NIST Technical Note
NIST TN 2367

NIST Special Database 302

Annotated Latent Distal Phalanxes

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Abstract

National Institute of Standards and Technology (NIST) Special Database 302 contains 10 000 latent impression distal phalanx images. This collection of data came from the Intelligence Advanced Research Projects Activity's Nail to Nail Fingerprint Challenge. NIST worked with Certified Latent Print Examiners to annotate these images with features (e.g., minutiae, orientation, ridge quality maps) and determine their ground truth finger positions. The fully-annotated collection of data is made freely available for research purposes.

Keywords

biometrics; extended feature set; fingerprints; images; latent.

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Acknowledgments

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Author Contributions

Gregory Fiumara: conceptualization, data curation, funding acquisition, methodology, software, writing — original draft. **Matthew Schwarz**: conceptualization, data curation, investigation, methodology, validation. **Jessica Heising**: data curation, investigation. **Jennifer Peterson**: data curation, investigation. **Kenneth Ko**: software, data curation. **Patricia Flanagan**: software, data curation. **Karen Marshall**: resources.

1. Introduction

National Institute of Standards and Technology *Special Database (SD) 302* [1, 2] is a collection of friction ridge images collected during the Intelligence Advanced Research Projects Activity (IARPA)'s *Nail to Nail (N2N) Fingerprint Challenge*. The dataset has been updated several times since its initial release in December 2019. The first release contained plain and rolled impression exemplar fingerprint images from 200 study participants. Each study participant was imaged by numerous capture devices. In addition, 50 latent impression distal phalanx images left by each study participant were included.

NIST began working with certified latent print examiners (CLPEs) to annotate those 10 000 latent impression distal phalanx images, as well as to determine their ground truth finger positions. This process was time and resource intensive, taking several years to complete. In November 2021, NIST released around half of the CLPE-annotated images [3]. As of this publication, the remainder of the 10 000 latent impression distal phalanx images in SD 302 have been annotated and are available.

Taking advantage of this second supplemental release, NIST has made other additions to SD 302 to help provide the research community with frequently requested resources. Today, SD 302 consists of the following datasets, referred to as SD 302a–i:

- **SD 302a**: challenger rolled-equivalent friction ridge images
- **SD 302b**: baseline operator-assisted rolled fingerprint impressions and 4-4-2 slap impressions
- **SD 302c**: palm images and fingerprint images segmented from upper palms
- **SD 302d**: plain fingerprint images collected by auxiliary devices
- **SD 302e**: latent impression distal phalanx images at native resolution
- **SD 302f**: unprocessed photographs collected by Challenger T's prototype device
- **SD 302g**: annotation records of exemplar fingerprint images from SD 302b
- **SD 302h**: annotation records of latent impression distal phalanx images from SD 302e
- **SD 302i**: records of minutiae correspondence between SD 302g and SD 302h

2. Annotations and Adjustments

NIST researchers continued to use services from CLPEs to perform the necessary annotation activities for the final 81 study participants in SD 302 that were not released in the initial SD 302 supplement, described in *NIST Technical Note (TN) 2190* [3]. As detailed in that document, for all 200 study participants, CLPEs were asked to:

- manually label all features required by Extended Feature Set (EFS) Profile 2 [4] on 10 rolled exemplar fingerprint and 50 latent impression distal phalanx images
- determine ground truth finger position for each of the latent impression distal phalanx images
- link sufficient corresponding minutiae from latent impression distal phalanx images to a ground truth source exemplar image

2.1. Ridge Quality Map

Not all pixels in a latent impression distal phalanx image are of equal quality. Best practices for friction ridge analysis suggest documentation of the quality of features being annotated [5]. At each location in the image, examiners should document the reliability of reproduction of the friction ridge features observed. Given this best practice, NIST instructed CLPEs to produce this documentation for all SD 302 latent impression distal phalanx images.

This documentation is provided in terms of a *ridge quality map*, as defined in *NIST Special Publication (SP) 500-290e3* [6]. Each pixel in the image is binned into 1 of 6 categories. Each category also corresponds to a color that can be non-destructively superimposed on the latent impression distal phalanx image alongside other annotations to guide an examiner. The categories are:

0. black (or clear): background
1. red: debatable ridge flow
2. yellow: definitive ridge flow, questionable minutiae
3. green: definitive minutiae, questionable ridge edges
4. blue: definitive ridge edges, questionable pores
5. aqua: all features definitive

An example of a ridge quality map from SD 302 is shown in Fig. 1. Ridge quality map information is stored in fields 9.308–9.309 for all records in SD 302h, including those from the previous supplement.

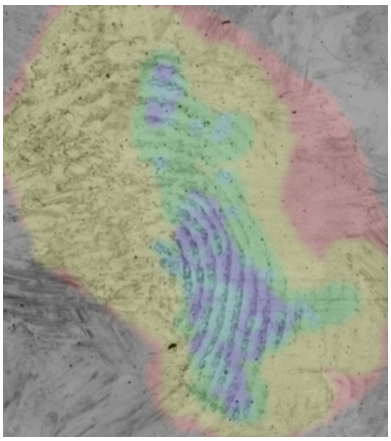

Fig. 1: A latent impression distal phalanx image with ridge quality map color values superimposed. Source: SD 302h.

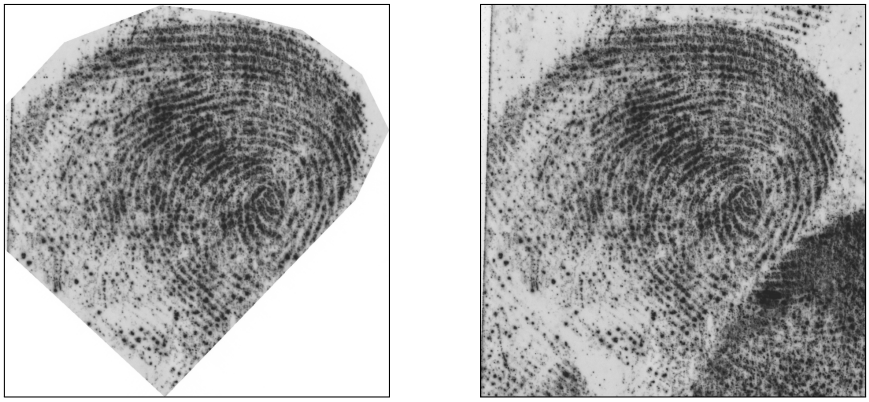

Fig. 2: A latent impression distal phalanx image with pixels outside the region of interest masked in white (left) and unmasked (right), each with a solid black border indicating the image bounds. Source: SD 302e.

2.2. Region of Interest Masking

CLPEs annotated regions of interest in all latent impression distal phalanx images present in SD 302. These regions of interest were used to create the resulting images in SD 302e and SD 302h–i. In the previous releases of SD 302, NIST opted to mask the area outside of the region of interest with white pixels. NIST received feedback that it would be useful to have the full, unmasked image. SD 302e and SD 302h–i have been updated to include both masked and unmasked versions of these images. An example of the same image masked and unmasked can be seen in Fig. 2. Note that unmasked versions may contain friction ridge information for other finger positions from the same study participant.

3. Statistics

The data in this release of SD 302g–i encompasses data from 200 study participants. This document continues the work of *NIST TN 2190* in gleaning insights about the nature of the latent impression distal phalanx images in SD 302.

3.1. Overall

There are 10 092 latent impression distal phalanx annotation records released as part of SD 302h, encompassing 200 study participants. This accounts for 50 latent impression distal phalanx images per subject, with 65 images removed due to labeling errata and 102 images depicting multiple distinct impressions that were annotated individually. 4 666 (46 %) have a CLPE-verified source determination, within 1 percentage point of the value noted in *NIST TN 2190*.

3.2. Sufficiency of Baseline Exemplar Set

The baseline exemplar set is a set of ten rolled impression fingerprint images for each subject captured by an expert, all captured using the same fingerprint capture device. CLPEs first attempted to use this set of exemplar fingerprint images to find the source of the latent impression distal phalanx images. If there was not enough overlapping region in the baseline exemplar set to determine the source, or if the quality of the overlapping region was too low, CLPEs looked to other sets of exemplar fingerprints captured on other capture devices[1].

For the source determinations that were completed, an additional 381 exemplar fingerprint images needed to be investigated, above and beyond the 2 000 of the baseline exemplar set. These exemplar images are spread across the dataset, with 133 (67 %) study participants requiring at least 1 additional exemplar image to determine ground truth, and 20 (10 %) requiring at least 5 more exemplar images. That means for 1 in 10 study participants, CLPEs increased their exemplar workload by 50 % to find the source of a latent impression distal phalanx image. Multiple sets of exemplar images are not always present in typical casework or searchable with Automated Fingerprint Identification Software (AFIS), making quality and completeness of exemplars of the utmost importance.

3.3. Examiner Analysis Assessment

CLPEs performed an initial assessment of the value of each latent impression distal phalanx image. This assessment helped determine if it would be possible to find the ground truth source exemplar fingerprint image. The assessment guidelines and codes used were that of

[1] Looking to exemplars outside of the baseline exemplar set was not in the statement of work for 37 of the 200 study participants.

CLPE Analysis Assessment	Quantity	Percent
Value	3 815	37.8
Limited	1 639	16.3
No Value	4 636	45.9
Not a Print	2	0.0

Table 1: Summary of the examiner analysis assessment values of latent impression distal phalanx images observed in SD 302h.

Pattern Classification	Female (%)	Male (%)
Arch	8.8	6.9
Left Loop	28.5	31.4
Right Loop	31.9	30.9
Whorl	29.9	30.0
Unclassifiable	0.9	0.8

Table 2: Summary of the pattern classifications of exemplar fingerprints observed in SD 302g.

NIST SP 500-290e3, Table 61. Over the duration of work annotating these images, the fingerprint community has accepted a new best practice for assessment of *utility* [5]. To maintain consistency throughout the entire dataset, as well as to best support interoperable exchange of this data in Electronic Biometric Transmission Specification (EBTS) [7] records, NIST opted to retain the original assessment guidelines and codes from *NIST SP 500-290e3*. A summary of examiner analysis assessment values can be seen in Table 1.

3.4. Pattern Classification

One of the basic features annotated by CLPEs was classifying the pattern of the exemplar fingerprints. That information has been combined with the reported sex of the study participants in Table 2. The overall reported female population was 65 % [8].

3.5. Minutiae Count

A summary of the quantity of minutiae types observed by CLPEs is shown in Table 3. For latent impression distal phalanx images, it is also useful to look at the minutiae counts per examiner analysis assessment level (Section 3.3), as shown in Table 4.

3.6. Comparison to Algorithms

NIST TN 2190 made several comparisons between features discovered by CLPEs and a commercial off-the-shelf (COTS) AFIS. Since that publication, AFIS products have rapidly ad-

	Exemplar		Latent	
	Mean	Median	Mean	Median
Minutiae	112.4	107	9.4	4
Cores	1.1	1	0.3	0
Deltas	0.0	0	0.0	0

Table 3: Summary of minutiae counts for exemplar and latent fingerprint images from SD 302 as observed by CLPEs.

	Number of Minutiae	
Examiner Analysis Assessment	Mean	Median
Value	21.7	17
Limited	5.2	5
No Value	0.8	0

Table 4: Summary of minutiae counts in latent impression distal phalanx images from SD 302 as observed by CLPEs, separated by examiner analysis assessment.

vanced, as measured by NIST's Evaluation of Latent Friction Ridge Technology (ELFT) program [9]. This analysis would need to be repeated with a modern version of the AFIS to be reasonable. However, this is no longer prudent. For one, SD 302 is known to be training data for the current generation of AFIS algorithms, which would bias results. Additionally, ELFT testing has shown that many of the top-performing AFIS algorithms do not use (or do not report) traditional fingerprint features, such as minutiae.

4. Obtaining and Using Special Database 302

The datasets can be downloaded by researchers via the Internet for free by visiting the website https://fingerprint.nist.gov/datasets. Before downloading, researchers must agree to the terms and conditions that are listed on the web page. Upon approval, a unique, time-sensitive URL is e-mailed to the requester for download.

Note that SD 302 is a series of distributions, each containing a logical subset of the N2N Fingerprint Challenge data collection images and CLPE-annotated records. For instance, SD 302a contains only exemplar friction ridge imagery in Portable Network Graphics (PNG) encoding as generated by the Challengers. A description of subsets is available on the SD 302 website. The annotations mentioned in this document are part of the distributions named SD 302g–i.

The directory structure of the files in this distribution is largely the same as documented in *NIST TN 2190*, with the exception of new `masked` and `unmasked` directories in SD 302e and SD 302h–i. These directories correspond to whether the latent impression distal phalanx image has pixels outside of the region of interest masked with white (Section 2.2). An example directory structure for SD 302h and SD 302i with this change is shown in Fig. 3 and Fig. 4. Information about file naming and the other SD 302 distributions is thoroughly documented in previous publications [1, 3] and is not duplicated here.

4.1. Validity

A comma-separated value (CSV) file, `checksum_latent_EXT[_COLOR_MASK].csv`, accompanies every directory of files. Contained in this file are the Secure Hash Algorithm (SHA) 256 checksums of the files contained within the named directory. Additionally, all image types contained within EBTS records have the optional *hash* field (i.e., `13.996` and `14.996`) containing the SHA 256 checksum of the embedded image data.

4.2. Tools

A variety of software tools exist for parsing EBTS and other record types conformant to *NIST SP 500-290e3*. NIST distributes the source code to `an2ktool` and `an2k2txt` as part of its NIST Biometric Image Software (NBIS) package [10]. NIST also distributes Biometric Evaluation framework, a software library which, in part, allows parsing of records in C# [11]. These tools are all capable of processing the EBTS records contained within SD 302.

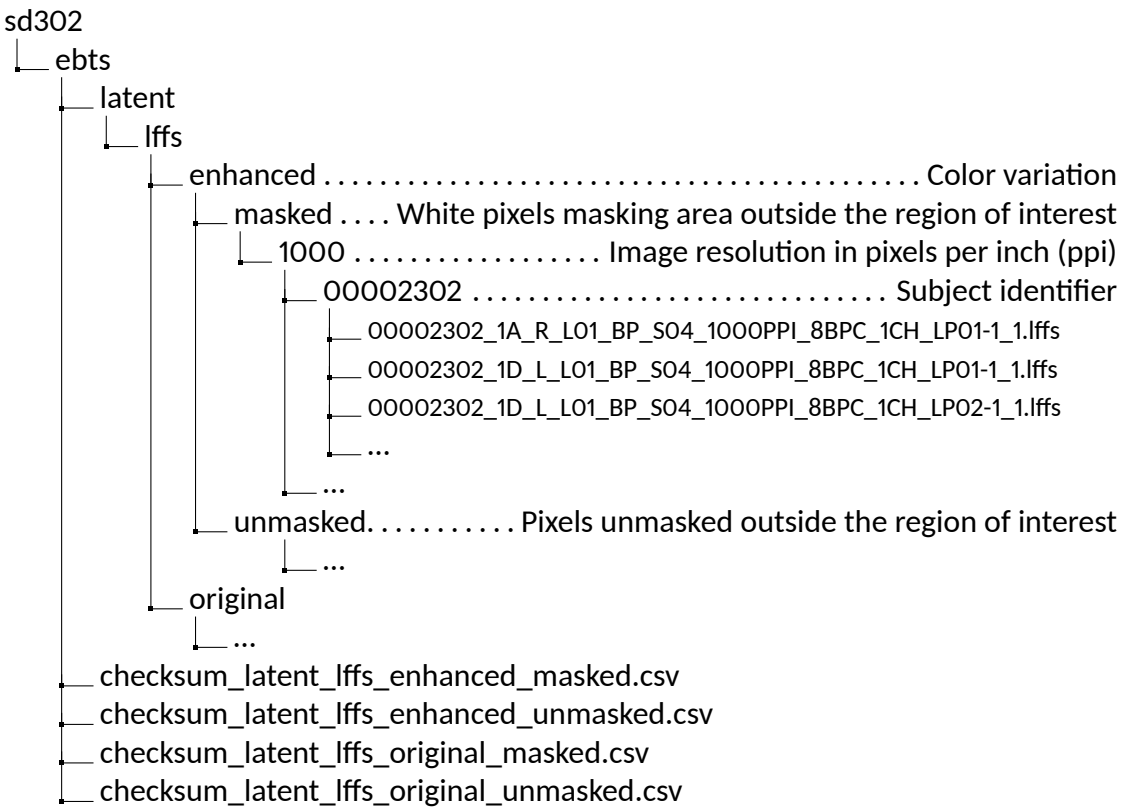

Fig. 3: Example directory structure of SD 302h.

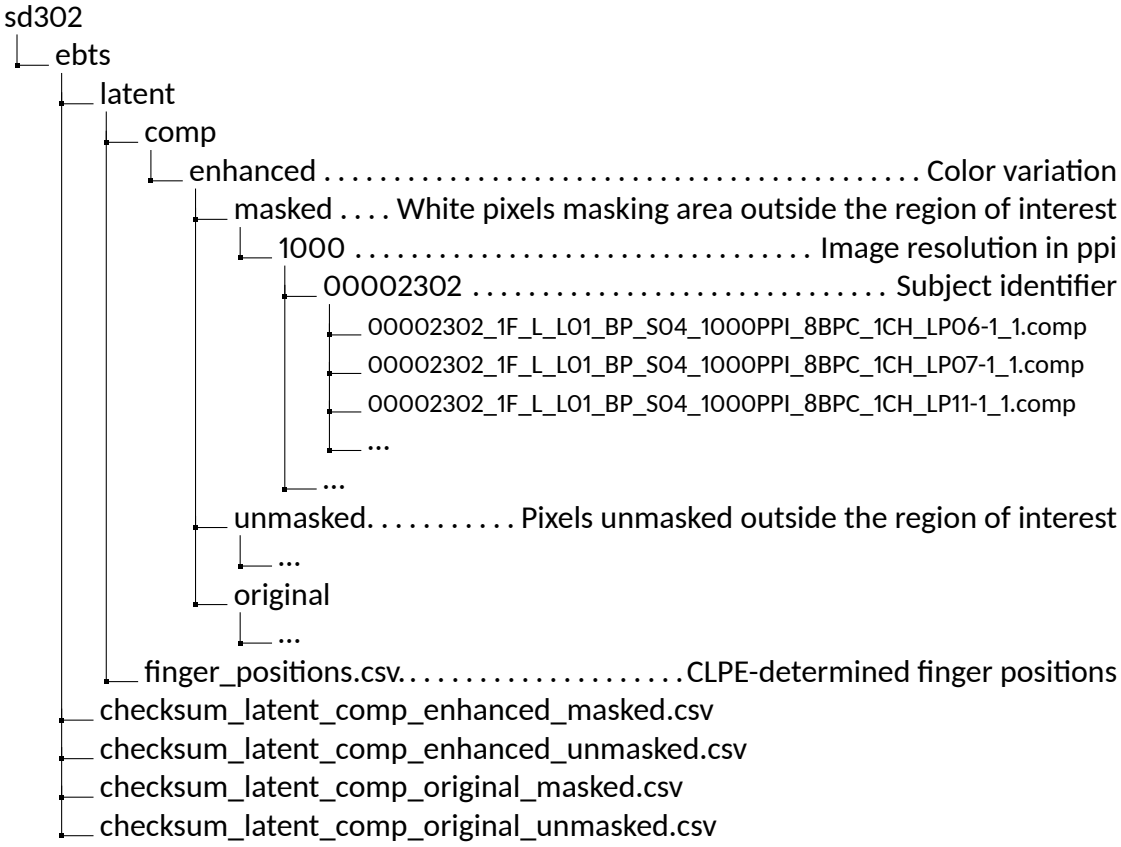

Fig. 4: Example directory structure of SD 302i.

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