Fingerprint Presentation Attack Detection: Generalization and Efficiency

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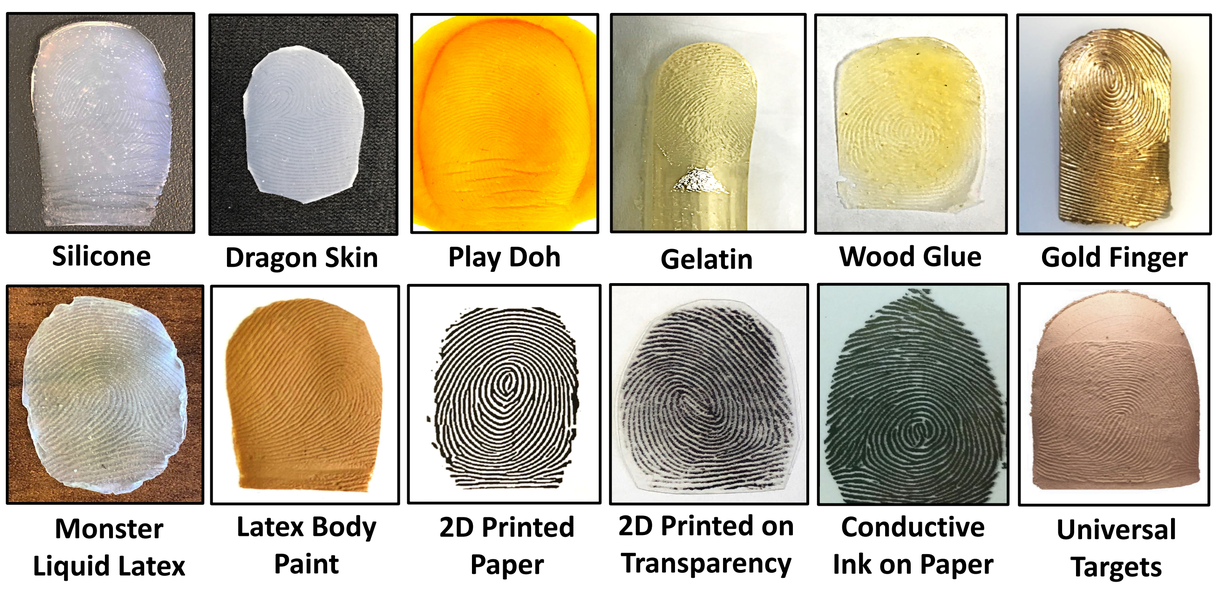
Introduction

Presentation Attacks: *"presentation to the biometric subsystem with the goal of interfering with the operation of the biometric system"*

– ISO standard IEC30107-1:2006 (E)

Gummy Fingers | Printed Fingerprint Targets | Altered Fingerprint | Cadaver Finger

12 Different Presentation Attack (PA) Fabrication Materials



Silicone | Dragon Skin | Play Doh | Gelatin | Wood Glue | Gold Finger

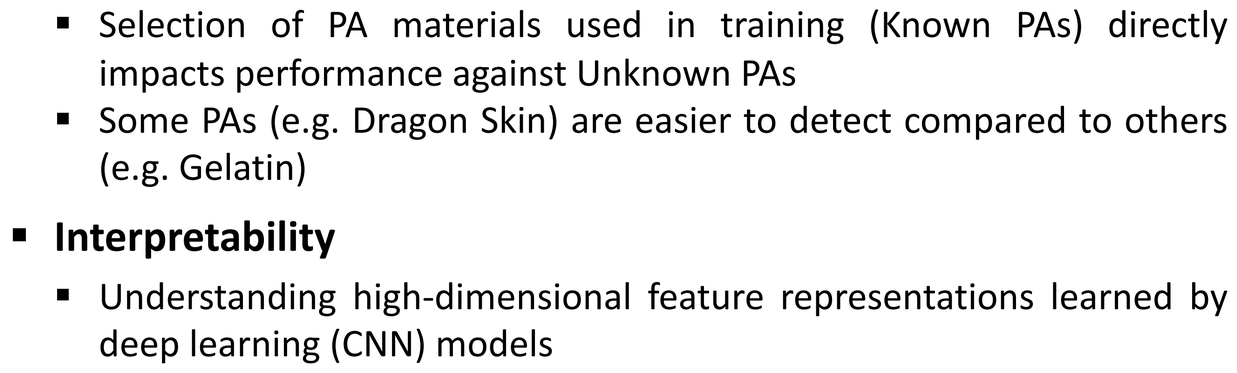
Monster Liquid Latex | Latex Body Paint | 2D Printed Paper | 2D Printed on Transparency | Conductive Ink on Paper | Universal Targets

Challenges

- **Generalization**
  - Selection of PA materials used in training (Known PAs) directly impacts performance against Unknown PAs
  - Some PAs (e.g. Dragon Skin) are easier to detect compared to others (e.g. Gelatin)
- **Interpretability**
  - Understanding high-dimensional feature representations learned by deep learning (CNN) models
- **Efficiency**
  - High memory and computation requirement inhibits use of PAD solutions in low resource environments i.e. smartphones

Proposed Approach

PA detection using CNNs trained on minutiae-based local patches

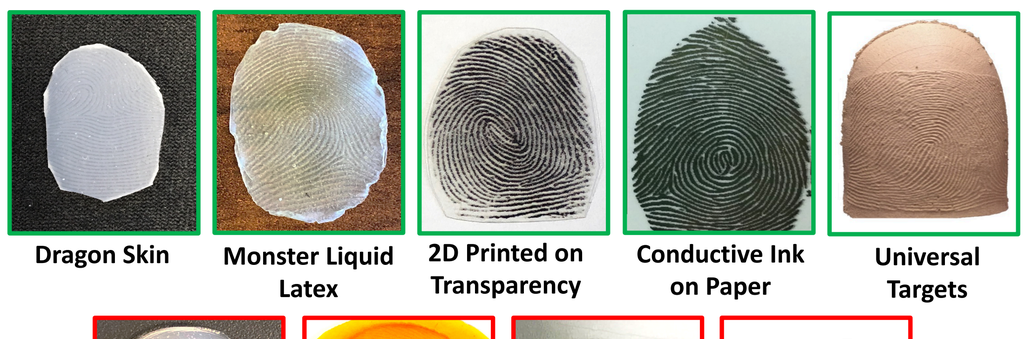


- Low-cost software solution applicable to variety of sensors
- Robust to different fingerprint image sizes
- Low training sample size requirement
- Local and global analysis of fingerprint images

Performance Against Unknown Materials

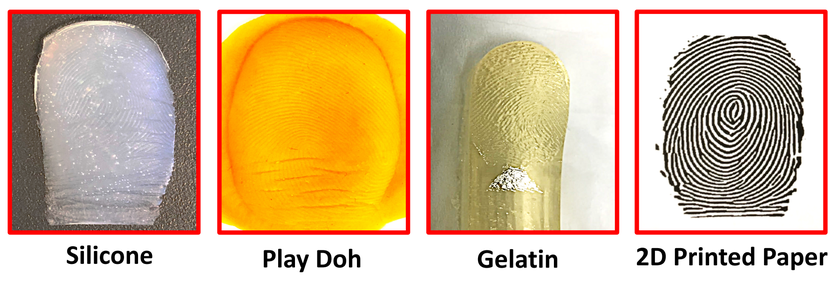
- Evaluated generalization performance using leave-one-out

TDR > 90% @ FDR = 0.2%



Dragon Skin | Monster Liquid Latex | 2D Printed on Transparency | Conductive Ink on Paper | Universal Targets

TDR < 70% @ FDR = 0.2%



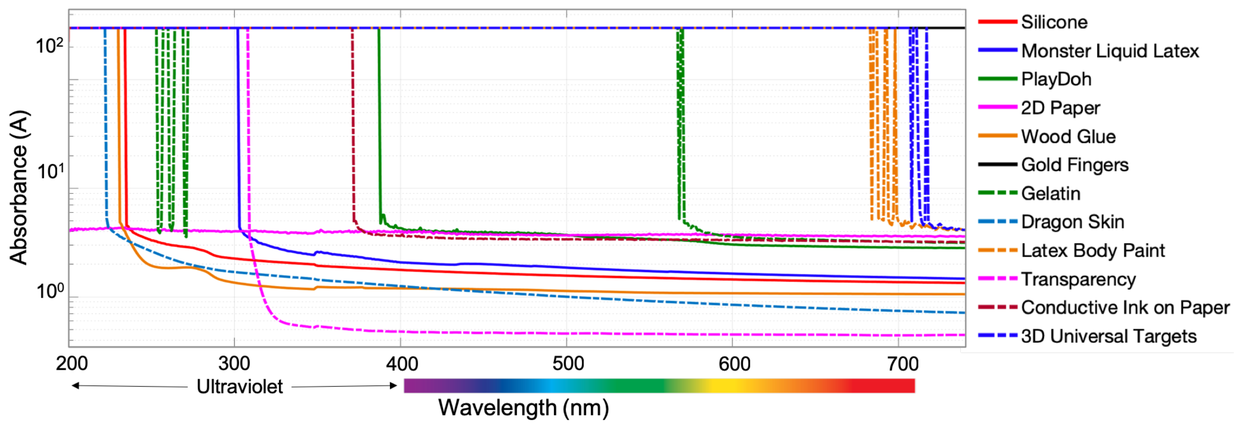
Silicone | Play Doh | Gelatin | 2D Printed Paper

Research Questions

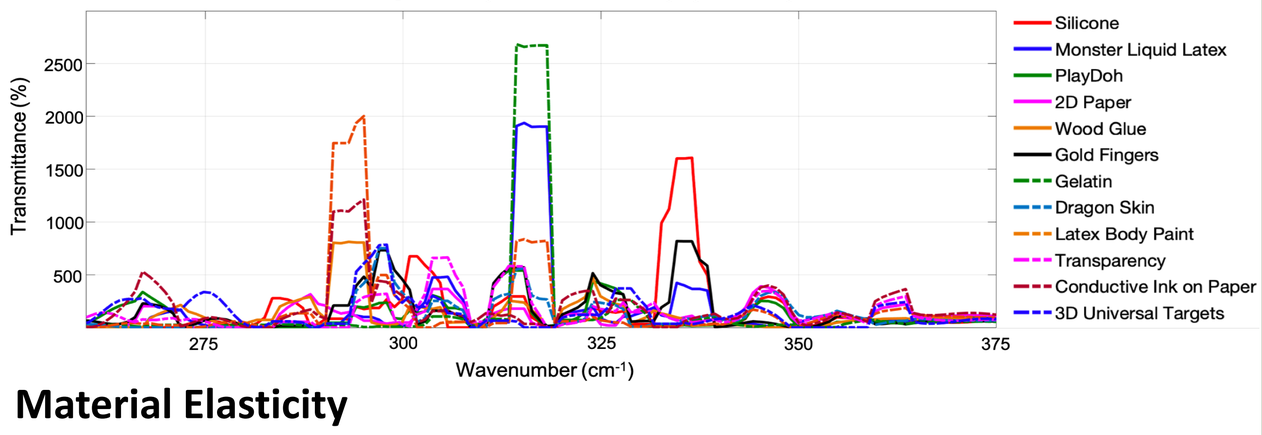
- Why are some PA materials easier to detect than others?
- Is there a correlation between detection performance and material characteristics?
- Can we identify a representative set of PA materials that could be used to train a robust and generalized model?
- How can we optimize the spoof detector to reduce memory and computation requirements while maintaining PAD performance?

Material Characteristics

UV-Vis Spectroscopy Response



FT/IR Spectroscopy Response



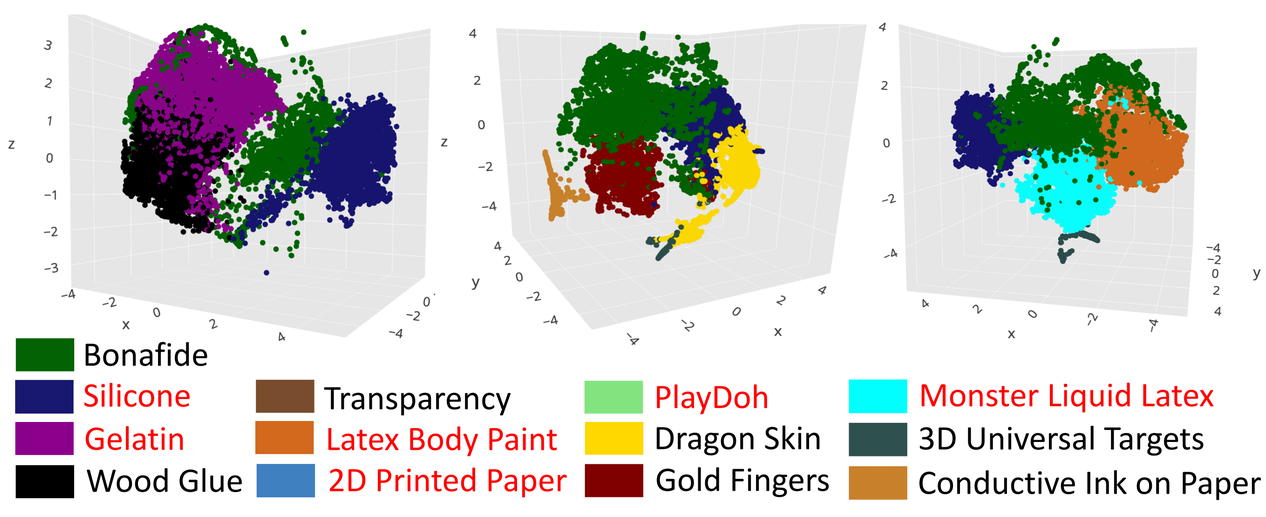
Material Elasticity

High: Silicone, Monster Liquid Latex, Dragon Skin, WoodGlue, Gelatin
Medium: PlayDoh, Latex Body Paint, 3D Targets
Low: 2D paper, Gold Fingers, Transparency, Conductive Ink on Paper

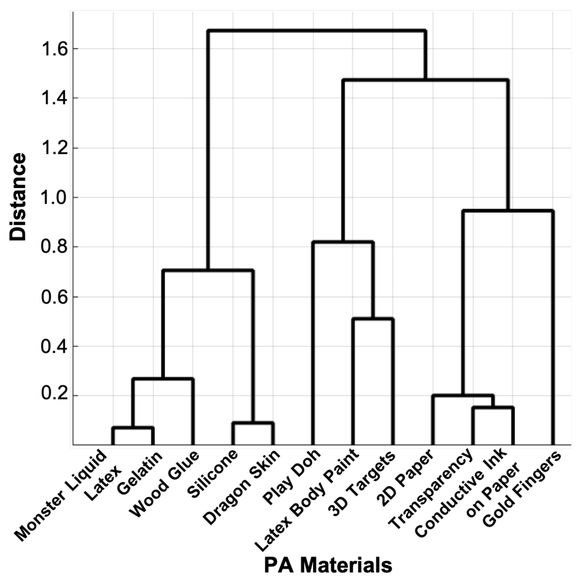
Moisture Content

High: Silicone, PlayDoh, Dragon Skin
Medium: Monster Liquid latex, WoodGlue, Gold Fingers, Gelatin, 3D Targets
Low: 2D Paper, Latex Body Paint, Transparency, Conductive Ink on Paper

Representative Set of PA Materials



- Computed Pearson correlation matrix using material characteristics
- Performed complete-link hierarchical clustering to identify a representative set of PA materials to train a robust and generalized model
- A set of 6 materials (highlighted in red above) achieved comparable average generalization performance to the models trained using 11 materials
- Significant drop in performance when the identified set of 6 crucial materials missing from training set



Complete-link Dendrogram

Fingerprint Spoof Buster Lite

- Quantized CNN model to perform byte computations instead of float computations; 80% reduction in memory and time complexity
- Clustered minutiae using K-means followed by weighted score fusion
- Developed an android application capable to perform PAD on live-scan images in less than 100ms on a commodity smartphone

Android Mobile Solution

Summary

- Evaluated generalization performance of state-of-the-art Spoof Detector using 12 different PA Materials
- Investigated clustering of PA Materials based on material characteristics and 3D t-SNE visualization to explain generalization performance
- Identified PA materials: Silicone, PlayDoh, Monster Liquid Latex, Gelatin, Latex Body Paint, and 2D paper essential for training a robust PAD
- Proposed two optimizations to reduce computation and memory requirements, and developed an efficient android application