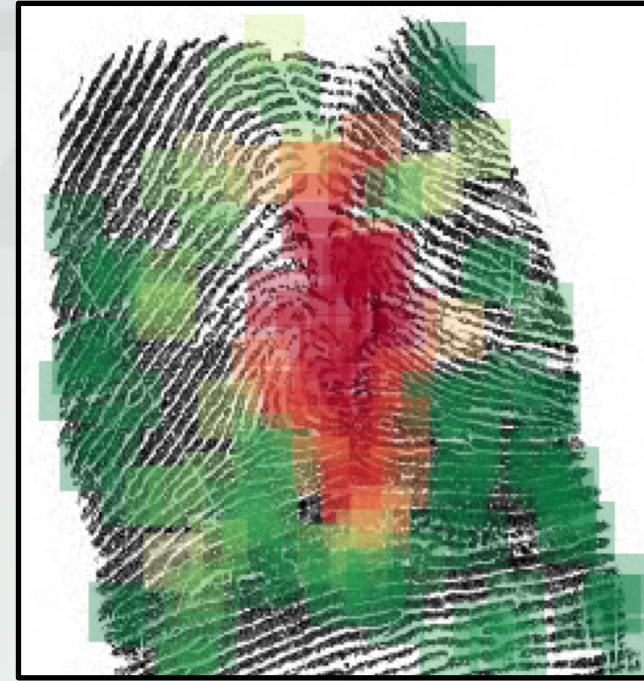# Altered Fingerprints: Detection and Localization

Elham Tabassi, **Tarang Chugh**, Debayan Deb, Anil K. Jain

Dept. of Computer Science & Engineering
Michigan State University

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Altered Fingerprints

Intentional destruction of friction ridge structures to obfuscate the true identity

Transplanted from Foot

Burnt with Acid

Fingerprint Alteration Cases

In 2009, a Chinese woman underwent a surgery to alter her fingerprints in order to deceive the immigrant fingerprint system in Japan

All foreigners are fingerprinted when they arrive in Japan. [1]

Some asylum seekers to EU, torch skin off their fingertips so they can not be identified by AFIS (EURODAC)

Eduardo Ravelo, part of FBI's top-10 most wanted list (2017), is believed to have had a plastic surgery and altered his fingerprints to evade authorities [2]

[1] http://news.bbc.co.uk/2/hi/asia-pacific/8400222.stm
[2] https://www.businessinsider.com/fbi-10-most-wanted-criminals-list-2017-11

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Previous Approaches

Study	Method	Altered Fingerprint Dataset	Performance
Feng, Jain, and Ross, 2010	Orientation Field	1,976 simulated altered fingerprints	TDR = 92% @ FDR = 7%
Tiribuzi et al., 2012	Minutiae density maps, orientation entropies	1,000 genuine and synthetic altered fingerprints	Avg. Accuracy = 90.4%
Yoon et al. [2012, 2013]	Orientation field, minutiae distribution	4,433 operational altered fingerprints	TDR = 70.2% @ FDR = 2.1%
Ellingsgaard and Busch, [2014, 2017]	Orientation field, minutiae orientation	116 altered fingerprints	TDR = 92% @ FDR = 2.3%

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Altered Fingerprint Dataset

- 4,815 operational altered fingerprints (635 tenprint cards of 270 subjects)

- # Tenprint cards/subject: 1 to 16 (multiple encounters)

- # Altered fingerprint instances/subject: 1 to 137

- 4,815 operational valid fingerprints

- 5-fold cross-validation employed
  - Training: 3,852 altered / 3,852 valid fingerprints
  - Testing : 963 altered / 963 valid fingerprints

	Valid	Altered
Train	NFIQ2.0 = 64	NFIQ2.0 = 7
Test	NFIQ2.0 = 76	NFIQ2.0 = 12

Altered Fingerprint Detection

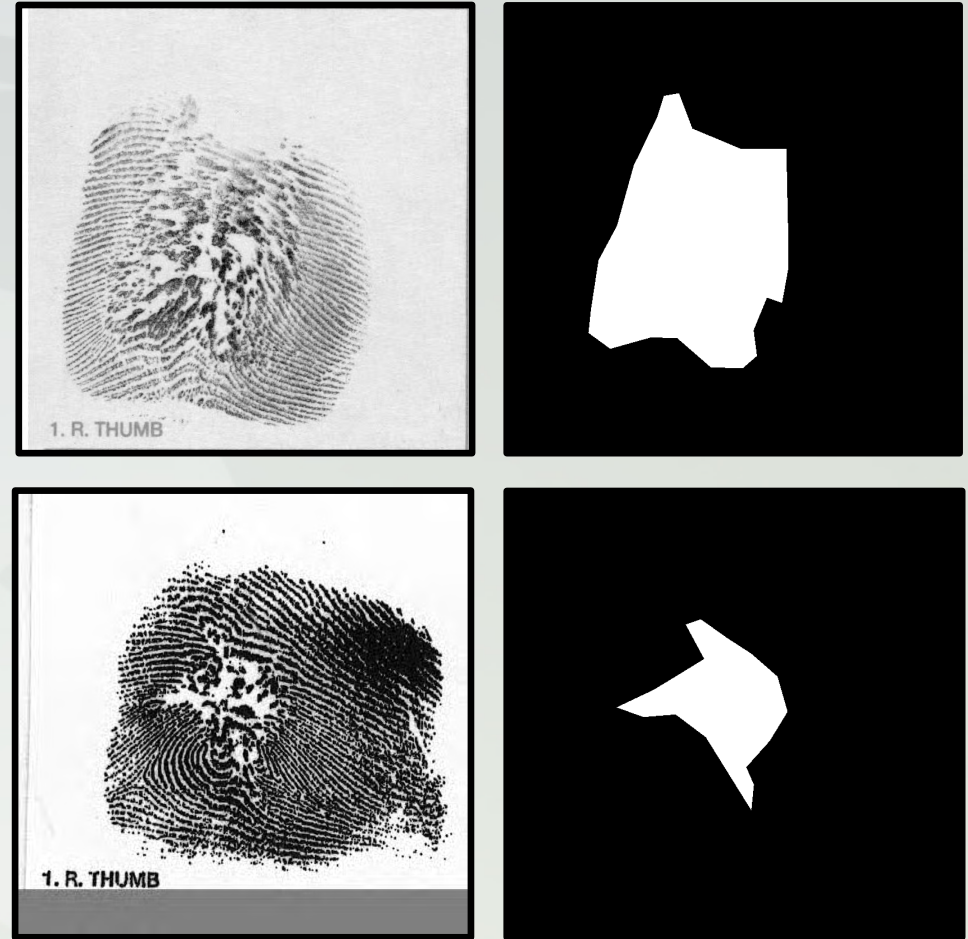- Fingerprint alteration classes based on alteration procedure:
  - **Obliteration**: abrading, cutting, burning, etc.
  - **Distortion**: surgical procedures to transplant skin causing unusual patterns
  - **Imitation**: surgical procedures to transplant / remove skin while retaining fingerprint pattern

- Utilized single CNN model for all three alteration types due to:
  - Insufficient data for each alteration type,
  - Manual labeling is subjective; multiple alterations may exist in single fingerprint image.

Obliteration	Distortion	Imitation
Scar	Transplantation with Z-Cut	Removal of portion of skin
Mutilation	Transplantation from other friction ridge, e.g. palm	Transplantation to match ridge pattern

Altered Fingerprint Localization

- Manually marked ROI (i.e. areas of alterations) for randomly selected 1,182 altered fingerprints

- Patches (96 x 96) centered around minutiae are cropped; fingerprint alterations create spurious minutiae

- Local patches with ≥ 50% overlap with the manually marked ROI labelled as *Altered,* remaining patches as *Valid*

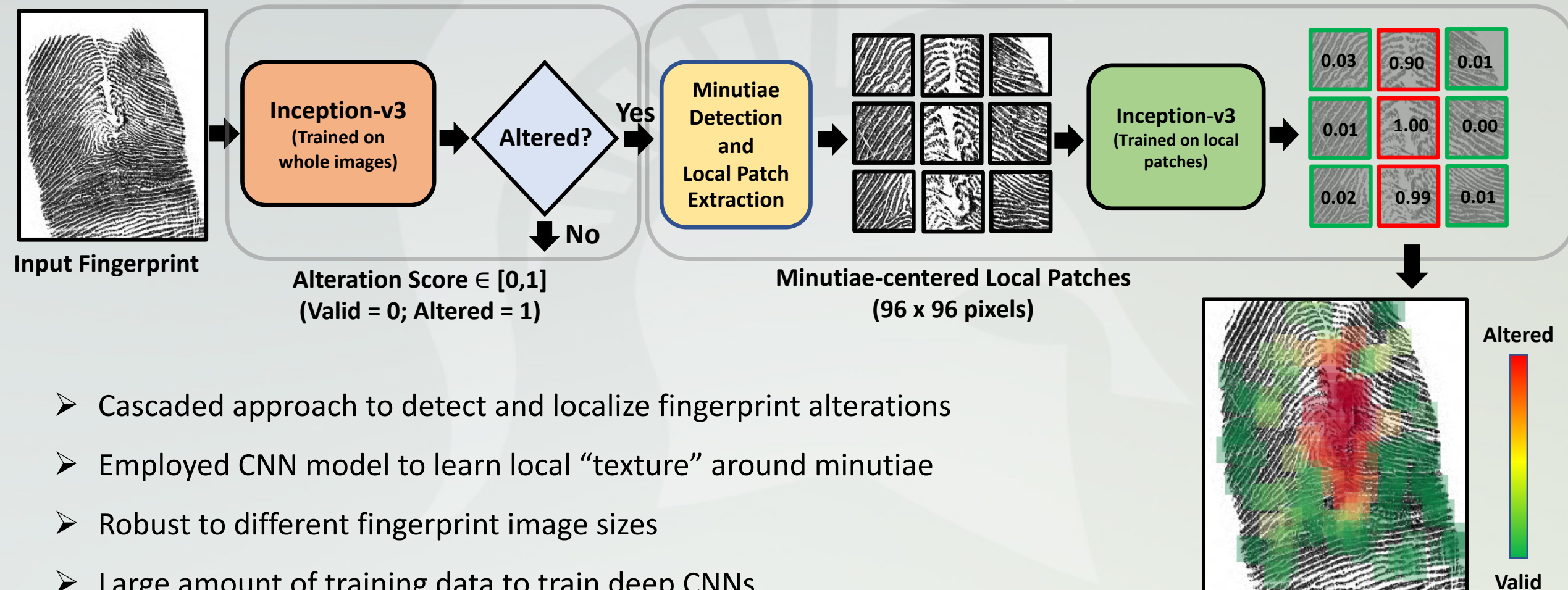ROI marked for altered regions in fingerprints

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Proposed Approach

Altered Fingerprint Detection

Altered Fingerprint Localization

Input Fingerprint

Inception-v3 (Trained on whole images)

Altered? — Yes → — No

Alteration Score ∈ [0,1] (Valid = 0; Altered = 1)

Minutiae Detection and Local Patch Extraction

Minutiae-centered Local Patches (96 x 96 pixels)

Inception-v3 (Trained on local patches)

0.03 | 0.90 | 0.01
0.01 | 1.00 | 0.00
0.02 | 0.99 | 0.01

Altered

Valid

➢ Cascaded approach to detect and localize fingerprint alterations

➢ Employed CNN model to learn local "texture" around minutiae

➢ Robust to different fingerprint image sizes

➢ Large amount of training data to train deep CNNs

Experimental Results

- Achieved avg. **TDR = 99.24% @ FDR = 2%** across five folds (std. = 0.58%)

- Inception-v3 CNN model (99.24%) outperformed MobileNet-v1 model (92.40%); Computational requirement for Mobilenet-v1 model is almost 10 times lower compared to Inception-v3.

- Both models beat the previous state-of-the-art performance of TDR = 70.2% @ FDR = 2.1% for similar sized operational database

- Evaluation time/image = 50ms (Inception-v3), and 6ms (Mobilenet-v1) on NVIDIA 1080Ti GPU

- Performance on *altered fingerprint localization*:
  - 2-fold cross validation on manually labeled Altered/Valid patches (81,969 valid, and 89,979 altered); **EER = 8.5%**
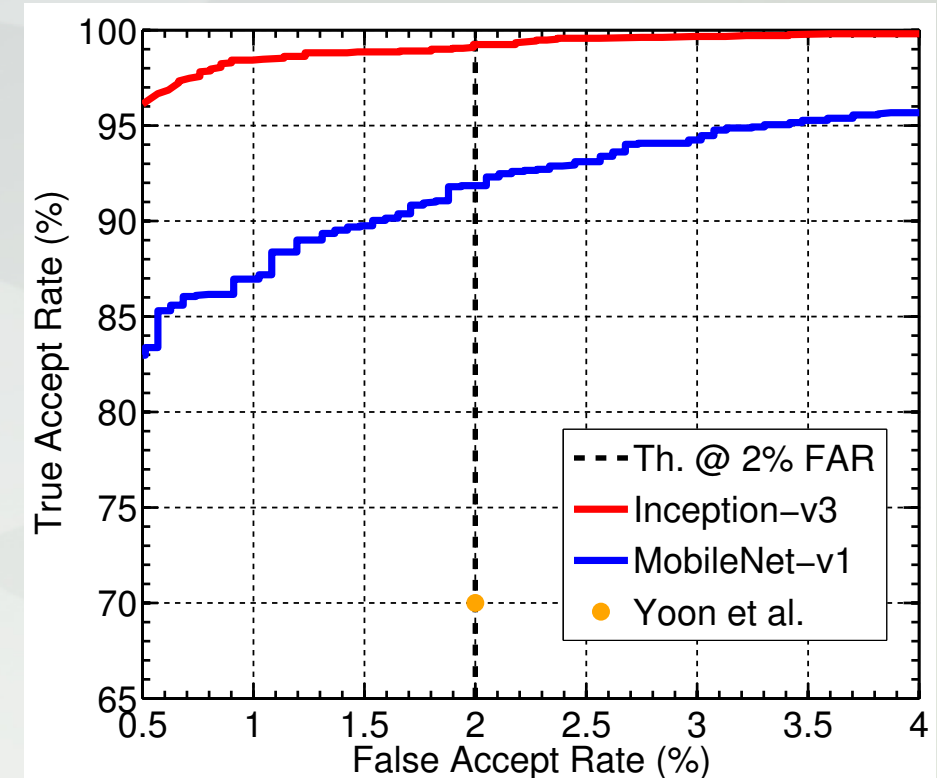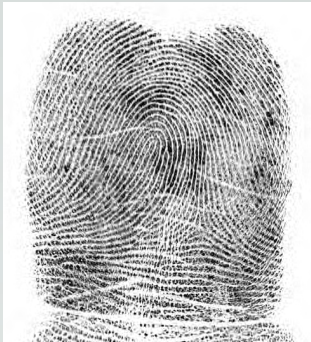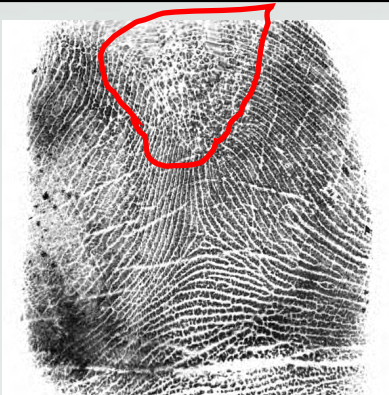

ROC curves for altered fingerprint detection.

Experimental Results

Altered Fingerprint Detection

Output

	Valid	Altered
Valid	Alteration Score: 0.0	Alteration Score: 0.78
Altered	Alteration Score: 0.31	Alteration Score: 0.98

Ground Truth

Altered Fingerprint Localization
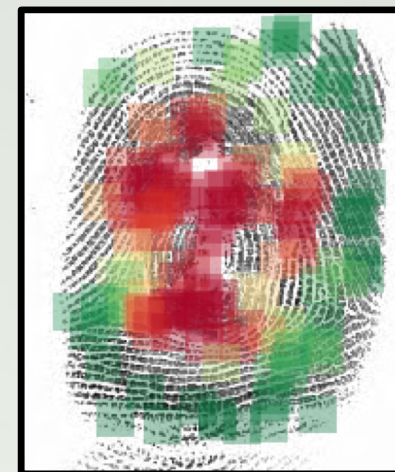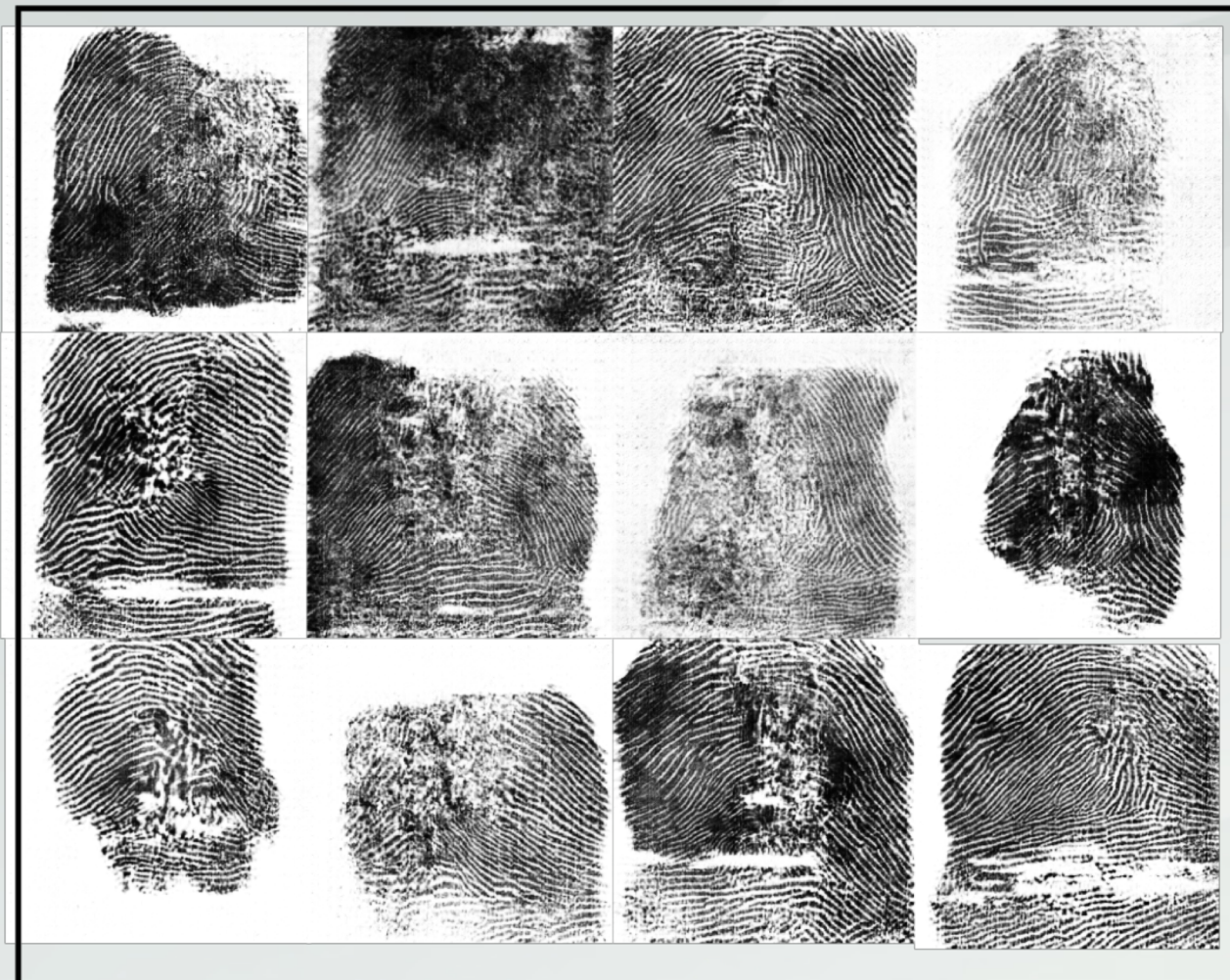
Synthetic Altered Fingerprint Generation

➤ To remedy the lack of publicly available altered fingerprint datasets, we trained a Generative Adversarial Network to generate synthetic altered fingerprints.

➤ Utilized DC-GAN architecture with following parameters [1]; trained on all of the 4,815 operational altered fingerprints

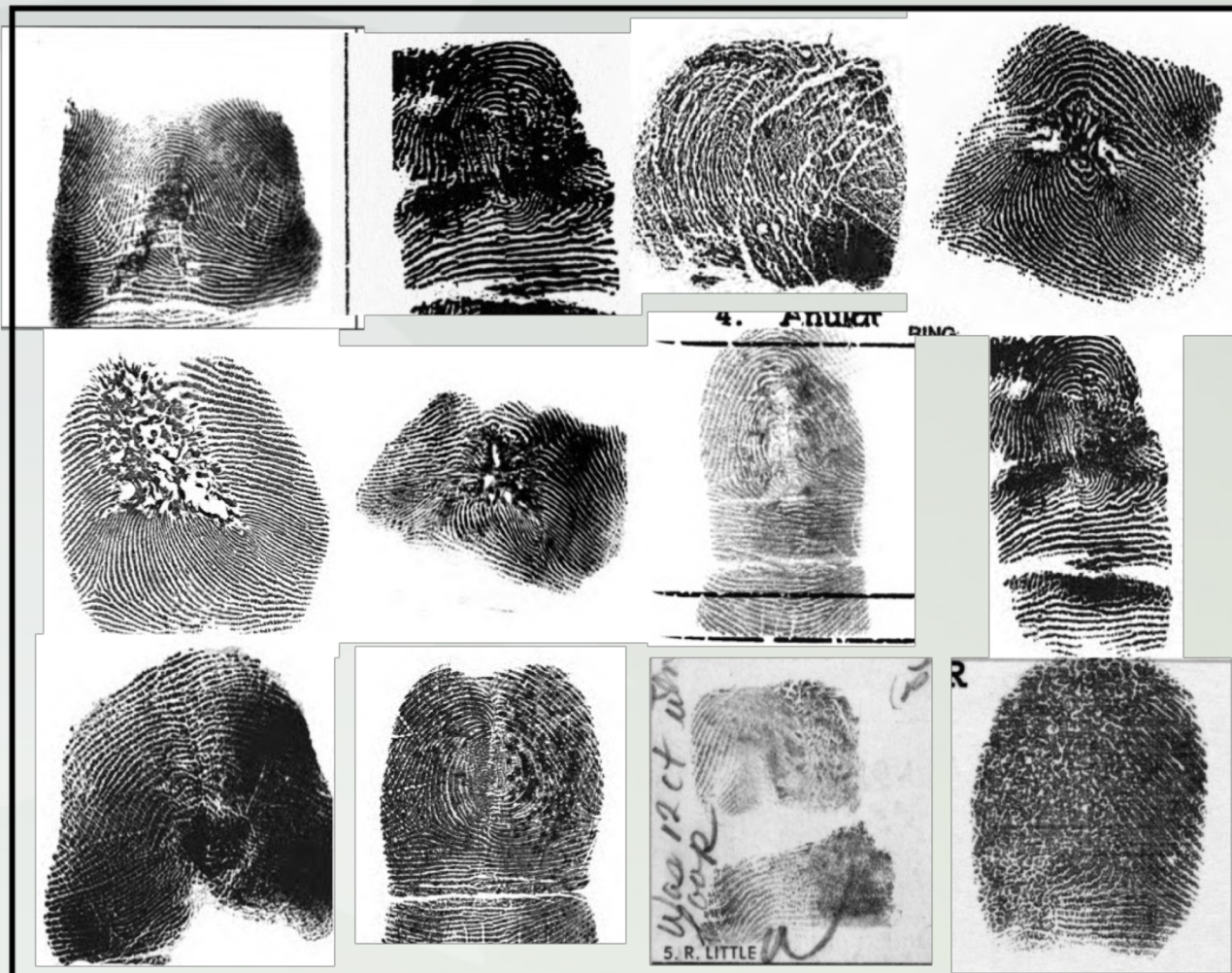| Architecture	DC-GAN
Input Size	512 x 512
Batch Size	64
Optimizer	Adam
Learning Rate	0.0002
Momentum	0.5
Iterations	1,350
Output Size	256 x 256

➤ Generated a total of 4,060 synthetic altered fingerprints

Synthetic Altered Fingerprint Generation

Synthetic Altered Fingerprints

Operational Altered Fingerprints

Summary

- Proposed a robust and accurate method of altered fingerprint detection and localization,

- Achieved a TDR = 99.24% @ FDR = 2% on an operational dataset of 4,815 altered, and 4,815 valid fingerprint images,

- Trained a GAN model to alleviate the lack of publicly available altered fingerprint datasets by generating synthetic altered fingerprints.

Future Work

- Refining the GAN network to improve the characteristics of synthetic altered fingerprints, control the type of alterations, and use fingerprint match scores to evaluate GAN model,

- Pre- and post-analysis of altered fingerprint images to benchmark the effect of alteration on recognition accuracy.