Virtual U: Defeating Face Liveness Detection by Building Virtual Models From Your Public Photos

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USENIX Security
August 11, 2016
Face Authentication: Convenient Security
Evolution of Adversarial Models

- **Attack:** Still-image Spoofing
Evolution of Adversarial Models

- **Attack:** Still-image Spoofing
- **Defense:** Liveness Detection
Evolution of Adversarial Models

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- **Attack:** Video Spoofing
- **Defense:** Motion Consistency
- **Attack:** 3D-Printed Masks
Virtual U: A New Attack

We introduce a new VR-based attack on face authentication systems solely using publicly available photos of the victim
Virtual U: A New Attack

1. Input Web Photos
2. Landmark Extraction
3. 3D Model Reconstruction
4. Image-based Texturing
5. Gaze Correction
6. Viewing with Virtual Reality System

Expression Animation
Leveraging Social Media
Landmark Extraction
3D Face Model

- Identity Variation (e.g., thin-to-heavyset)
- Expression Variation (e.g., frowning-to-smiling)
3D Face Model

\[ S = \bar{S} + A_{id} \alpha_{id} + A_{exp} \alpha_{exp} \]

Identity Variation (e.g., thin-to-heavyset)

Expression Variation (e.g., frowning-to-smiling)
3D Face Model

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Pose
\[ \alpha_{id} \]
\[ \alpha_{exp} \]
3D Face Model
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3D Face Model
3D Face Model
Multi-Image Modeling
Texturing

Direct Texturing

2D Poisson Editing
Texturing

Direct Texturing  2D Poisson Editing  3D Poisson Editing
Gaze Correction
Gaze Correction
Virtual U: A New Attack

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Expression Animation
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VR Display

Printed Marker

VR System

Authentication Device
VR Display
Experiments

KeyLemon

Mobius

TrueKey

BioID

1U

Interaction-based liveness detection

Motion-based liveness detection

Texture-based liveness detection
Experiments

- 20 participants
  - Aged 24 to 44
  - 14 males, 6 females
  - Various ethnicities

- Two tests
  - Indoor photo of the subject in the same environment as registration
  - Publicly accessible photos
    - Anywhere from 3 to 27 photos per person
    - Low-, medium-, and high-quality
    - Potentially strong changes in appearance over time
Experiments

<table>
<thead>
<tr>
<th></th>
<th>Indoor Image (Single frontal image)</th>
<th>Online</th>
<th>Avg. # Tries</th>
</tr>
</thead>
<tbody>
<tr>
<td>KeyLemon</td>
<td>100%</td>
<td>85%</td>
<td>1.6</td>
</tr>
<tr>
<td>Mobius</td>
<td>100%</td>
<td>80%</td>
<td>1.5</td>
</tr>
<tr>
<td>TrueKey</td>
<td>100%</td>
<td>70%</td>
<td>1.3</td>
</tr>
<tr>
<td>BioID</td>
<td>100%</td>
<td>55%</td>
<td>1.7</td>
</tr>
<tr>
<td>1U</td>
<td>100%</td>
<td>0%</td>
<td>--</td>
</tr>
</tbody>
</table>
Observations

- Medium- and high-resolution photos work best
  - Photos from professional photographers (weddings, etc.)

- Group photos provide consistent frontal views
  - Often lower resolution

- Only a small number of photos required
  - One or two forward-facing photos
  - One or two higher-resolution photos
Experiments

How does resolution affect reconstruction quality?
Experiments

How does rotation affect reconstruction quality?
Experiments

Combining high-res rotation with low-res front-facing?
Experiments

- Virtual U is successful against *liveness detection*
Experiments

- Virtual U is successful against *liveness* detection

- Also successful against *motion consistency*
Experiments

- “Seeing Your Face is Not Enough: An Inertial Sensor-Based Liveness Detection for Face Authentication” (Li et al., ACM CCS’15)
  - Device motion measured by inertial sensor data
  - Head pose estimated from input video
  - Train a classifier to identify real data (correlated signals) versus spoofed video data

![Graph showing normalized movement vector over frame number]
## Experiments

<table>
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<tr>
<th>Training Data (Pos. Data vs. Neg. Data)</th>
<th>Test Result (Accept Rate)</th>
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<tr>
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<td>Real vs. Video</td>
<td>98.0%</td>
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## Experiments

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(Pos. Data vs. Neg. Data)

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<td>Real Face: 70.0%</td>
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Mitigations

- Alternative/additional hardware
  - Infrared imaging (e.g. Windows Hello)
  - Random structured light projection
Mitigations

- Alternative/additional hardware
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- Improved defense against low-resolution synthetic textures
Conclusion

- We introduce a new VR-based attack on face authentication systems solely using publicly available photos of the victim.

- This attack bypasses existing defenses of liveness detection and motion consistency.

- At a minimum, face authentication software must improve against VR-based attacks with low-resolution textures.

- The increasing ubiquity of VR will continue to challenge computer-vision-based authentication systems.
Thank you!

Questions?