligence Advanced Research Projects Activity for sponsoring the N2N Fingerprint Challenge and supporting advancements in fingerprint capture and recognition.
- Thank you to Rebecca Allegar, Nathaniel Short, and the many members of the Booz Allen Hamilton (BAH) team that helped IARPA create, organize, plan, and successfully execute the N2N Fingerprint Challenge dry run.
- Thank you to Arun Vemury, Jerry Tipton, and the rest of the Department of Homeland Security (DHS), DHS Maryland Test Facility (MdTF), and Martin Research and Consulting (MRAC) teams for graciously hosting the N2N Fingerprint Challenge dry run. These teams were instrumental in the design of the N2N Fingerprint Challenge data collection.
- Thank you to the *many* individuals from NIST, the Johns Hopkins University Applied Physics Laboratory (JHU APL), the United States Army Research Laboratory (ARL), the Federal Bureau of Investigation (FBI), DHS/MdTF, and Schwarz Forensic Enterprises (SFE) for providing biometric capture devices, operating them, and providing the images to NIST for public distribution.

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1. Introduction

In September 2017, the Intelligence Advanced Research Projects Activity (IARPA) held a fingerprint data collection as part of the *Nail to Nail (N2N) Fingerprint Challenge*, hosted by Johns Hopkins University Applied Physics Laboratory (JHU APL) [1]. During the event, participating Challengers deployed devices designed to collect an image of the full *nail to nail* surface area of a fingerprint—equivalent to a rolled fingerprint—from an unacclimated user without assistance from a trained operator. IARPA additionally provided for the capture of baseline operator-assisted rolled and plain fingerprints, as well as a robust elicitation and collection of latent fingerprints.

Challenge test staff determined that several hundred live human subjects would need to flow through the data collection in the time frame of a single work week in order to have enough data to confidently award the Challenge winners. To help answer many questions about feasibility and logistics, the Challenge test staff decided to hold a *dry run* of the data collection. The dry run was designed to mimic the full scope of full data collection. However, instead of capturing data for a full week, the dry run was conducted for half of one day. IARPA chose the DHS Maryland Test Facility (MdTF) to host and coordinate the dry run.

The dry run was held in April 2017, a full six months before Challengers were expected to have their prototype devices ready to be used. It was not reasonable to expect Challengers to travel to MdTF with early-stage prototypes for half of one day. Instead, Challenge test staff operated commercial off-the-shelf (COTS) biometric devices in place of the Challenger's prototypes.

It was still critical to collect data from unhabituated users instead of United States Government (USG) volunteers, to ensure that things like signage and verbal instructions from Challenge test staff were clear. This required human subject recruitment, and thus Institutional Review Board (IRB) oversight. Challenge test staff solicited permission from the IRB and the study participants to create a public dataset from the biometric data that was to be captured. The result is a new Special Database (SD) from the National Institute of Standards and Technology: SD 301.

`dryrun-A`	*FBI*	Crossmatch Guardian 300	`dryrun-B`	*FBI*	Crossmatch Guardian 300	`dryrun-C`	*MdTF*	Crossmatch Guardian 300
`dryrun-D`	*NIST*	EikonTouch 710	`dryrun-E`	*NIST*	Futronic FS88	`dryrun-F`	*MdTF*	Jenetric LIVETOUCH QUATTRO
`dryrun-G`	*MdTF*	Jenetric LIVETOUCH QUATTRO	`dryrun-H`	*NIST*	Crossmatch L SCAN 1000P	`dryrun-J`	*MdTF*	HID Lumidigm V302
`dryrun-K`	*NIST*	IDEMIA MorphoWave Desktop	`dryrun-L`	*MdTF*	AOS ANDI OTG 3.0	`dryrun-M`	*JHU APL*	Crossmatch Guardian 200
`dryrun-N`	*JHU APL*	HID Lumidigm V302	`dryrun-P`	*NIST*	Samsung Galaxy S6	`dryrun-R`	*JHU APL*	Iris ID IrisAccess 7000
`dryrun-S`	*JHU APL*	Canon EOS Rebel T6	`dryrun-T`	*ARL*	Polaris Sensor Technologies Vela	`dryrun-U`	*ARL*	Balser Scout scA640-70gm

Gender	Count
Male	24
Female	25
No Answer	2

Age	Count
21 to 30	17
31 to 40	15
41 to 50	7
51 to 60	10
No Answer	2

Occupation	Count
Manual Labor	11
Office Work	16
Other	13
No Answer	11

Table 1. A summary of genders, ages, and occupations of study participants whose biometrics were captured as part of the N2N Fingerprint Challenge dry run data collection.

2. Data Collection

The dry run was designed to be as similar as possible to the full N2N Fingerprint Challenge data collection, held at JHU APL. Refer to National Institute of Standards and Technology (NIST) Interagency Report 8210 [1] for in-depth details.

2.1 Facility

The MdTF is a facility originally designed as a controlled environment for operational testing of airport biometric entry and exit. All three bays of the facility were used, totaling approximately 10 000 square feet of floor space. Environmental factors in the facility were akin to an airport, with climate control, high ceilings, and fluorescent lighting. There were no windows in the facility.

2.2 Study Participant Population

Study participants were recruited by a third-party recruitment company, Martin Research and Consulting (MRAC), on behalf of MdTF. Study participants were required to have all 10 fingers imaged. Those with any amputated or bandaged fingers when arriving for the data collection were excluded. Study participants were required to be able to speak, read, and understand the English language, and have full mobility in their fingers, arms, and wrists. They also needed the ability to stand for the duration of the data collection, but were encouraged to sit when their interactions with a station were complete. A summary of genders, ages, and occupations of these study participants is shown in Table 1.

2.3 Baseline Data

In the full data collection, study participants needed to have their fingerprints captured using traditional operator-assisted techniques in order to quantify the performance of the Challenger devices. IARPA invited members of the Federal Bureau of Investigation (FBI) Biometric Training Team to the data collection to perform this task. Each study participant had N2N fingerprint images captured twice, each by a different FBI expert, resulting in two N2N *baseline* datasets.

To ensure the veracity of recorded N2N finger positions in the baseline datasets, Challenge test staff also captured plain fingerprint impressions in a 4-4-2 *slap* configuration. This capture method refers to simultaneously imaging the index, middle, ring, and little fingers on the right hand (4), then repeating the process on the left hand (4), and finishing with the simultaneous capture of the left and right thumbs (2). This technique is a best practice to ensure finger sequence order, since it is physically challenging for a study participant to change the ordering of fingers when imaging them simultaneously.

Operators at operator-assisted rolled and slap stations were given at most 5 min with each study participant, totaling 15 min of collection time per study participant dedicated to establishing a baseline dataset.

`dryrun-A`	*FBI*	Crossmatch Guardian 300	`dryrun-B`	*FBI*	Crossmatch Guardian 300	`dryrun-C`	*MdTF*	Crossmatch Guardian 300
`dryrun-D`	*NIST*	EikonTouch 710	`dryrun-E`	*NIST*	Futronic FS88	`dryrun-F`	*MdTF*	Jenetric LIVETOUCH QUATTRO
`dryrun-G`	*MdTF*	Jenetric LIVETOUCH QUATTRO	`dryrun-H`	*NIST*	Crossmatch L SCAN 1000P	`dryrun-J`	*MdTF*	HID Lumidigm V302
`dryrun-K`	*NIST*	IDEMIA MorphoWave Desktop	`dryrun-L`	*MdTF*	AOS ANDI OTG 3.0	`dryrun-M`	*JHU APL*	Crossmatch Guardian 200
`dryrun-N`	*JHU APL*	HID Lumidigm V302	`dryrun-P`	*NIST*	Samsung Galaxy S6	`dryrun-R`	*JHU APL*	Iris ID IrisAccess 7000
`dryrun-S`	*JHU APL*	Canon EOS Rebel T6	`dryrun-T`	*ARL*	Polaris Sensor Technologies Vela	`dryrun-U`	*ARL*	Balser Scout scA640-70gm

2.4 Challengers

Challenge test staff from N2N and other IARPA programs were asked to take the place of Challengers as device operators during the dry run. These Challenger surrogates were required to bring their own biometric devices and any software and hardware required to capture with the device. MdTF provided an application programming interface (API) to simplify data organization, but did not require its use for the dry run. Participating organizations were JHU APL, MdTF, and the United States Army Research Laboratory (ARL).

IARPA planned to host up to 12 Challengers in the full N2N Fingerprint Challenge, and so 12 Challenger surrogate stations were configured at MdTF. Each Challenger was given at most 5 min to interact with a study participant, totaling 60 min of collection time per study participant dedicated to Challenger surrogates. All devices used by Challenger surrogates were approved by the IRB and were all COTS products.

2.5 Latent Fingerprints

NIST partnered with the FBI and Schwarz Forensic Enterprises (SFE) to design activity scenarios in which subjects would likely leave fingerprints on different objects. The activities and associated objects were chosen in order to use a number of latent print development techniques and simulate the types of objects often found in real law enforcement case work.

For brevity, the activities and latent development techniques are not described in this document. Refer to Section 5 of NIST Interagency Report 8210 [1] for details.

SFE additionally conducted the latent print data collection for the N2N Fingerprint Challenge. Members of SFE instructed study participants to interact naturally with a variety of objects. SFE had 10 min to interact with each study participant. Not every study participant performed every activity, but the activities were distributed such that each study participant performed activities with similar characteristics.

2.6 Flow

One of the primary tasks of the dry run was to address the feasibility of the proposed flow of study participants. In total, study participants needed to make their way around to 16 stations (12 Challenger surrogates, 2 operator-assisted baseline rolls, 1 baseline slap, and 1 latent) before they could leave.

Study participants arrived at MdTF in groups of 17—one more subject than there were stations, to account for the duration of the latent collection. In a separate room, an IRB representative guided study participants through the informed consent process required before providing their biometric data. After all study participants in a group were consented, they were escorted into the data collection area. Inside, Challenge test staff paired with each study participant and accompanied them to their starting station. An announcement was made to begin, at which time a member of the Challenge test staff started a five min timer. After five min, study participants had one min to move to the next station, where the process would repeat. When each 100 min round of data collection had completed (15 stations of duration 5 min, 1 station of duration 10 min, and 15 transitions of duration 1 min), subjects were paid for their time and signed out of the facility.

In the single day of the dry run, three rounds of 17 study participants had data captured.

`dryrun-A`	*FBI*	Crossmatch Guardian 300	`dryrun-B`	*FBI*	Crossmatch Guardian 300	`dryrun-C`	*MdTF*	Crossmatch Guardian 300
`dryrun-D`	*NIST*	EikonTouch 710	`dryrun-E`	*NIST*	Futronic FS88	`dryrun-F`	*MdTF*	Jenetric LIVETOUCH QUATTRO
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`dryrun-K`	*NIST*	IDEMIA MorphoWave Desktop	`dryrun-L`	*MdTF*	AOS ANDI OTG 3.0	`dryrun-M`	*JHU APL*	Crossmatch Guardian 200
`dryrun-N`	*JHU APL*	HID Lumidigm V302	`dryrun-P`	*NIST*	Samsung Galaxy S6	`dryrun-R`	*JHU APL*	Iris ID IrisAccess 7000
`dryrun-S`	*JHU APL*	Canon EOS Rebel T6	`dryrun-T`	*ARL*	Polaris Sensor Technologies Vela	`dryrun-U`	*ARL*	Balser Scout scA640-70gm

3. Devices

Code	Operator	Friction Ridge Capture Device	Technology	Data
A	FBI	Crossmatch Guardian 300	Optical	10 rolled
B	FBI	Crossmatch Guardian 300	Optical	10 rolled
C	MdTF	Crossmatch Guardian 300	Optical	4-4-1-1 plain
D	NIST	Crossmatch EikonTouch 710	Solid-state	10 plain
E	NIST	Futronic FS88	Optical	10 plain
F	MdTF	Jenetric LIVETOUCH QUATTRO	Solid-state	4-4-1-1 plain
G	MdTF	Jenetric LIVETOUCH QUATTRO	Solid-state	4-4-2 plain
H	NIST	Crossmatch L SCAN 1000P	Optical	Palm, 4-4-2 plain
J	MdTF	HID Lumidigm V302	Optical	10 plain
K	NIST	IDEMIA MorphoWave Desktop	Touch-free	4-4-2 plain
L	MdTF	Advanced Optical Systems ANDI OTG 3.0	Touch-free	Right slap
M	JHU APL	Crossmatch Guardian 200	Optical	10 plain
N	JHU APL	HID Lumidigm V302	Optical	10 plain
P	NIST	Samsung Galaxy S6	Touch-free	4-4 plain

Table 2. Friction ridge capture technologies used during the N2N Fingerprint Challenge dry run.

Code	Operator	Iris Capture Device	Technology	Data
R	JHU APL	Iris ID IrisAccess 7000	Near infrared	Left and right irides

Table 3. Iris capture technologies used during the N2N Fingerprint Challenge dry run.

Code	Operator	Face Capture Device	Technology	Data
S	JHU APL	Canon Electro-Optical System (EOS) Rebel T6	Digital single-lens reflex	Still
T	ARL	Polaris Sensor Technologies Vela	Polarimetric Thermal	Still, Speech[1]
U	ARL	Basler Scout scA640-70gm	Area scan	Still, Speech[1]

Table 4. Face capture technologies used during the N2N Fingerprint Challenge dry run.

Tables [2–4] shows the friction ridge, face, and iris capture technologies used during the N2N Fingerprint Challenge dry run data collection. Plain, rolled, and touch-free impression fingerprints were captured from a multitude of devices, as well as a set of plain palm impressions. A single iris camera captured both left and right irides. Several kinds of camera technologies were employed to capture images of faces.

[1]No audio was recorded, only video of study participants talking.

4. Data

4.1 Operators

Devices `dryrun-A` and `dryrun-B` were operated by skilled device operators from the FBI. These operators were individuals who routinely interact with the public to facilitate biometric capture. All other devices were operated by employees from organizations involved in the N2N Fingerprint Challenge and other IARPA programs. Although these individuals are knowledgeable in the field of biometrics, efficient capture techniques, enrollment quality control, and public interaction are not necessarily a part of their professional responsibilities.

4.2 Fingerprint

A total of 15 fingerprint sensors were deployed during the data collection, amassing a series of rolled and plain images. It was required that devices `dryrun-A`, `dryrun-B`, and `dryrun-C` achieve 100 % acquisition rate, in order to verify the recorded friction ridge generalized positions (FRGPs) and study participant identifiers for other devices. There were no such requirements for Challenger devices. Not all devices were able to achieve 100 % acquisition rate.

4.2.1 Device Description

Although the underlying capture technology varies, interaction with nearly all devices was identical. For all devices except `dryrun-K`, `dryrun-L`, and `dryrun-P`, the study participant approached the device and physically touched 1 to 4 fingers to a platen. With devices `dryrun-K` and `dryrun-L`, the study participant instead passed their hand without contact through an opening in the capture system, and a photograph of the image was taken. With `dryrun-P`, an Android smartphone's camera was used to capture a photograph of the study participant's fingerprints.

All devices operated at 196.85 PPCM (500 PPI), except for `dryrun-H` (393.7 PPCM or 1 000 PPI) and `dryrun-P` (unknown). Properly downsampled versions [2] of `dryrun-H`'s images at 196.85 PPCM (500 PPI) are provided to maximize compatibility with algorithms designed around that resolution.

Two devices captured multiple encounters of the study participants during their collection time. `dryrun-H` captured images of traditional identification flats (FRGPs 13 to 15) and upper palms (FRGPs 26 and 28). `dryrun-P`'s first encounter captured study participant's fingerprints with the palmar surface of their hands facing toward the ceiling, hovering overtop of a waist-high brown table. The second encounter captured fingerprints with the palmar surface of the study participant's hands facing outward and their arms raised on either side of their body, adjacent to their ears. A gray fabric soundproofing barrier served as the backdrop for `dryrun-P`'s second encounter.

4.2.2 Ground Truth

To ensure the veracity of the recorded FRGPs of individual fingerprint captures, commercial feature extraction and matching algorithms were used. One-to-one matching of the segmented plain (FRGPs 11 to 15) captures was performed against all other fingerprint captures of the same subject. High-scoring non-mated pairs and low-scoring mated pairs in common between the majority of the algorithms were visually inspected to check for finger sequencing errors.

4.2.3 Image Quality

A cursory overview of the observed fingerprint quality from devices `dryrun-A` through `dryrun-P` are provided in Figs. [1–3] and Table 5. Fig. 1 shows a stacked bar graph of values of the original NIST Fingerprint

NFIQ 2.0	A	B	C	D	E	F	G	H_P	H_S	J	K	L	M	N	P_1	P_2
0 to 9	25	20	23	9	30	10	38	21	15	0	102	2	26	0	1	2
10 to 19	26	37	24	5	12	7	18	17	11	0	100	0	30	1	9	10
20 to 29	37	41	28	16	36	11	23	47	18	0	83	2	33	1	24	19
30 to 39	34	53	49	24	41	20	53	43	39	2	72	2	48	2	44	43
40 to 49	64	70	37	68	84	41	51	61	23	13	59	22	68	30	62	56
50 to 59	122	106	64	119	110	57	89	61	53	107	53	36	71	196	79	107
60 to 69	115	118	88	158	94	45	69	73	82	237	28	69	89	204	117	88
70 to 79	69	54	122	87	73	44	79	81	135	113	12	52	84	68	59	36
80 to 89	17	11	75	21	29	11	35	43	73	37	1	7	44	8	13	14
90 to 100	1	0	10	3	1	1	4	3	9	1	0	0	7	0	0	1

Table 5. Bins of NFIQ 2.0 values for friction ridge devices, separated by capture device. For devices that captured multiple fingers simultaneously, the fingerprint images were segmented and visually inspected before running NFIQ 2.0. Note that NFIQ 2.0 is an algorithm that has been trained on a specific type of data, which may not be the type of data created by all devices. Values depicted here for such unsupported devices should be considered unofficial.

Image Quality (NFIQ) algorithm [3], separated by device and FRGP. A series of violin plots of NFIQ 2.0 [4] values separated by device and FRGP are presented Fig. 2. A tabular version of this data with aggregate FRGPs can be seen in Table 5.

Of the 155 total quality features tested during development of the NFIQ 2.0 algorithm, minutiae counts were selected as one of the final 14 features incorporated into the overall quality score. The count of high-quality minutiae found for images in this dataset, as discovered by *FingerJet FX OSE* via NFIQ 2.0, are presented in Fig. 3. These values were derived by multiplying the `FingerJetFX_MinutiaeCount` NFIQ 2.0 feature value by the `FJFXPos_OCL_MinutiaeQuality_80` NFIQ 2.0 feature value.

In each plot, left and right FRGPs are adjacent to facilitate an easier visual comparison between left and right hands. It should be noted that both NFIQ algorithms are trained on and designed for particular kinds of fingerprint images. Not all fingerprint devices used in the data collection captured data that met this criteria, and so values depicted here for such unsupported devices should be considered unofficial.

`dryrun-H` captured data at 393.7 PPCM (1 000 PPI). Images from `dryrun-H` were downsampled to 196.85 PPCM (500 PPI) before running any image quality algorithms. Additionally, for all images depicting simultaneous finger captures (FRGPs 13, 14, 15, 26, and 28), the `nfseg` fingerprint segmenter, distributed with NIST Biometric Image Software (NBIS) [5], was used to create rectangular polygons around the 1 to 4 individual fingers present in the image. Each set of segmentation position coordinates was visually inspected for accuracy and adjusted if necessary. These coordinates were used by another tool, `slapcrop` [6], to segment the simultaneous captures into individual images. The coordinates are provided as part of SD 301.

Some image compression artifacts can be seen in a number of images operated by FBI and MdTF staff. Due to a software misconfiguration, a number of images were stored in Joint Photographic Experts Group (JPEG) format, rather than in an uncompressed encoding. JPEG makes use of a lossy compression algorithm that can disrupt the fidelity of the image. This was noted as a lesson learned in the dry run to avoid in the full N2N Fingerprint Challenge. Refer to Section 6 to learn more about this and other lessons learned.

4.3 Face

Face images from three different types of cameras were captured during the data collection. The dataset contains both still images, as well as a series of image frames captured during an oral exercise.

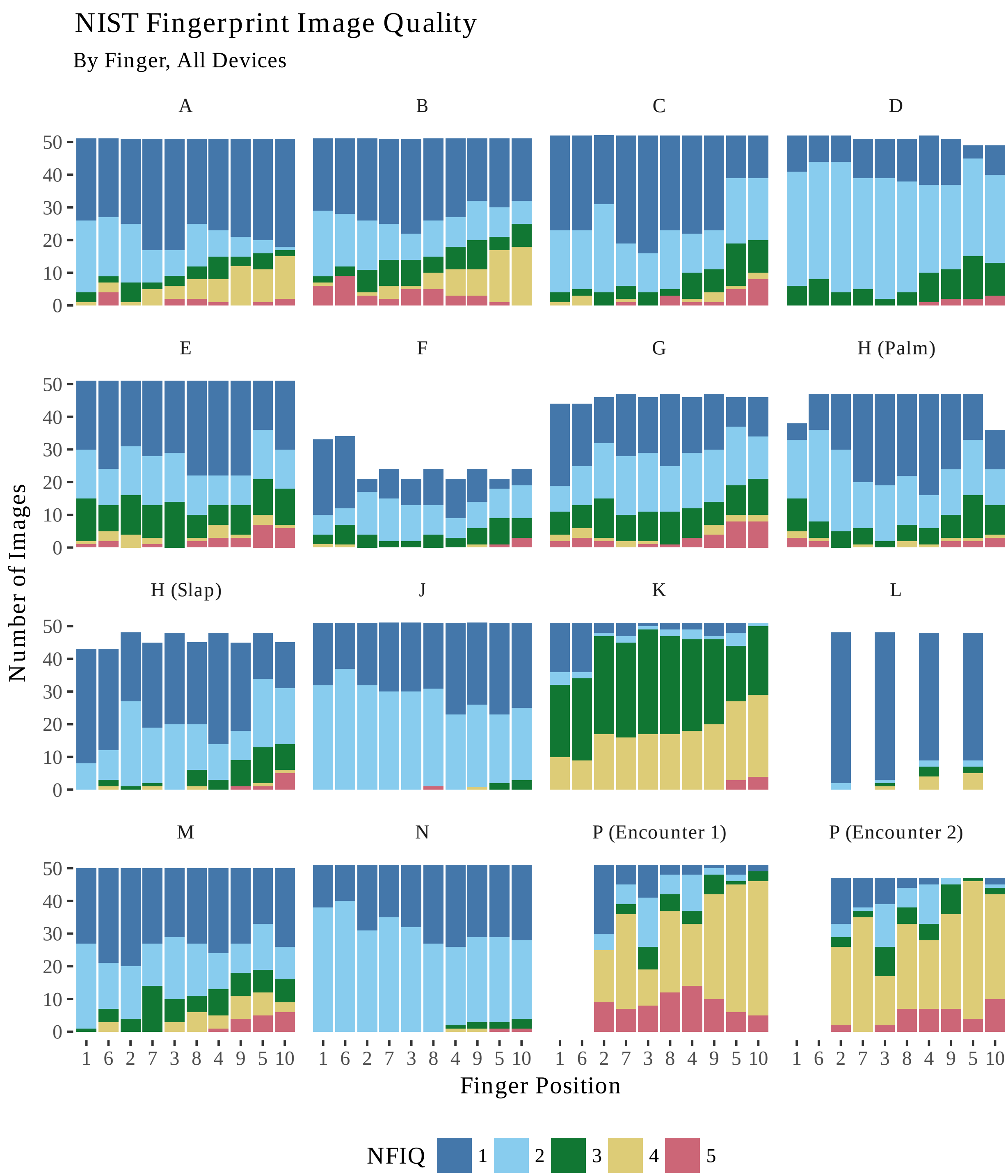

Fig. 1. Stacked bar plots of NFIQ values for friction ridge devices, separated by capture device and FRGP, with equivalent left and right FRGPs adjacent to each other. For devices that captured multiple fingers simultaneously, the fingerprint images were segmented and visually inspected before running NFIQ. Note that NFIQ is an algorithm that has been trained on a specific type of data, which may not be the type of data created by all devices. Values depicted here for such unsupported devices should be considered unofficial.

`dryrun-A`	*FBI*	Crossmatch Guardian 300	`dryrun-B`	*FBI*	Crossmatch Guardian 300	`dryrun-C`	*MdTF*	Crossmatch Guardian 300
`dryrun-D`	*NIST*	EikonTouch 710	`dryrun-E`	*NIST*	Futronic FS88	`dryrun-F`	*MdTF*	Jenetric LIVETOUCH QUATTRO
`dryrun-G`	*MdTF*	Jenetric LIVETOUCH QUATTRO	`dryrun-H`	*NIST*	Crossmatch L SCAN 1000P	`dryrun-J`	*MdTF*	HID Lumidigm V302
`dryrun-K`	*NIST*	IDEMIA MorphoWave Desktop	`dryrun-L`	*MdTF*	AOS ANDI OTG 3.0	`dryrun-M`	*JHU APL*	Crossmatch Guardian 200
`dryrun-N`	*JHU APL*	HID Lumidigm V302	`dryrun-P`	*NIST*	Samsung Galaxy S6	`dryrun-R`	*JHU APL*	Iris ID IrisAccess 7000
`dryrun-S`	*JHU APL*	Canon EOS Rebel T6	`dryrun-T`	*ARL*	Polaris Sensor Technologies Vela	`dryrun-U`	*ARL*	Balser Scout scA640-70gm

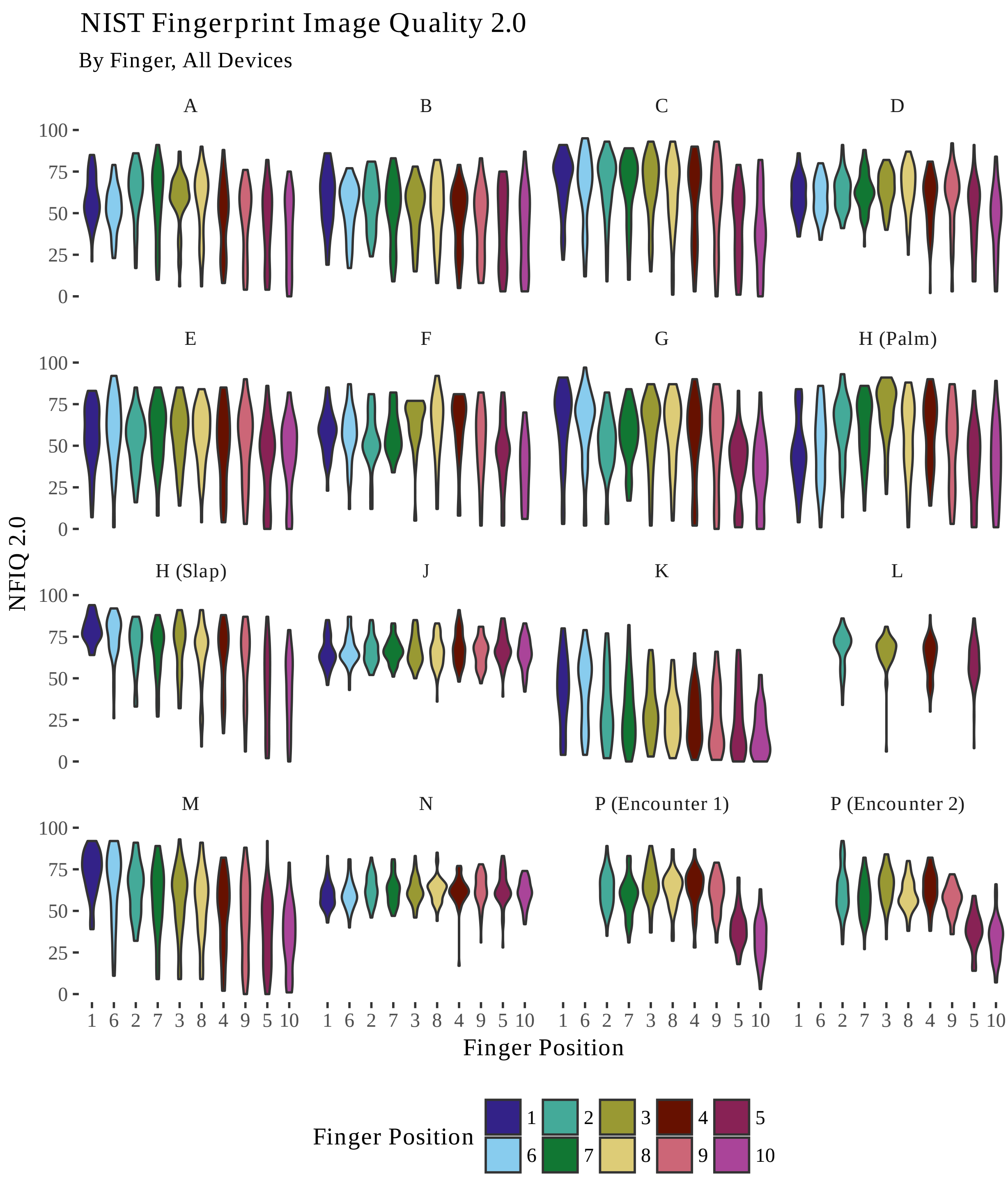

Fig. 2. Violin plots of NFIQ 2.0 values for friction ridge devices, separated by capture device and FRGP, with equivalent left and right FRGPs adjacent to each other. For devices that captured multiple fingers simultaneously, the fingerprint images were segmented and visually inspected before running NFIQ 2.0. Note that NFIQ 2.0 is an algorithm that has been trained on a specific type of data, which may not be the type of data created by all devices. Values depicted here for such unsupported devices should be considered unofficial.

`dryrun-A`	*FBI*	Crossmatch Guardian 300	`dryrun-B`	*FBI*	Crossmatch Guardian 300	`dryrun-C`	*MdTF*	Crossmatch Guardian 300
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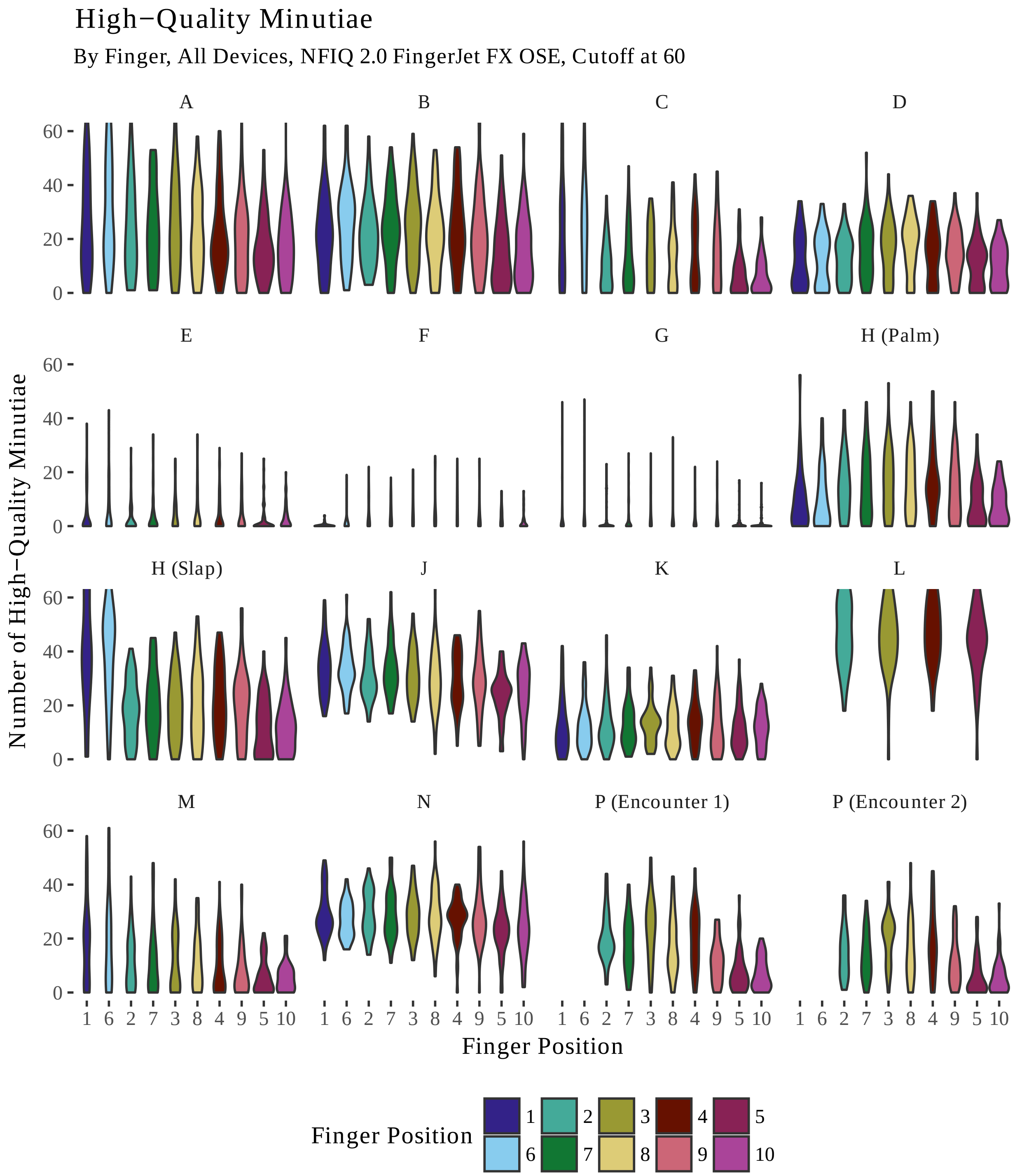

Fig. 3. Violin plots of high-quality minutia extracted by *FingerJet FX OSE* as part of NFIQ 2.0, separated by capture device and FRGP, with equivalent left and right FRGPs adjacent to each other. The charts show a maximum of 60 minutiae. For devices that captured multiple fingers simultaneously, the fingerprint images were segmented and visually inspected before running NFIQ 2.0. Note that NFIQ is an algorithm that has been trained on a specific type of data, which may not be the type of data created by a device. Values depicted here for such unsupported devices should be considered unofficial.

dryrun-A	*FBI*	Crossmatch Guardian 300	dryrun-B	*FBI*	Crossmatch Guardian 300	dryrun-C	*MdTF*	Crossmatch Guardian 300
dryrun-D	*NIST*	EikonTouch 710	dryrun-E	*NIST*	Futronic FS88	dryrun-F	*MdTF*	Jenetric LIVETOUCH QUATTRO
dryrun-G	*MdTF*	Jenetric LIVETOUCH QUATTRO	dryrun-H	*NIST*	Crossmatch L SCAN 1000P	dryrun-J	*MdTF*	HID Lumidigm V302
dryrun-K	*NIST*	IDEMIA MorphoWave Desktop	dryrun-L	*MdTF*	AOS ANDI OTG 3.0	dryrun-M	*JHU APL*	Crossmatch Guardian 200
dryrun-N	*JHU APL*	HID Lumidigm V302	dryrun-P	*NIST*	Samsung Galaxy S6	dryrun-R	*JHU APL*	Iris ID IrisAccess 7000
dryrun-S	*JHU APL*	Canon EOS Rebel T6	dryrun-T	*ARL*	Polaris Sensor Technologies Vela	dryrun-U	*ARL*	Balser Scout scA640-70gm

4.3.1 Ground Truth

Because of the relatively diminutive size of this dataset, the face images provided were groundtruthed by visual inspection of the two visible light spectra devices. No inconsistencies in study participant identifiers were observed. Polarimetric images from device `dryrun-T` were captured simultaneously with the visible light images from `dryrun-U`.

4.3.2 Capture Scenarios

The face data captured by `dryrun-S` is similar in content to traditional distributions of public face data. The face data captured by ARL is not. The system was configured to collect data from both `dryrun-T` and `dryrun-U` simultaneously, with frames from the two devices being synchronized to ≈50 ms. A set of neutral expression frames were captured of the study participants. Then, the study participants were asked to count from 1 to 10 out loud. For each study participant, 30 synchronized visible and polarimetric frames were extracted.

Each frame returned from `dryrun-T` comes in four variants, each referring to one of three Stokes parameters (S_0, S_1, S_2) or the Degree of Linear Polarization (DoLP) [7]. Data was provided to NIST as matrix laboratory (MATLAB) cell arrays of floating point pixel representations. NIST applied a median filter and exported these arrays as 16 bit grayscale images for simpler visualization. Comma-separated value (CSV) files of the untouched floating point values are also provided for researchers without MATLAB.

4.3.3 Device Descriptions

Canon EOS (`dryrun-S`)
A digital single-lens reflex camera with built-in flash capable of capturing ≈18 Mpixels. Exchangeable image file format (Exif) data with detailed information regarding each capture is provided.

Polaris Sensor Technologies Vela (`dryrun-T`)
A cooled long-wave infrared (LWIR) thermal imager using a division-of-time spinning achromatic retarder design for polarimetric imaging. The device captures at 30 frames/s in the 7.5 µm to 11.1 µm waveband, with a field of view of 10.6° × 7.9°.

Basler Scout scA640-70gm (`dryrun-U`)
A area-scan camera capable of capturing 12 bit color images at 70 frames/s. During the N2N Fingerprint Challenge dry run data collection, the device was operated at 35 frames/s, capturing images of size 640 pixels × 492 pixels at a depth of 8 bits per pixel.

4.4 Iris

A single iris camera, Iris ID's IrisAccess 7000, was used to capture iris data. This device uses near-infrared wavelength light to capture an image of the iris and the periocular region. The camera produces a grayscale image with dimensions of 640 pixels × 480 pixels.

As there was only a single near-infrared spectra capture of iris data, there was no established method to ensure the veracity of the study participant identifiers or eye positions. Anecdotally, a groundtruthed visible light spectra face image was taken during the same five min session where the iris data was captured, and so it can be assumed that study participant identifiers were recorded accurately.

5. Obtaining and Using Special Database 301

The dataset can be downloaded from the Internet for free by visiting our website, https://www.nist.gov/itl/iad/image-group/special-database-301. Before downloading, researchers must agree to the terms and conditions of SD 301 that are listed on the webpage.

Note that SD 301 is a series of distributions, each containing a logical subset of the N2N Fingerprint Challenge dry run data collection images. For instance, SD 301a contains only friction ridge imagery in Portable Network Graphics (PNG) encoding. A subset of study participant imagery has been held back for future NIST activities.

The directory structure of SD 301 after expanding the downloaded archive can be found in Figs. [4–6]. This directory structure was chosen to allow for NIST to easily deliver future versions of the same images in different file formats alongside the series of partial distributions that make up the entirety of SD 301.

The topmost directory contains a directory for each of the collection types (`face`, `friction-ridge`, `iris`, and `latent`). Collection type directories contain a directory for each capture device used. Inside each capture device directory are nested options for the file formats within.

5.1 Friction Ridge

Each file format directory contains a description of the data contained within, namely `palm`, `roll`, `slap`, and `segmented` captures. For those devices that captured at a resolution other than 196.85 PPCM (500 PPI), images resampled at 196.85 PPCM (500 PPI) are available.

Images files are contained in the deepest directory and are named in the form **`SUBJECT_ENCOUNTER_DEVICE_CAPTURE_RESOLUTION_FRGP.EXT`**, where:

`SUBJECT` Unique identifier for this study participant.

`ENCOUNTER` Encounter number for the study participant at this device.

`DEVICE` The short code used to refer to the device (Section 3).

`CAPTURE` The capture type characterized by the image. In the case of segmented images, the capture type characterized by the source image.

`RESOLUTION` The resolution of the image in PPI.

`FRGP` The ANSI/NIST-ITL 1-2011 Update:2015 friction ridge generalized position code (Table 6).

`EXT` File format extension.

For devices that images more than one finger in a simultaneous capture, a CSV file, `segmentation_`**`DEVICE_PPI`**`.csv`, is included, which contains the rectangular coordinates and rotation angle (in degrees) used to create the provided `segmented` images from the original simultaneous capture image.

5.2 Latent

A directory for `latent` fingerprints, although a capture of friction ridge information, is distributed as a separate collection type. Due to the quantity of images, latent fingerprints are separated by directory for each study participant identifier. Image names are in the form **`SUBJECT_ACTIVITY_HAND_ENCOUNTER_TECHNIQUE_DIGITIZER_RESOLUTION_DEPTH_CHANNELS_`**`LP`**`NUMBER_SOURCE.EXT`**, where:

`ACTIVITY` Activity performed to leave this latent impression. For a complete list of activities and their descriptions, refer to NIST Interagency Report 8210, Section 5.1 [1].

`HAND` **`L`** for left hand, **`R`** for right hand, or **`X`** if unknown.

`dryrun-A`	*FBI*	Crossmatch Guardian 300	`dryrun-B`	*FBI*	Crossmatch Guardian 300	`dryrun-C`	*MdTF*	Crossmatch Guardian 300
`dryrun-D`	*NIST*	EikonTouch 710	`dryrun-E`	*NIST*	Futronic FS88	`dryrun-F`	*MdTF*	Jenetric LIVETOUCH QUATTRO
`dryrun-G`	*MdTF*	Jenetric LIVETOUCH QUATTRO	`dryrun-H`	*NIST*	Crossmatch L SCAN 1000P	`dryrun-J`	*MdTF*	HID Lumidigm V302
`dryrun-K`	*NIST*	IDEMIA MorphoWave Desktop	`dryrun-L`	*MdTF*	AOS ANDI OTG 3.0	`dryrun-M`	*JHU APL*	Crossmatch Guardian 200
`dryrun-N`	*JHU APL*	HID Lumidigm V302	`dryrun-P`	*NIST*	Samsung Galaxy S6	`dryrun-R`	*JHU APL*	Iris ID IrisAccess 7000
`dryrun-S`	*JHU APL*	Canon EOS Rebel T6	`dryrun-T`	*ARL*	Polaris Sensor Technologies Vela	`dryrun-U`	*ARL*	Balser Scout scA640-70gm

ENCOUNTER A unique number to represent a particular encounter that was developed from this study participant and `ACTIVITY`.

TECHNIQUE The technique used to expose the print in this image. For a complete list of techniques and their descriptions, refer to NIST Interagency Report 8210, Section 5.2 [1]. This field is abbreviated, with **BP** meaning *black powder*, **IN** meaning *1,2-Indanedione*, **WT** and **BT** meaning *adhesive-side powder* (**w**hite and **b**lack, respectively), and **CA** meaning *cyanoacrylate*.

DIGITIZER The device used to digitize this image. For a complete list of devices and their descriptions, refer to NIST Interagency Report 8210, Section 5.3 [1]. Multiple flatbed scanners were used, indicated by **S#**. Only one piece of hardware was used for other digitization methods.

RESOLUTION The capture resolution of the image, in pixels per inch.

DEPTH The number of bits in a single color channel.

CHANNELS The number of color channels represented in a single pixel. **1** indicates grayscale and **3** represents color in a red, green, and blue arrangement.

NUMBER An identifier to represent an individual latent print of value from this `ENCOUNTER`.

SOURCE The likely source of the latent print, with **1** for distal phalanx, **2** for other phalanx, **3** for palm, and **4** for unknown.

5.3 Iris

Iris images are named similarly to friction ridge images, in the form **SUBJECT_ENCOUNTER_DEVICE_SIDE.EXT**, where:

SIDE **L** for the left iris and **R** for the right iris.

5.4 Face

Face images from the `dryrun-S` device are named in the form **SUBJECT_ENCOUNTER_DEVICE.EXT**. Images from `dryrun-T` and `dryrun-U` feature additional subdirectories to delineate between the baseline and oral counting sequence captures. Due to the number of files, the directory containing images from the oral counting sequence are further subdivided by Stokes parameters and DoLP, as detailed in Section 4.3.2. This data is also provided in CSV and MATLAB format. Images from the oral counting sequence are in the form **SUBJECT_ENCOUNTER_DEVICE_STOKES_FRAME.EXT**, where:

STOKES The Stokes parameter (**S#**) or Degree of Linear Polarization (**DoLP**).

FRAME Frame number of the sequence, from 1 to 30.

5.5 Validity

A CSV file, `checksum_`**DEVICE_EXT**`.csv`, accompanies every directory of images. Contained in this file are the Secure Hash Algorithm (SHA) 256 checksums of the files contained within the named directory.

```
images
└─ friction-ridge ........................................ Collection type
   ├─ dryrun-A ........................................... Device code (Section 3)
   │  └─ 500 ............................................. Resolution, in PPI
   │     └─ roll ......................................... Capture type
   │        ├─ png ....................................... Image format
   │        │  ├─ 00002223_01_dryrun-A_500_roll_01.png
   │        │  ├─ 00002223_01_dryrun-A_500_roll_02.png
   │        │  ├─ 00002223_01_dryrun-A_500_roll_03.png
   │        │  └─ . . .
   │        └─ checksum_dryrun-A_500_roll_png.csv ........ Image SHA 256 checksums
   ├─ . . .
   ├─ dryrun-H
   │  ├─ 1000
   │  │  ├─ palm
   │  │  │  ├─ png
   │  │  │  │  ├─ 00002223_01_dryrun-H_1000_palm_26.png
   │  │  │  │  ├─ 00002223_01_dryrun-H_1000_palm_28.png
   │  │  │  │  ├─ 00002225_01_dryrun-H_1000_palm_22.png
   │  │  │  │  └─ . . .
   │  │  │  ├─ checksum_dryrun-H_1000_palm_png.csv
   │  │  │  └─ segmentation_dryrun-H_1000_palm_png.csv ... Segmentation coordinates
   │  │  ├─ palm-segmented
   │  │  │  ├─ png
   │  │  │  │  ├─ 00002223_01_dryrun-H_1000_palm_02.png
   │  │  │  │  ├─ 00002223_01_dryrun-H_1000_palm_03.png
   │  │  │  │  ├─ 00002223_01_dryrun-H_1000_palm_04.png
   │  │  │  │  └─ . . .
   │  │  │  └─ checksum_dryrun-H_1000_palm-segmented_png.csv
   │  │  ├─ slap
   │  │  │  └─ . . .
   │  │  └─ slap-segmented
   │  │     └─ . . .
   │  └─ 500
   │     └─ . . .
   └─ . . .
└─ latent
   ├─ png
   │  ├─ 00002223 ........................................ Study participant identifier
   │  │  ├─ 00002223_1E_L_L01_BP_S04_1200PPI_8BPC_1CH_LP01_1.png
   │  │  ├─ 00002223_1E_L_L01_BP_S04_1200PPI_8BPC_1CH_LP03_1.png
   │  │  ├─ 00002223_1E_L_L01_BP_S04_1200PPI_8BPC_1CH_LP04_1.png
   │  │  └─ . . .
   │  └─ . . .
   └─ checksum_latent_png.csv
```

Fig. 4. Example directory listing of friction ridge and latent images in SD 301. For an explanation of filenames, refer to Section 5.

dryrun-A	*FBI*	Crossmatch Guardian 300	dryrun-B	*FBI*	Crossmatch Guardian 300	dryrun-C	*MdTF*	Crossmatch Guardian 300
dryrun-D	*NIST*	EikonTouch 710	dryrun-E	*NIST*	Futronic FS88	dryrun-F	*MdTF*	Jenetric LIVETOUCH QUATTRO
dryrun-G	*MdTF*	Jenetric LIVETOUCH QUATTRO	dryrun-H	*NIST*	Crossmatch L SCAN 1000P	dryrun-J	*MdTF*	HID Lumidigm V302
dryrun-K	*NIST*	IDEMIA MorphoWave Desktop	dryrun-L	*MdTF*	AOS ANDI OTG 3.0	dryrun-M	*JHU APL*	Crossmatch Guardian 200
dryrun-N	*JHU APL*	HID Lumidigm V302	dryrun-P	*NIST*	Samsung Galaxy S6	dryrun-R	*JHU APL*	Iris ID IrisAccess 7000
dryrun-S	*JHU APL*	Canon EOS Rebel T6	dryrun-T	*ARL*	Polaris Sensor Technologies Vela	dryrun-U	*ARL*	Balser Scout scA640-70gm

```
images
└── iris
    └── dryrun-R
        ├── png
        │   ├── 00002223_01_dryrun-R_L.png
        │   ├── 00002223_01_dryrun-R_R.png
        │   ├── 00002223_01_dryrun-R_L.png
        │   └── . . .
        └── checksum_dryrun-R_png.csv
```

Fig. 5. Example directory listing of iris images in SD 301. For an explanation of filenames, refer to Section 5.

```
images
└── face
    ├── . . .
    ├── dryrun-T
    │   ├── csv
    │   │   ├── baseline ........................................ Mugshot captures
    │   │   │   ├── 00002223 ............................ Study participant identifier
    │   │   │   │   ├── 00002223_01_dryrun-T_DoLP.csv
    │   │   │   │   ├── 00002223_01_dryrun-T_S0.csv
    │   │   │   │   └── . . .
    │   │   │   └── . . .
    │   │   ├── sequence ............................ Oral counting sequence captures
    │   │   │   └── 00002223
    │   │   │       ├── DoLP ............................ Stokes parameter or DoLP
    │   │   │       │   ├── 00002223_01_dryrun-T_DoLP_01.csv
    │   │   │       │   ├── 00002223_01_dryrun-T_DoLP_02.csv
    │   │   │       │   └── . . .
    │   │   │       └── . . .
    │   │   ├── checksum_dryrun-T_csv_baseline_face.csv
    │   │   └── checksum_dryrun-T_csv_sequence_face.csv
    │   ├── matlab
    │   │   └── . . .
    │   └── png
    │       └── . . .
    └── . . .
```

Fig. 6. Example directory listing of face images in SD 301. For an explanation of filenames, refer to Section 5.

FRGP	Description
1	Right Thumb
2	Right Index
3	Right Middle
4	Right Ring
5	Right Little
6	Left Thumb
7	Left Index
8	Left Middle
9	Left Ring
10	Left Little

FRGP	Description
11	Plain Right Thumb
12	Plain Left Thumb
13	Plain Left Four Fingers
14	Plain Right Four Fingers
15	Left and Right Thumbs

FRGP	Description
22	Right Writer's Palm
24	Left Writer's Palm
25	Right Lower Palm
26	Right Upper Palm
27	Left Lower Palm
28	Left Upper Palm

Table 6. Friction ridge generalized position values, reproduced from ANSI/NIST-ITL 1-2011 Update:2015, Table 9 [8].

dryrun-A	*FBI*	Crossmatch Guardian 300	dryrun-B	*FBI*	Crossmatch Guardian 300	dryrun-C	*MdTF*	Crossmatch Guardian 300
dryrun-D	*NIST*	EikonTouch 710	dryrun-E	*NIST*	Futronic FS88	dryrun-F	*MdTF*	Jenetric LIVETOUCH QUATTRO
dryrun-G	*MdTF*	Jenetric LIVETOUCH QUATTRO	dryrun-H	*NIST*	Crossmatch L SCAN 1000P	dryrun-J	*MdTF*	HID Lumidigm V302
dryrun-K	*NIST*	IDEMIA MorphoWave Desktop	dryrun-L	*MdTF*	AOS ANDI OTG 3.0	dryrun-M	*JHU APL*	Crossmatch Guardian 200
dryrun-N	*JHU APL*	HID Lumidigm V302	dryrun-P	*NIST*	Samsung Galaxy S6	dryrun-R	*JHU APL*	Iris ID IrisAccess 7000
dryrun-S	*JHU APL*	Canon EOS Rebel T6	dryrun-T	*ARL*	Polaris Sensor Technologies Vela	dryrun-U	*ARL*	Balser Scout scA640-70gm

6. Lessons Learned

One of the goals of holding a dry run for the N2N Fingerprint Challenge data collection was to ensure that the full data collection could be successfully completed without any major setbacks. The dry run helped identify several issues that were corrected for the full data collection. Many of the lessons learned affected the data being distributed in SD 301.

4-4-2 Slap Configuration

Although it had been discussed to collect slap fingerprint images to facilitate groundtruthing of the rolled fingerprint images, it was not explicitly stated that the configuration should be 4-4-2. The slap fingerprint station operator collected fingerprints in a 4-4-1-1 configuration, where the two thumbs are captured sequentially, not simultaneously. This introduces a scenario where the left and right thumbs could be labeled incorrectly, affecting the overall validity of the friction ridge dataset.

Luckily, a different dry run operator captured slap fingerprints in a 4-4-2 configuration for most study participants at their station, so thumb position validation could still take place.

Duration of Latent Fingerprint Capture

It was immediately evident that the number of activities performed by study participants requiring interaction with the glass table top would need to be reduced. While performing the activities was fast, the time required for the certified latent print examiners (CLPEs) from SFE to develop the prints with black powder and prepare the station for the next study participant was grossly underestimated. Within a few iterations of collection, the number of glass activities performed was decreased and supervisory staff were recruited to assist in station cleanup.

For the full data collection it was decided to add additional latent collection stations, reduce the number of glass activities, and provide dedicated personnel for station preparation and cleanup.

Time and Distance Between Stations

One min was provided for study participants to navigate between the 16 capture stations. At MdTF, capture stations were arranged in a semicircle, making the distance between all but one station very short. Even the slowest walkers were able to navigate between the two furthest stations within $\approx$20 s. Before starting the capture process, study participants started $\approx$13 m from Challenger surrogates. Study participants were not permitted to bring items to occupy their time, such as cell phones or magazines. The result is that study participants became increasingly lethargic and irritable between stations with nothing to do and no one to talk to. This short-term boredom may have affected the study participant's willingness to participate fully as they progressed through the data collection stations.

Although the layout and host facility changed for the full data collection, the time between stations was still reduced by 30 s. This shortened each day of the full N2N Fingerprint Challenge data collection by nearly 30 min and prevented nearly all study participant idle time. Although they were still not allowed to bring outside items during the full test, study participants were located immediately in front of Challengers and other Challenge test staff while waiting to begin collection. This resulted in many study participants engaging in friendly conversation during the remainder of the 30 s not used to transition stations, while Challenge test staff remained respectful the rules of human subjects research.

Image Compression

Friction ridge images should be stored digitally in a representation that mimics the arrangement of pixels returned from a sensor. Due to a software misconfiguration, a significant number of friction ridge sensors used during the dry run data collection saved images in JPEG, a image encoding that uses lossy compression. For the full data collection, it was required that all image data be encoded in PNG, a lossless image encoding. It was further specified that images not in PNG would not be used during analysis, and so it was in the best interest of the Challengers to ensure their images were returned as PNG.

References

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