# 3D Fingerprint Targets

Sunpreet S. Arora[1], Kai Cao[1], Anil K. Jain[1]

and Nicholas G. Paulter Jr.[2]

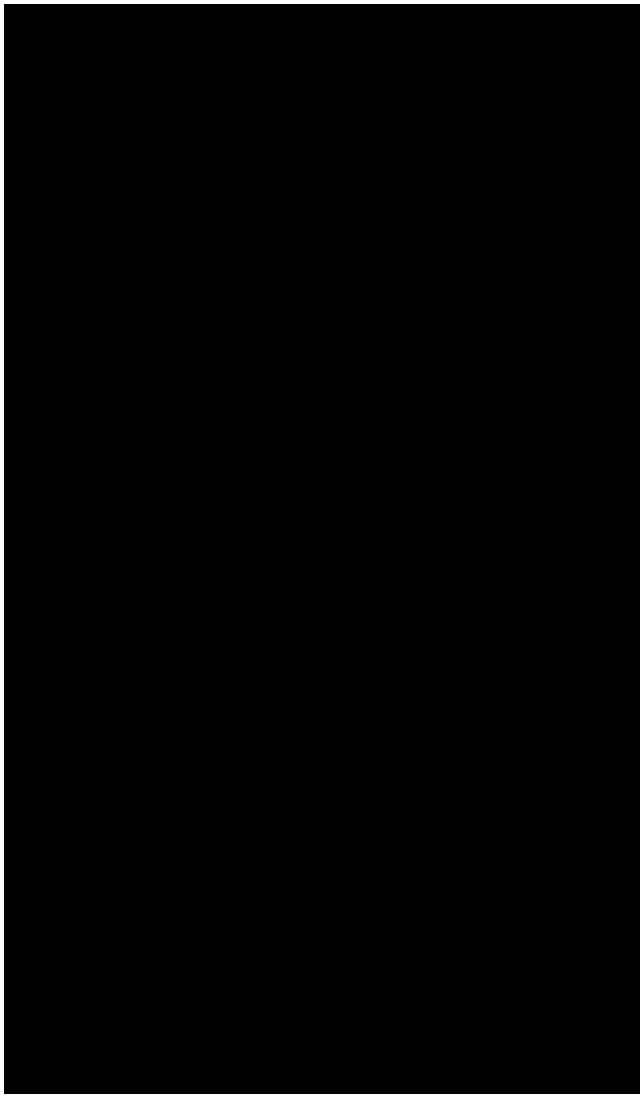
[1]Michigan State University

[2]National Institute of Standards and Technology

This research is supported by a grant from the NIST Measurement Science Program

# 3D Fingerprint Target

**2D fingerprint image**



**3D finger surface**

# Goal

- Build 3D targets to evaluate image acquisition capability of fingerprint readers

# Benefits

- Standards organizations: develop standard procedures to benchmark fingerprint readers
- Fingerprint vendors: improve performance of fingerprint readers
- End users: understand and compare the sources of limitations in different fingerprint readers

# Our Contributions

- Synthesize 3D targets by projecting 2D calibration patterns onto 3D finger surface

- Fabricate targets with material(s) similar in hardness and elasticity to the human finger skin using a state-of-the-art 3D printer

- Demonstrate utility of the targets for evaluation of fingerprint readers

# 3D Target Synthesis

3D finger surface

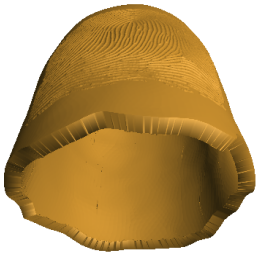
Preprocessing 3D finger surface

Mapping 2D fingerprint to 3D surface

2D calibration pattern

Preprocessing 2D calibration pattern

Engraving 2D calibration pattern on 3D surface



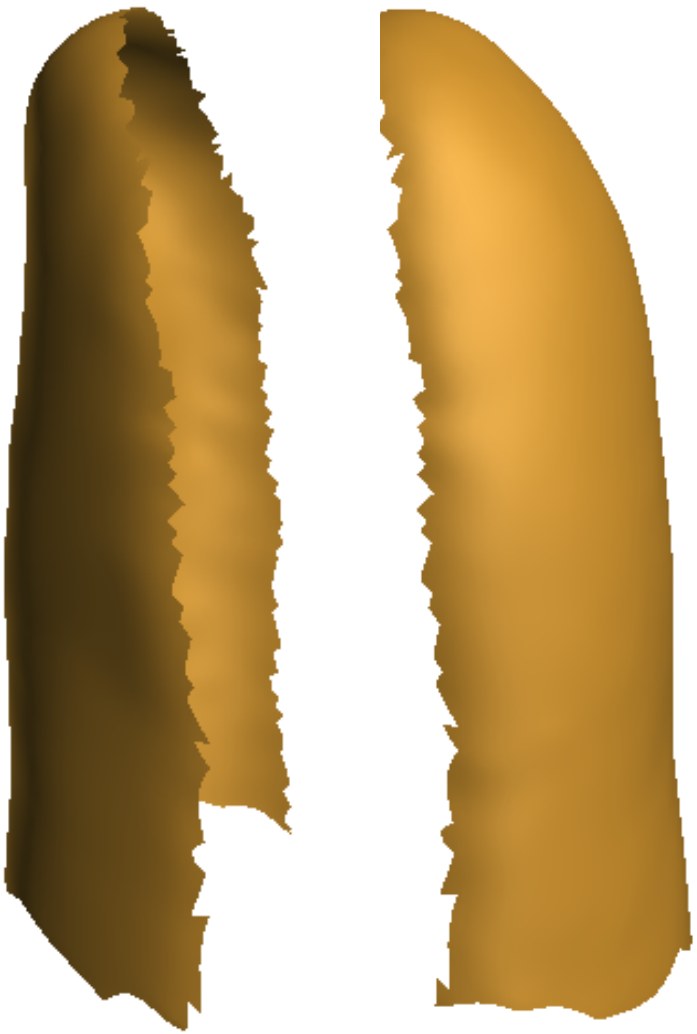
Postprocessing 3D finger surface

3D printing

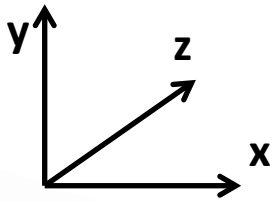
# Preprocessing 3D Finger Surface

Align the surface

Sample vertices and triangles



3D finger surface




Make the surface dense

Separate front and back

# Preprocessing 2D Calibration Pattern

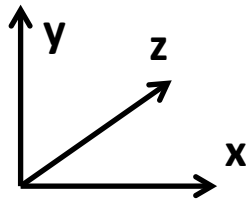
Extract Skeleton

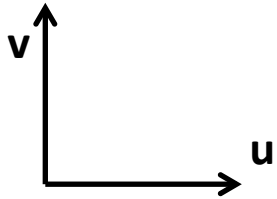
Smooth

Dilate

**2D calibration pattern**

# Mapping 2D Pattern to 3D Surface



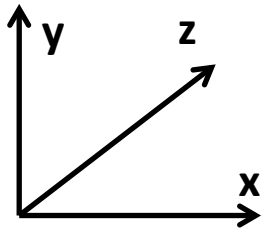

Unwrap to 2D

Make the surface dense

Map the 2D pattern

**Frontal finger surface**

# Engraving 2D Pattern on 3D Surface




Compute the surface normals

Displace the surface along the normals

**Frontal finger surface**

# Postprocessing 3D Finger Surface

Combine front and back

Inner finger surface

Stitch outer and inner surfaces

**3D finger surface**

# 3D Printing

**Electronic 3D target**


**Stratasys Objet Connex 350 (X & Y res: 600 dpi, Z res: 1600 dpi)**

**Physical 3D target**

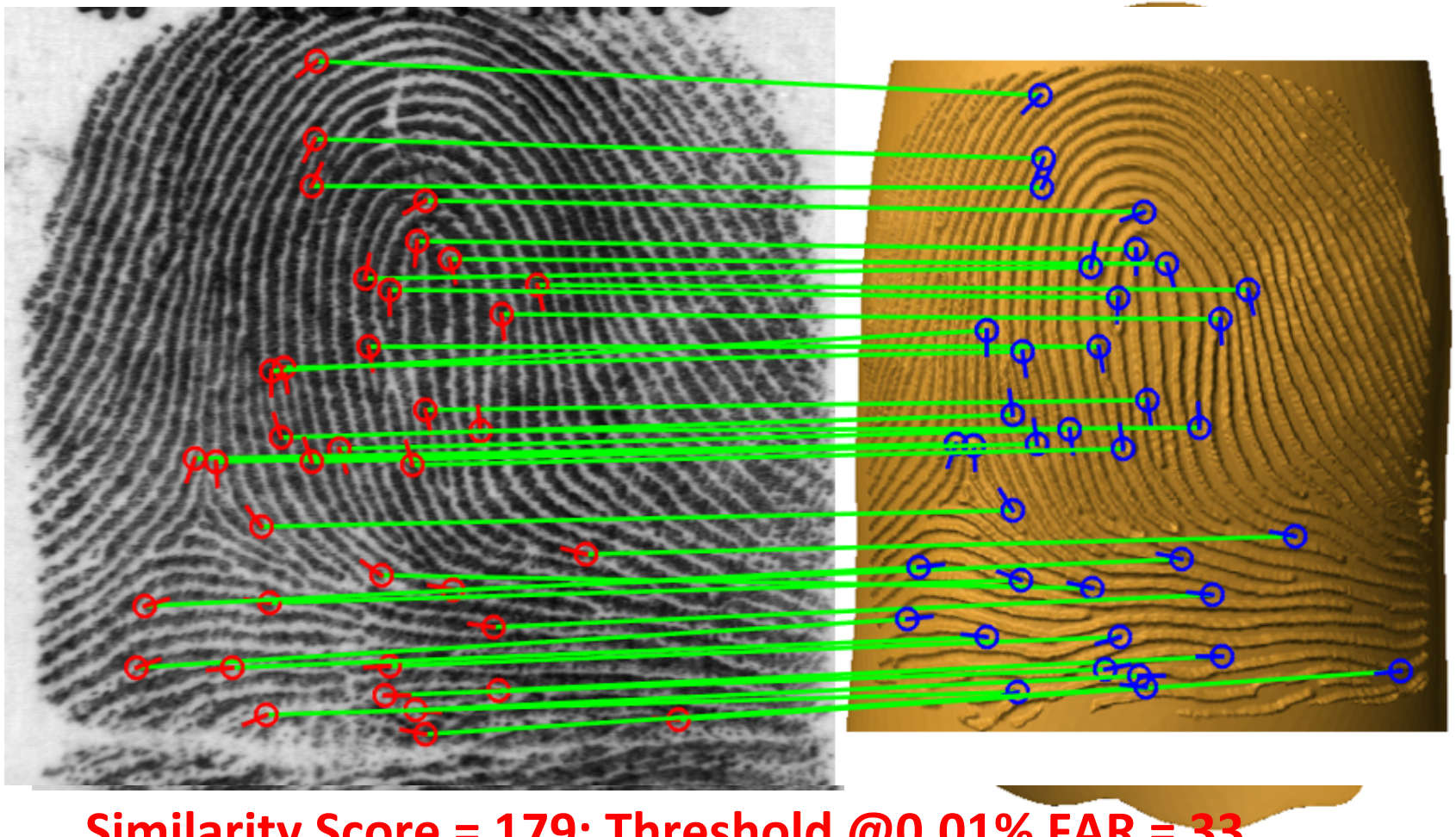
**Printing material similar in hardness and elasticity to human skin**

# Experiments

- How good is the synthesized and fabricated 3D target?
  - Fidelity of features after projection from 2D to 3D
  - Fidelity of engraved features after 3D printing
  - End-to-end fidelity of features
- Are the different impressions of a 3D target consistent (intra-class variability)?
- Evaluating fingerprint readers using 3D targets

# Fidelity of 3D Target Synthesis

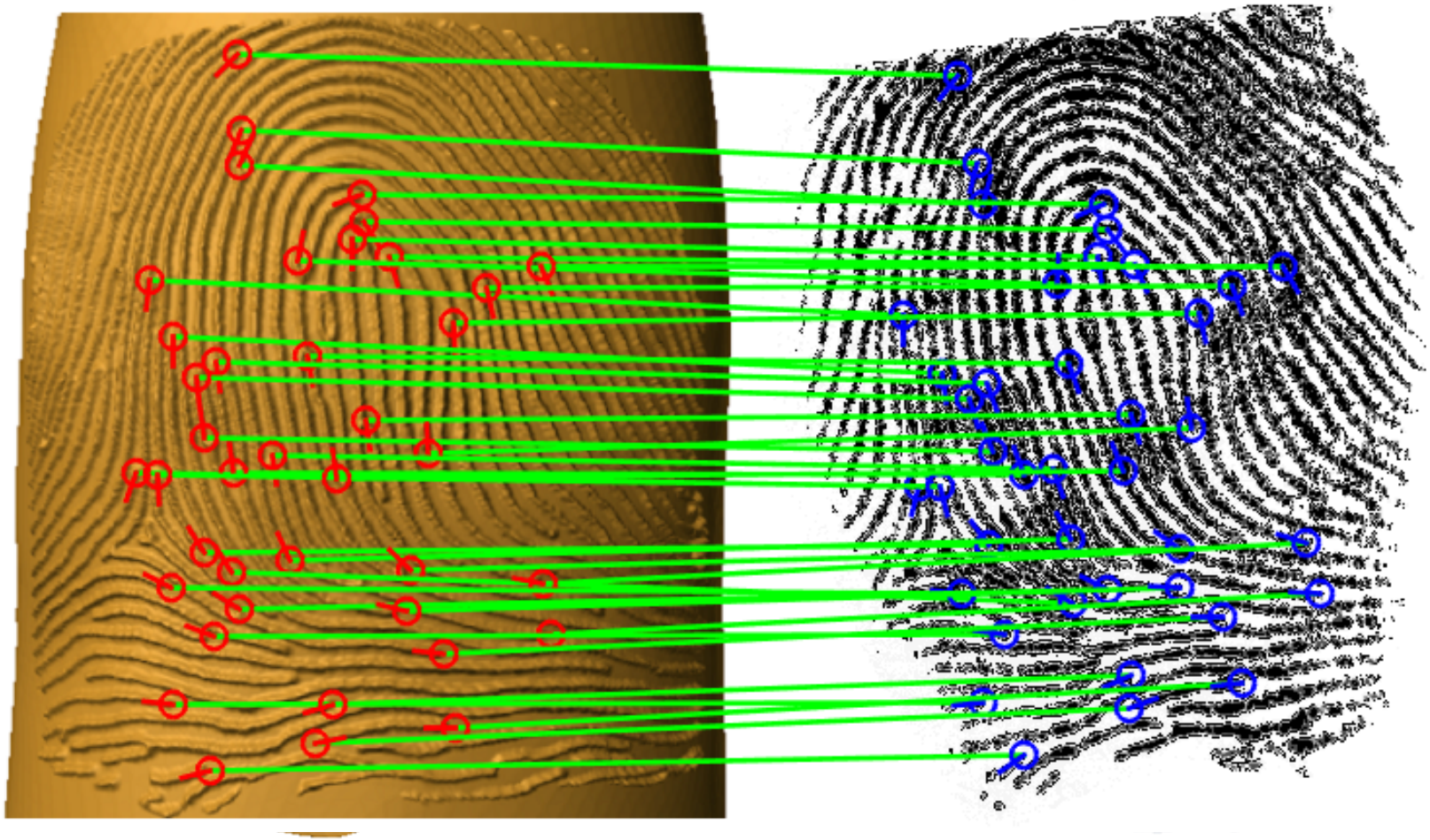
- Fidelity of features after 2D to 3D projection



**Similarity Score = 179; Threshold @0.01% FAR = 33**

# Fidelity of 3D Target Synthesis

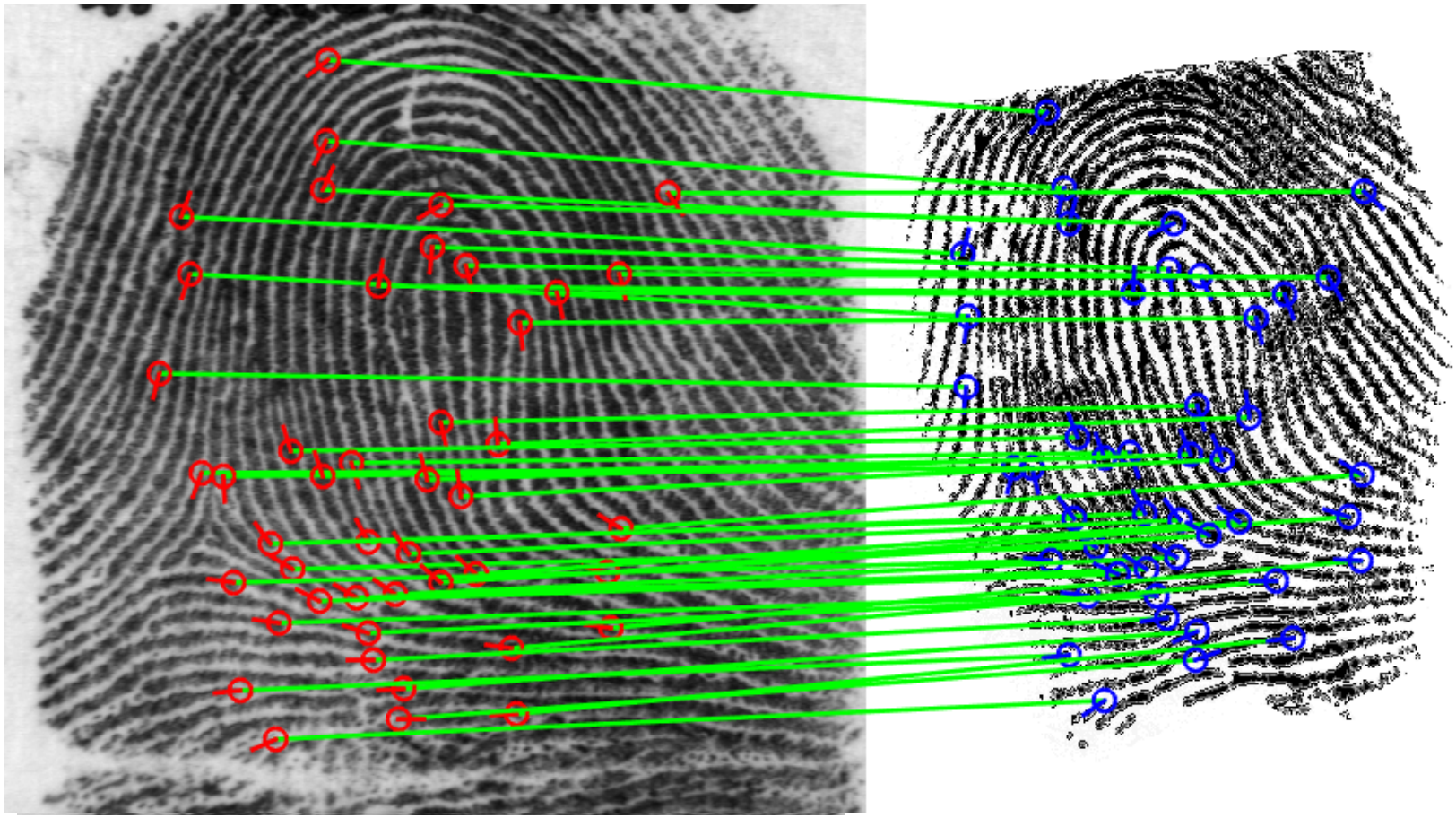
- Fidelity of engraved features after 3D printing



**Similarity Score = 500; Threshold @0.01% FAR = 33**

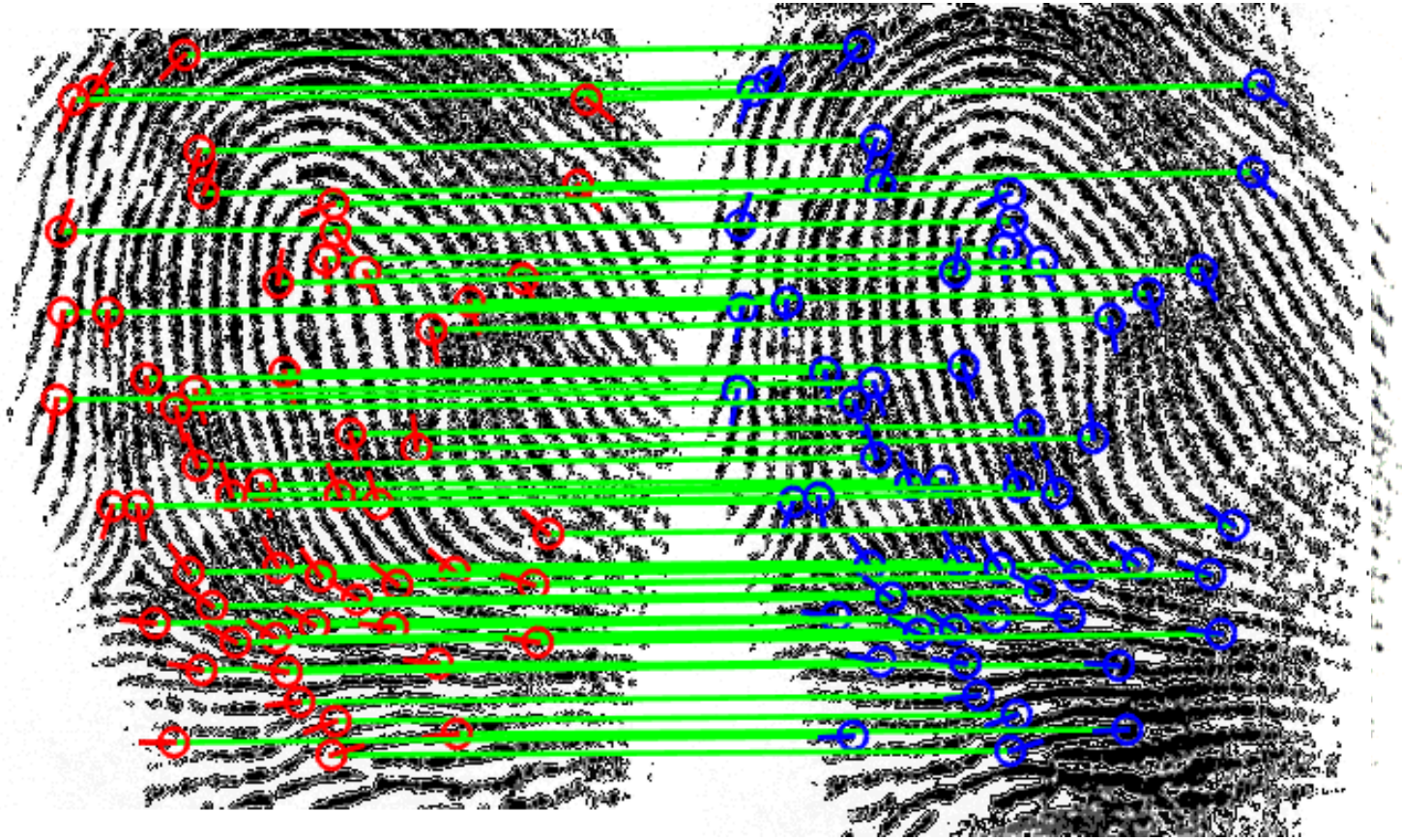
# Fidelity of 3D Target Synthesis

- End-to-end fidelity of features



**Similarity Score = 125; Threshold @0.01% FAR = 33**

# Intra-class Variability between 3D Target Impressions



**Impression 1** **Impression 2**

**Similarity Score = 1397; Threshold @0.01% FAR = 33**

# Evaluating Fingerprint Readers

- Project 2D calibration patterns (sine gratings/ fingerprints) of known spacing

Sine Grating
Average Spacing = 10.42 pixels

Fingerprint
Average Spacing = 10.42 pixels

3D Target

# Evaluating Fingerprint Readers

- Capture impressions of the 3D targets

# Evaluating Fingerprint Readers

- Measurements from 10 captured images of 3D targets synthesized using sine gratings

| Test pattern | Optical Reader 1 (500 ppi) | Optical Reader 2 (1000 ppi) |
|---|---|---|
| Horizontal grating | $\mu = 9.04, \sigma = 0.06$ | $\mu = 9.05, \sigma = 0.05$ |
| Vertical grating | $\mu = 9.51, \sigma = 0.23$ | $\mu = 9.46, \sigma = 0.09$ |
| Circular grating | $\mu = 9.80, \sigma = 0.31$ | $\mu = 9.59, \sigma = 0.08$ |

Mean ($\mu$) and Std. deviation ($\sigma$ ) of spacing computed in the captured images of targets using the two readers (pattern spacing = 10 pixels)

**Note:**

• To compensate for the distortion induced during 2D to 3D projection of the 2D pattern, ratio of the Euclidean to Geodesic distance (0.94) is factored into spacing computations

# Evaluating Fingerprint Readers

- Measurements from 5 captured images of 3D targets synthesized using fingerprints

| Test pattern | Optical Reader 1 (500 ppi) | Optical Reader 2 (1000 ppi) |
|---|---|---|
| S0005 (9.45) | $\mu = 8.93, \sigma = 0.12$ | $\mu = 8.59, \sigma = 0.09$ |
| S0010 (10.20) | $\mu = 10.10, \sigma = 0.04$ | $\mu = 9.65, \sigma = 0.12$ |
| S0017 (10.80) | $\mu = 10.85, \sigma = 0.13$ | $\mu = 10.20, \sigma = 0.08$ |
| S0083 (10.42) | $\mu = 9.92, \sigma = 0.23$ | $\mu = 9.55, \sigma = 0.03$ |
| S0096 (10.25) | $\mu = 9.56, \sigma = 0.08$ | $\mu = 9.25, \sigma = 0.02$ |

Mean ($\mu$ ) and Std. deviation ($\sigma$ ) of spacing computed in the captured images of targets using the two readers (average pattern spacing indicated in brackets)

# iPhone 5s: Enrolment and Verification

# Conclusions and Ongoing Work

- Devised a method to create 3D targets by (i) projecting a 2D calibration pattern onto a generic 3D finger surface, and (ii) fabricating using a 3D printer
- Demonstrated fidelity of the 3D target synthesis and fabrication process
- Showed the utility of the fabricated 3D targets for evaluating optical fingerprint readers
- **Ongoing Work**: Investigating alternative methods to fabricate the 3D targets with higher precision, and using materials with similar optical properties and conductivity to the human finger skin