usenix THE ADVANCED COMPUTING SYSTEMS ASSOCIATION
34TH USENIX SECURITY SYMPOSIUM

Scoop: Mitigation of Recapture Attacks on Provenance-Based Media Authentication

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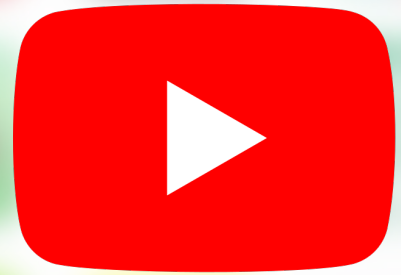
TrussLab

UCI University of California, Irvine

Microsoft

In the digital world, information spreads fast



So does fake and fraudulent information

- Great advances in AI facilitate equally impressive advances in deep fakes

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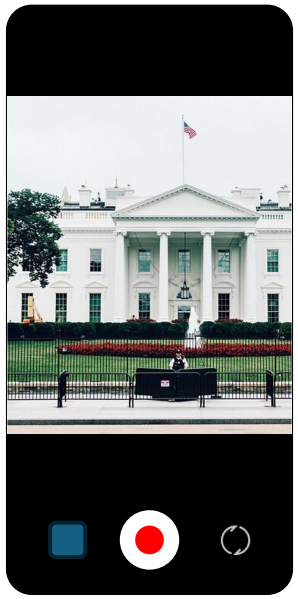
Detection-based approaches are an endless race that's unlikely to win

Provenance-based media authentication



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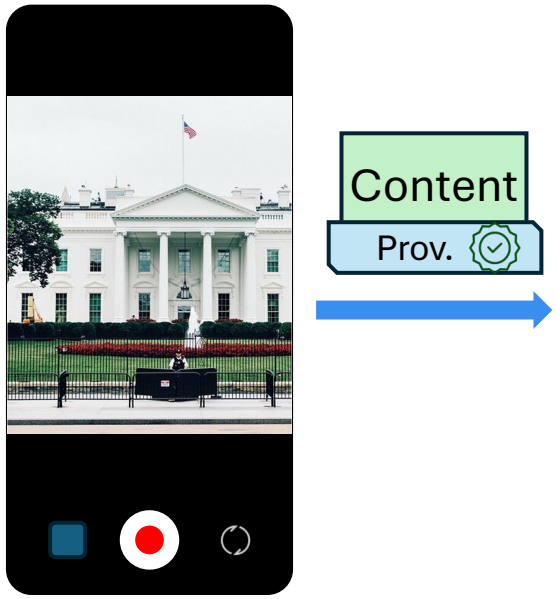

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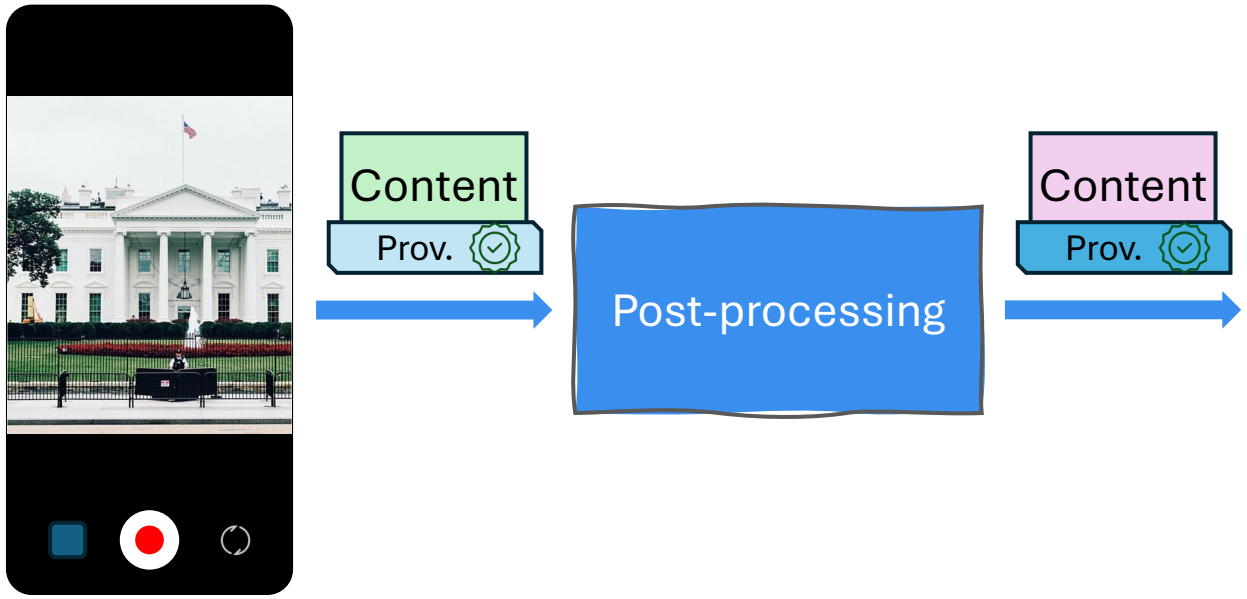

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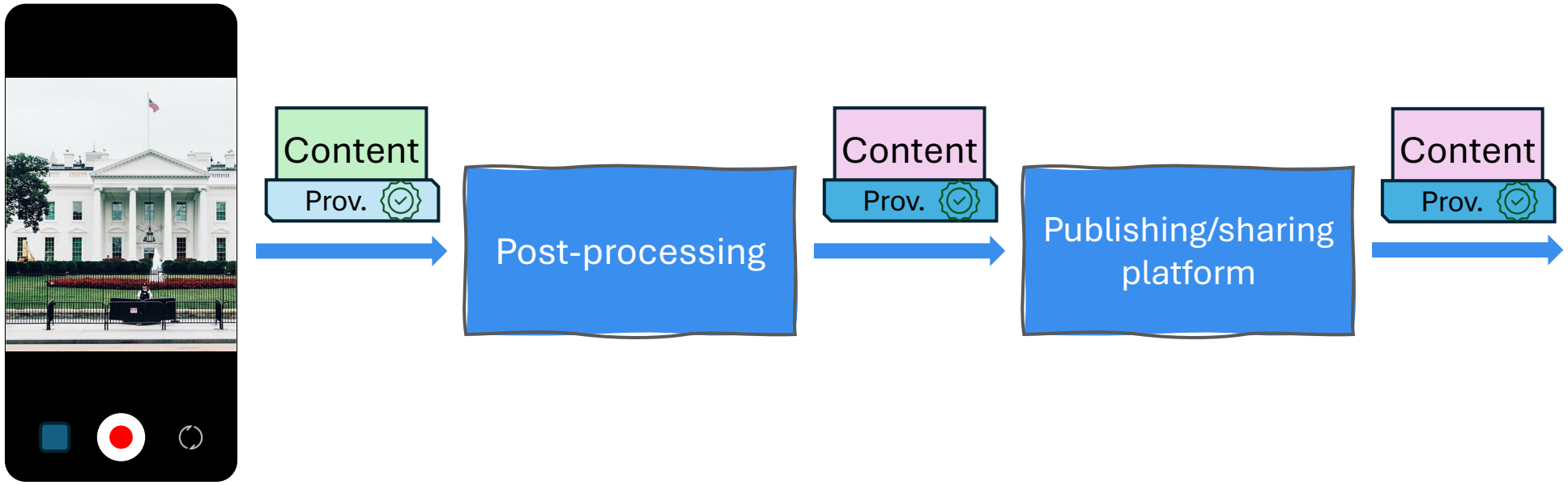

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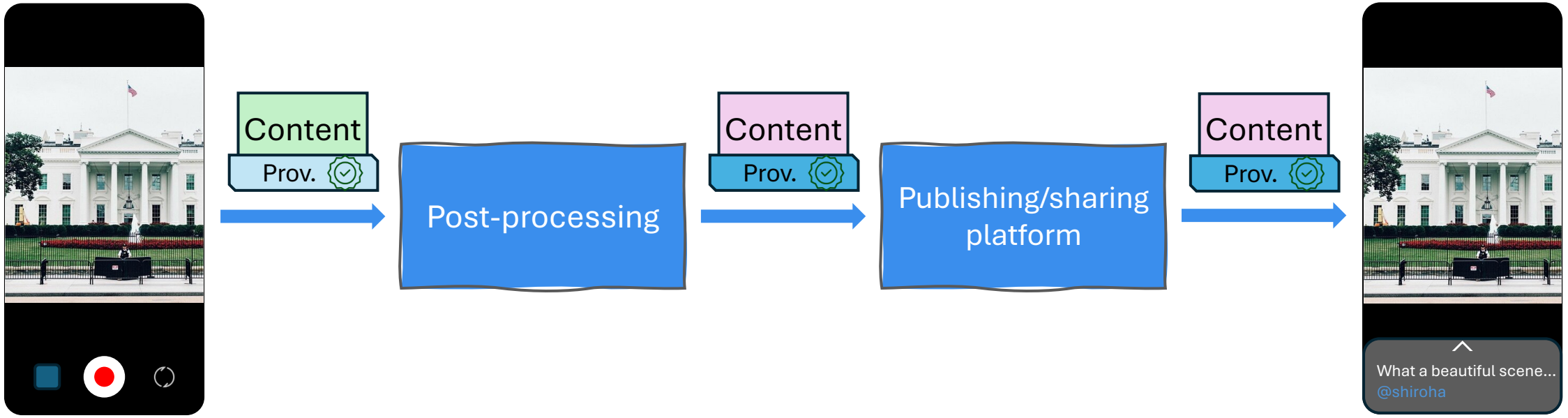

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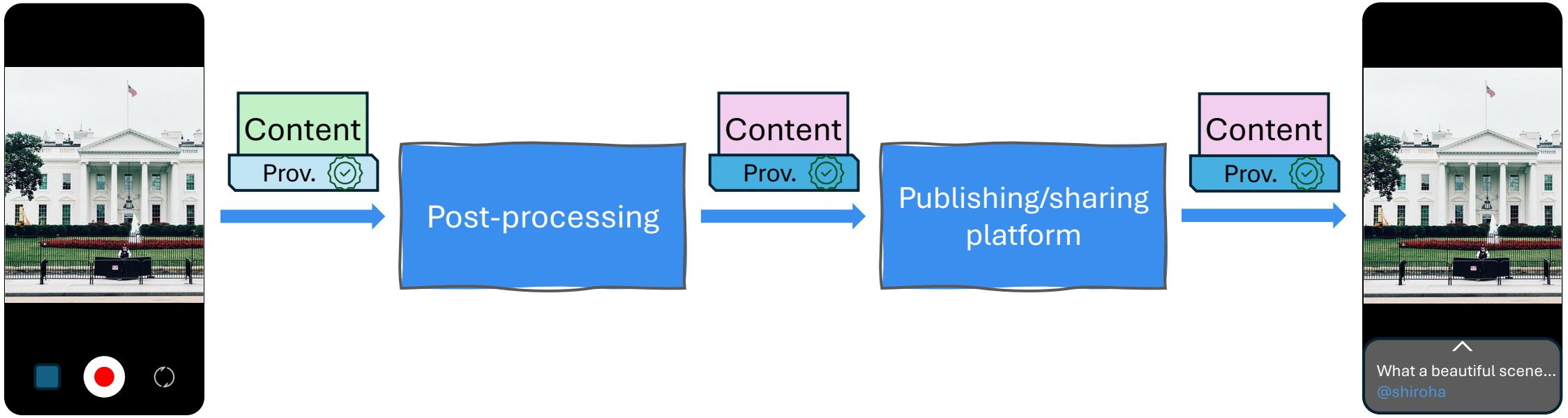
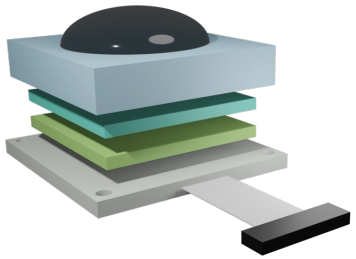
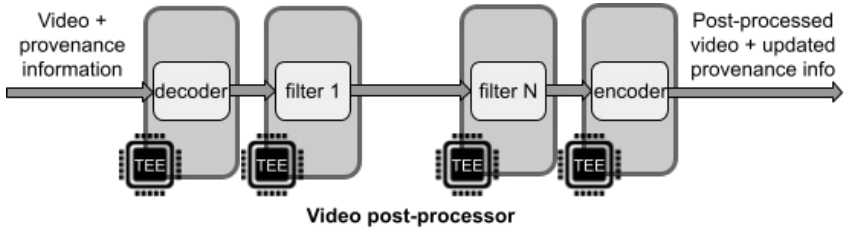


ProvCam (MobiCom '24)



Vronicle (MobiSys '22)



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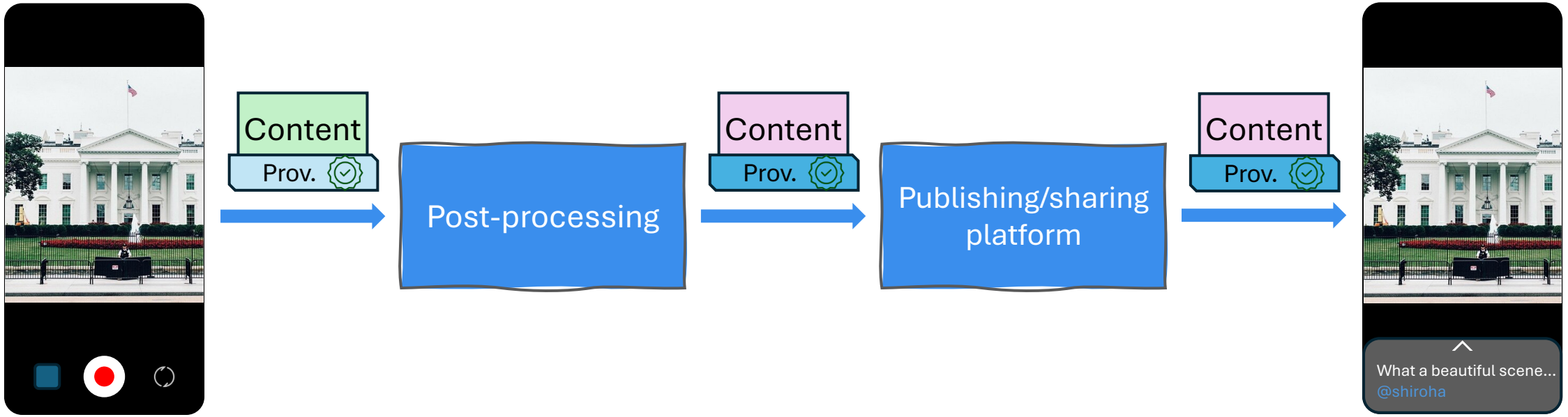

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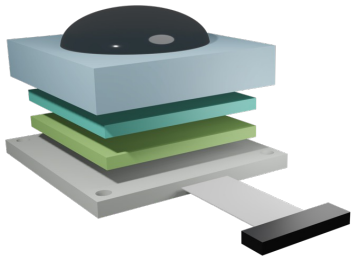

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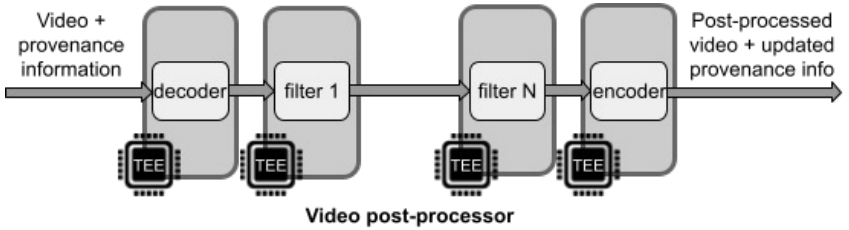

Content Authenticity Initiative

C2PA

Adobe BBC Microsoft

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Are we safe now?

Are we safe now?

- NO!

Challenge 1

- Provenance authenticates the origin and history of the content, but not the information within the content

Recapture attack in the provenance era

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Classic recapture attack --- renewed

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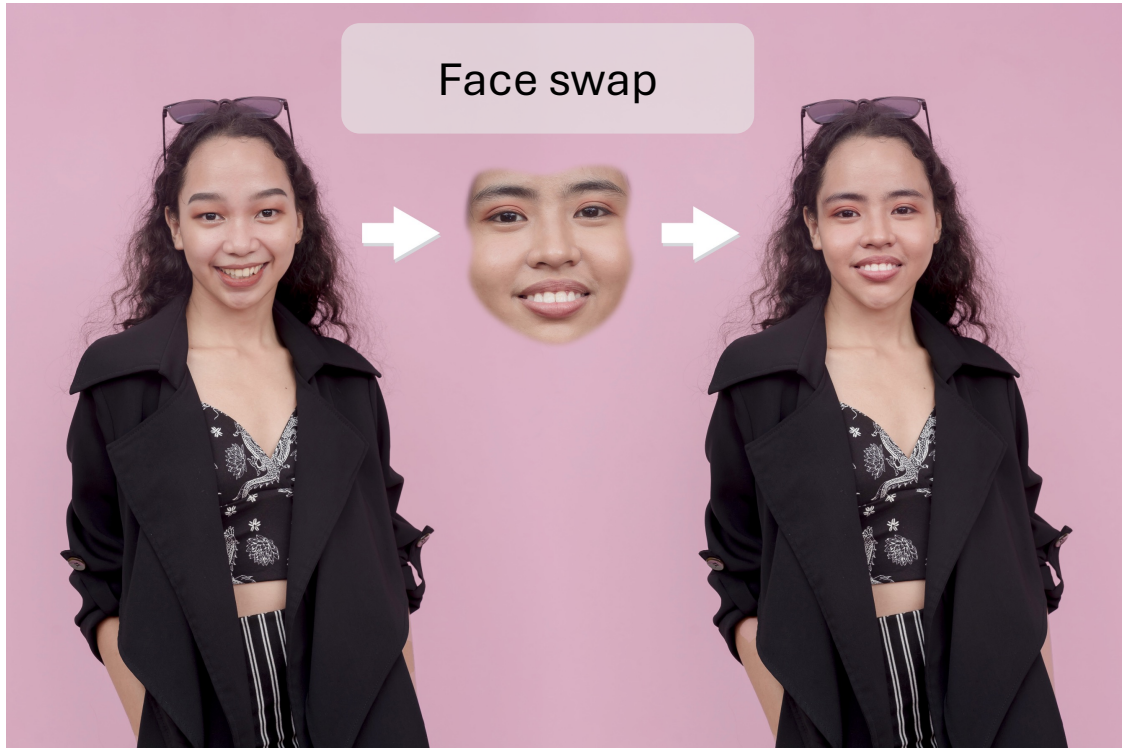
- Ease of content manipulation/fabrication (e.g., deepfake)



Classic recapture attack --- renewed

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- Illusion of reality (e.g., advanced displays)

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- Ease of content manipulation/fabrication (e.g., deepfake)
- Illusion of reality (e.g., advanced displays)
- False sense of trust (by provenance-based systems)

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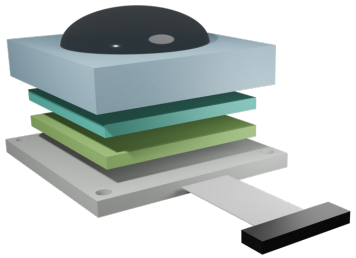

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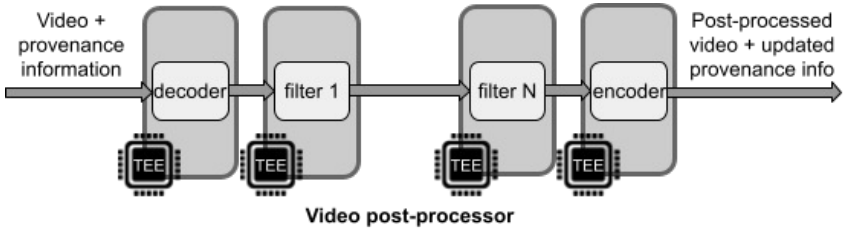

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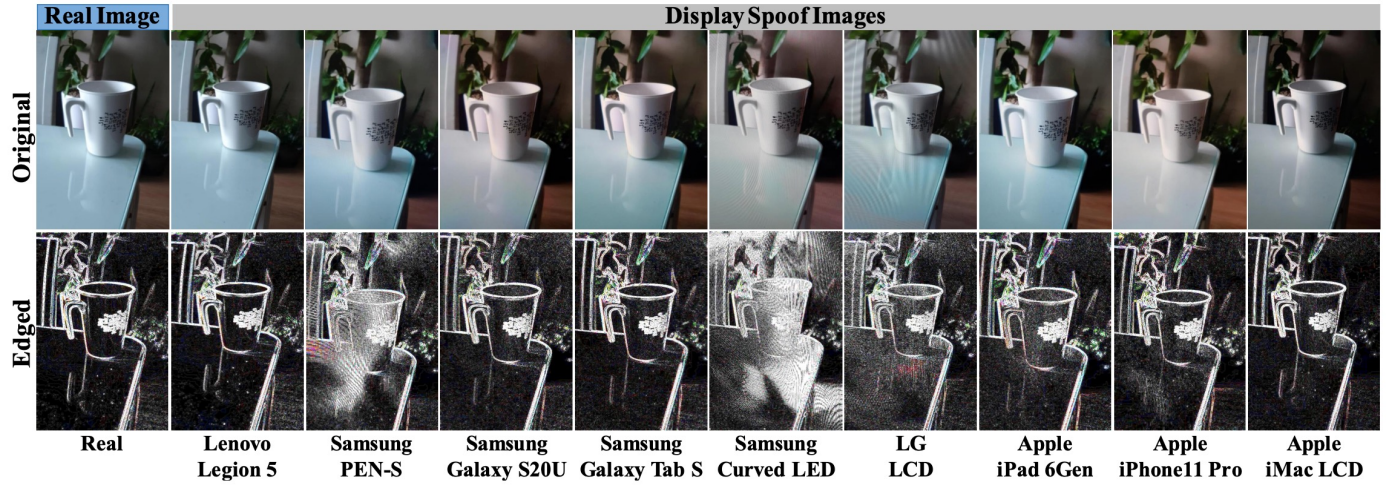
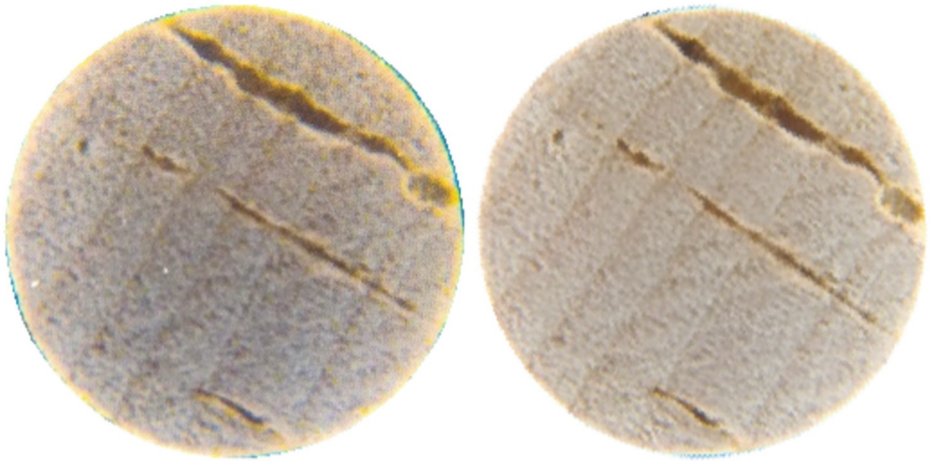
Any existing countermeasures?

Existing countermeasures

- Screen-based (e.g., LCD and OLED) recapture detection (e.g., using moiré pattern)
- Print-based (e.g., poster) recapture detection (e.g., using micro-surface pattern)



(Jeong et al.)



(Costa et al.)

Do they really work?

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- Majority of them depend on prior knowledge of the recapture medium and camera

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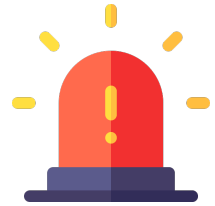
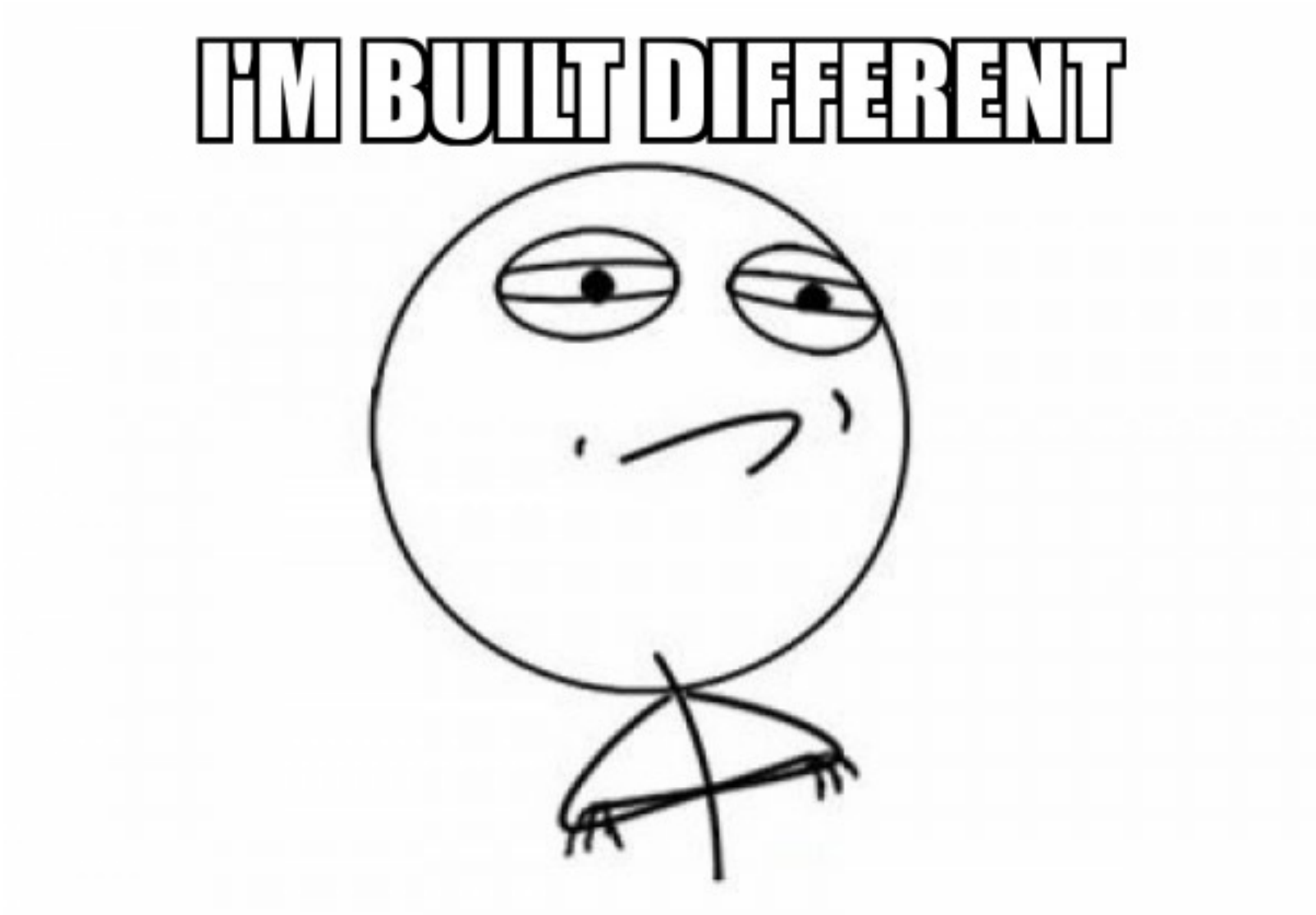
- Not really
- Majority of them depend on prior knowledge of the recapture medium and camera
- Attackers are **in control** here (for both the recapture medium and camera)

Spoiler alert



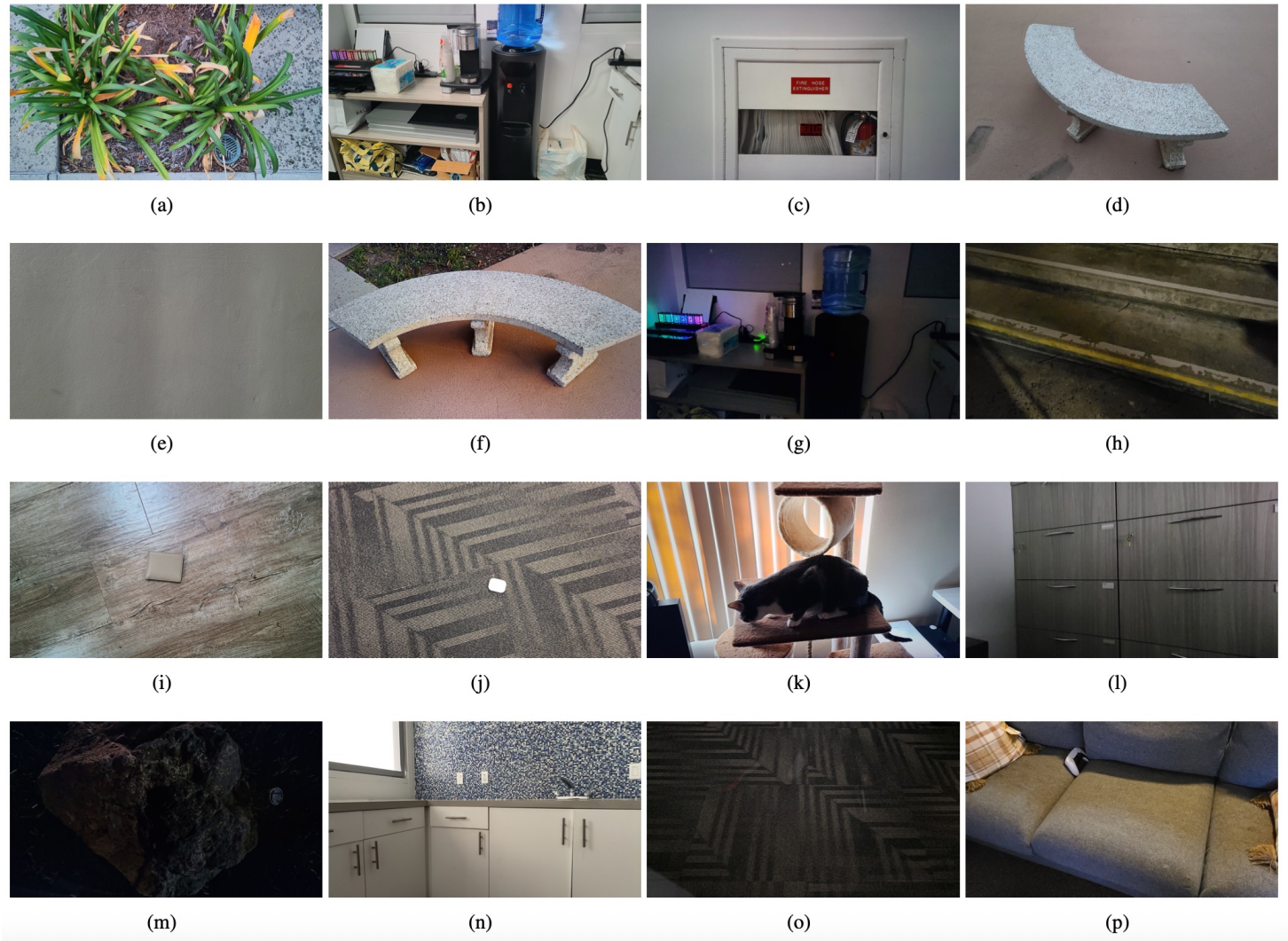
Chimera: Creating Digitally Signed Fake Photos by Fooling Image Recapture and Deepfake Detectors

Seongbin Park*, Alexander Vilesov*, Jinghui Zhang, Hossein Khalili,
Yuan Tian, Achuta Kadambi, Nader Sehatbakhsh
University of California, Los Angeles
{parkseongbin,vilesov}@ucla.edu


I'M BUILT DIFFERENT

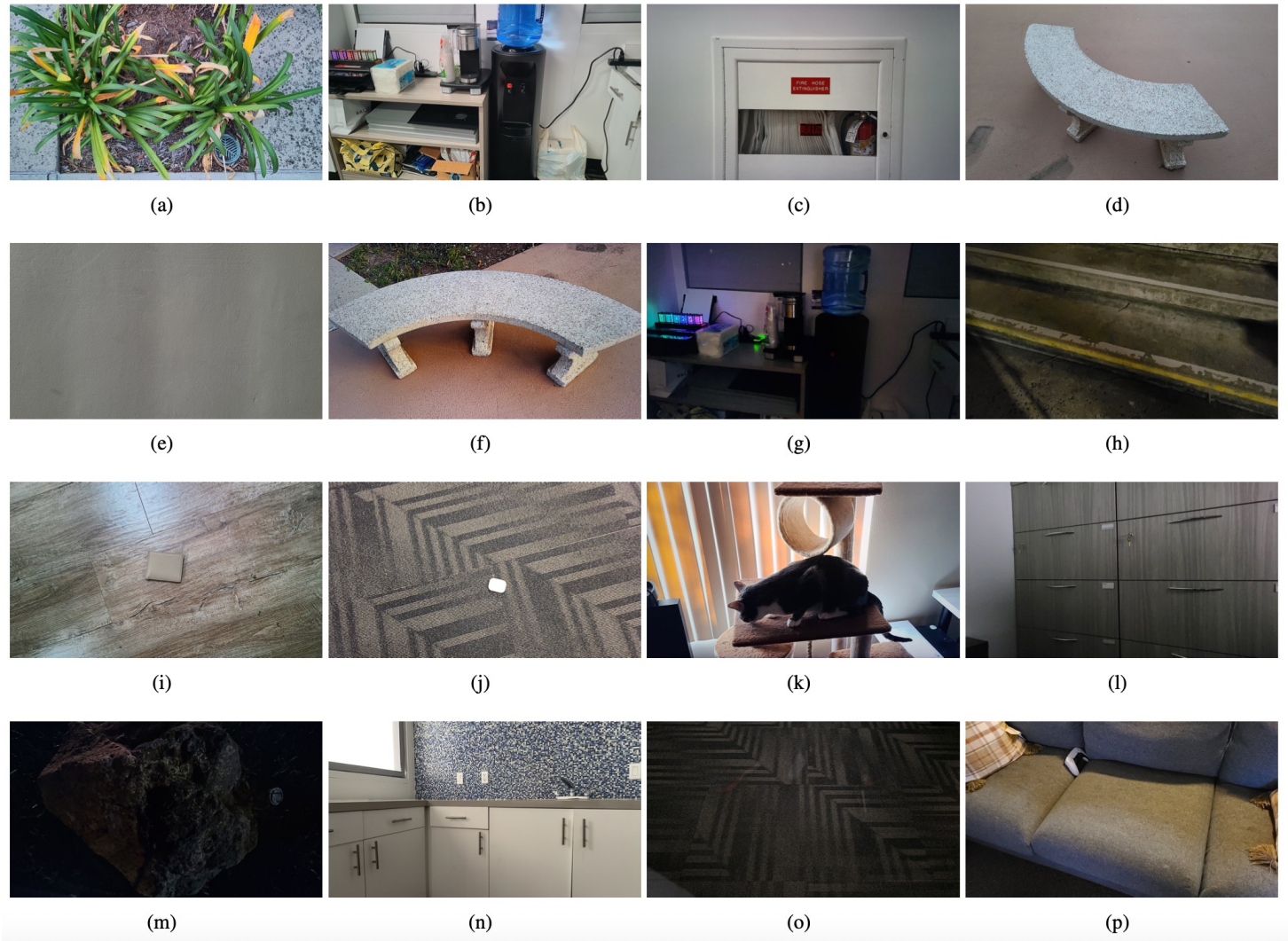
User study

- 16 photos (8 original / 8 recaptured)
- 43 adult participants
- All done on one 14-inch 2K display laptop



User study

- 16 photos (8 original / 8 recaptured)
- 43 adult participants
- All done on one 14-inch 2K display laptop
- Accuracy (correct classification) at 50.15% $(t(42) = 0.071, p = 0.944)$



So how do we tackle such an attack?

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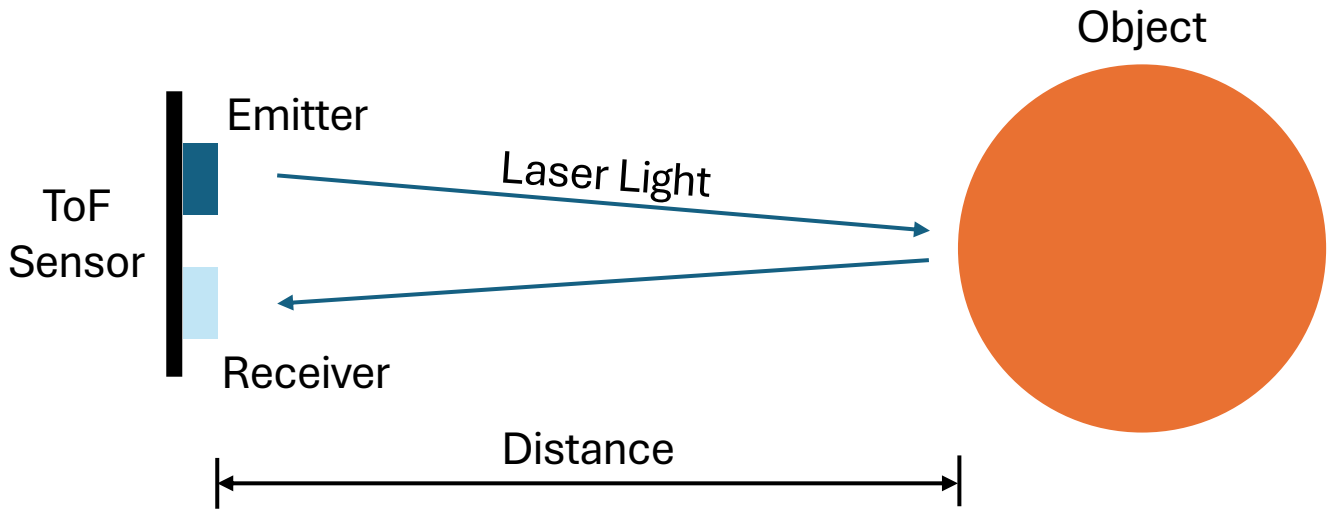
- Aftermath analysis-based approaches are an endless race that’s unlikely to win

So how do we tackle such an attack?

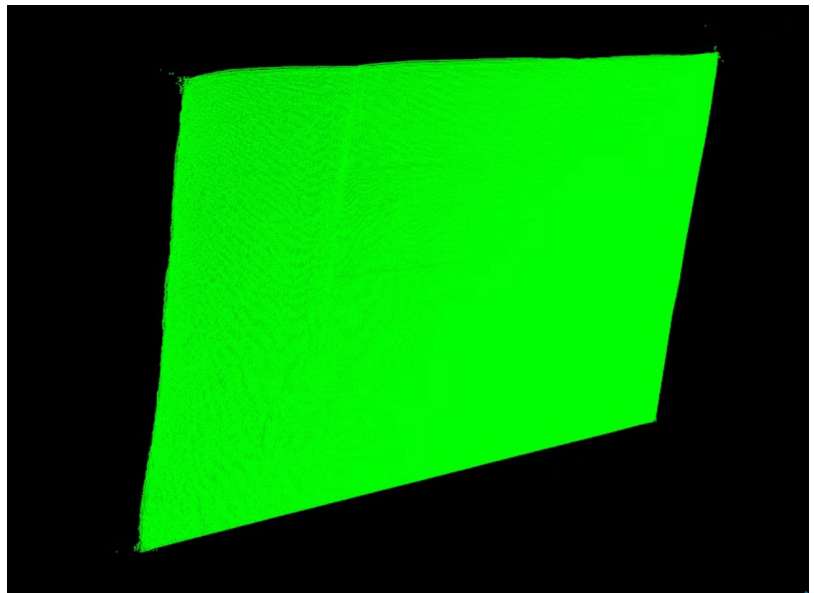
- Aftermath analysis-based approaches are an endless race that's unlikely to win
- Provenance can still help

Depth-enabled provenance

- Time-of-Flight depth sensors (dToF and iToF)
- Measure distance to a target
- Equipped on modern smartphones (e.g., Apple, Samsung, etc.)




Depth Prov.

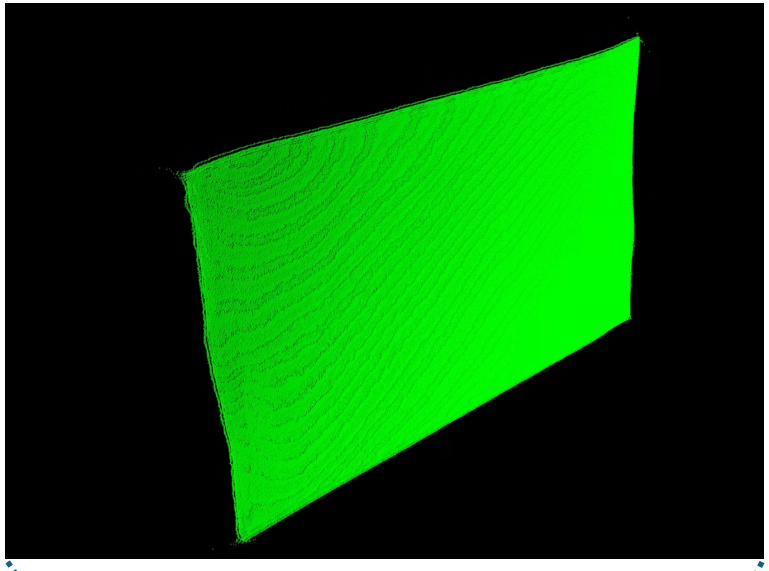


Depth Prov.

Challenge 2

- Not all flat surfaces are recaptures


Depth Prov.



Depth Prov.

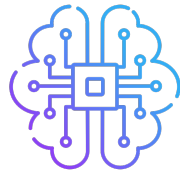
Catching misleading recaptures

Catching misleading recaptures

- Let’s compare human perception of depth with the provenance depth

Catching real recaptures

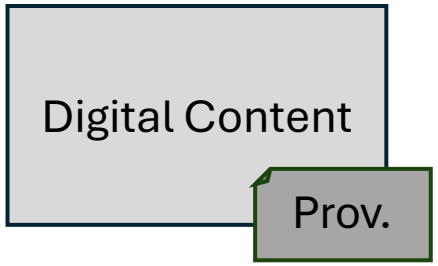
- Let’s compare human perception of depth with the provenance depth
  - Learning-based monocular depth estimation



Introducing Scoop

- **In**: A photo/video with depth-enabled provenance
- **Out**: The same photo/video with misleading recapture regions highlighted

Scoop’s design



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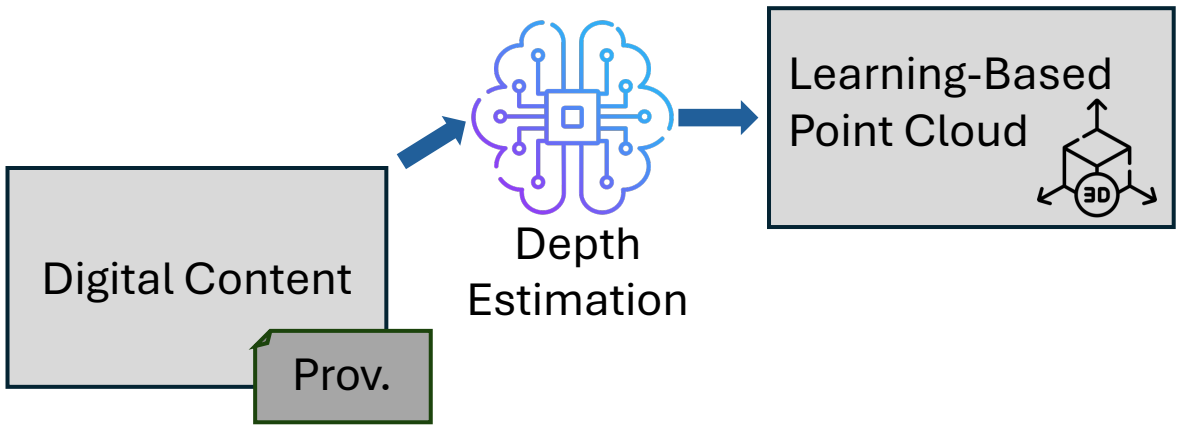

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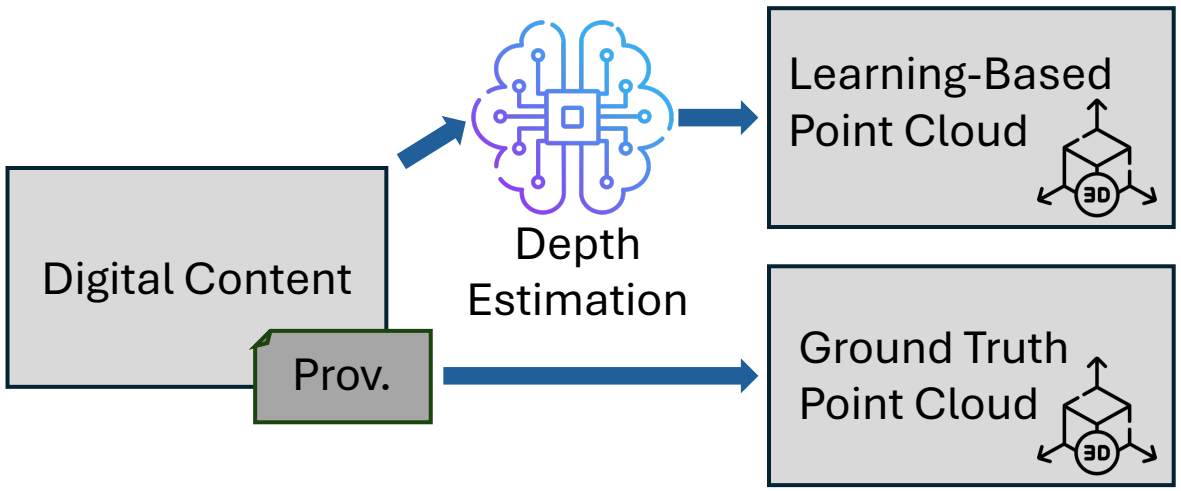

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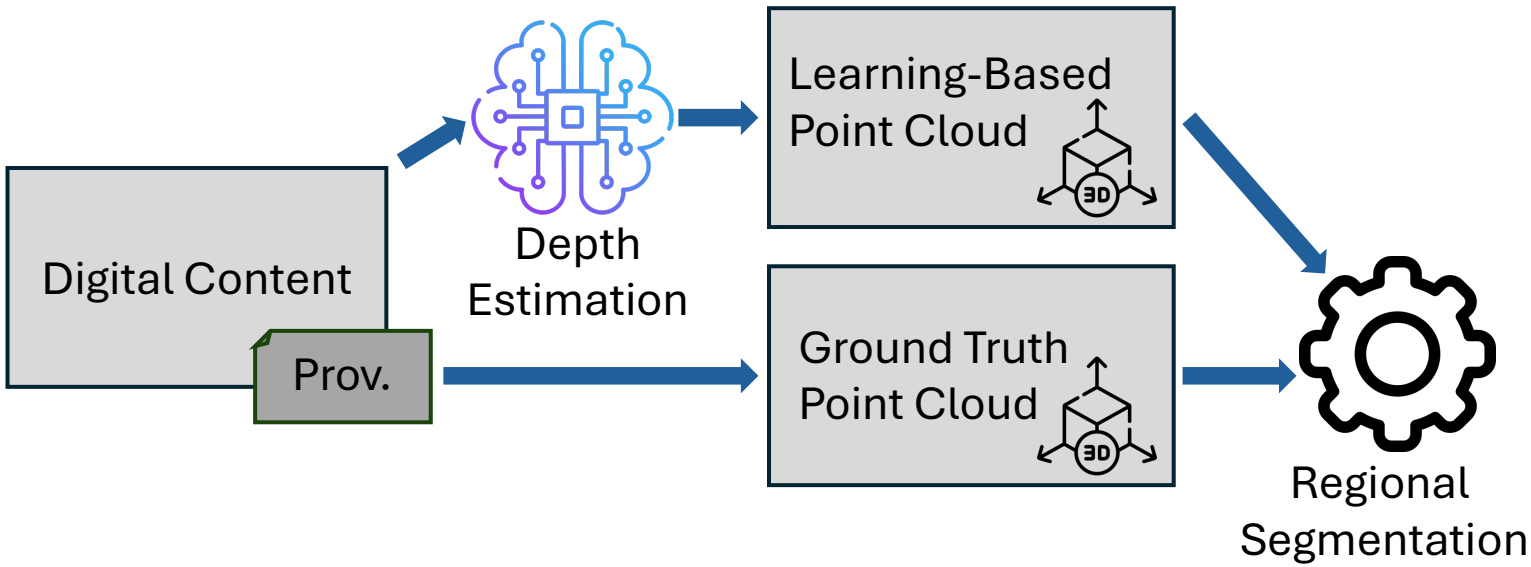

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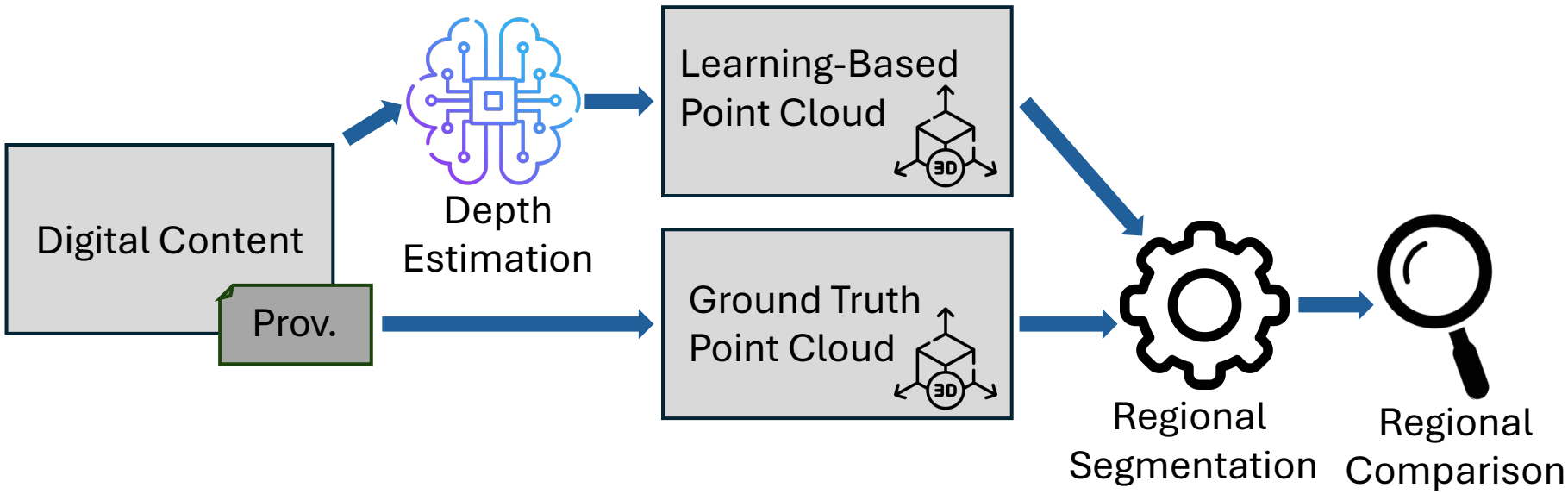

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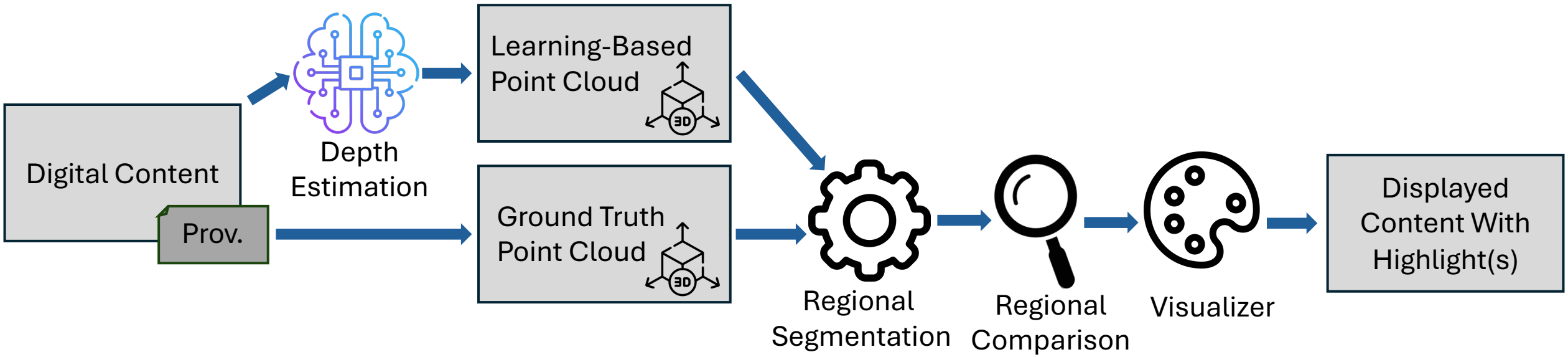

Scoop in action

Captured photo
(w/ Depth Provenance)

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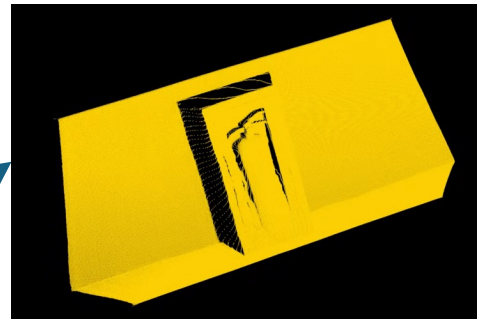
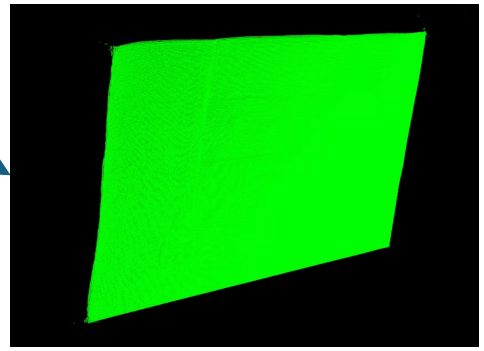


Learning-based point cloud



Ground truth point cloud

Scoop in action

Captured photo
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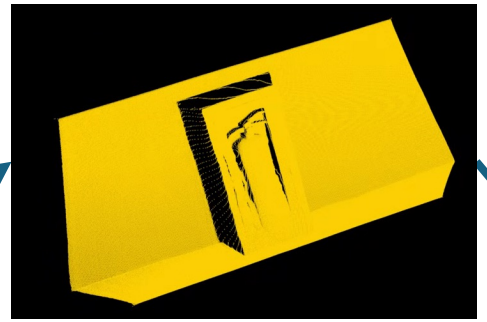

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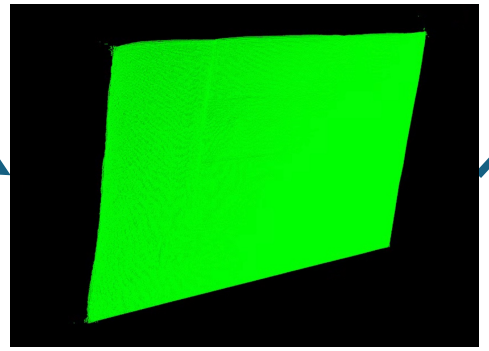

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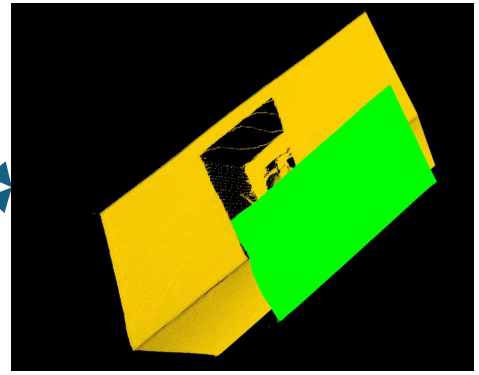
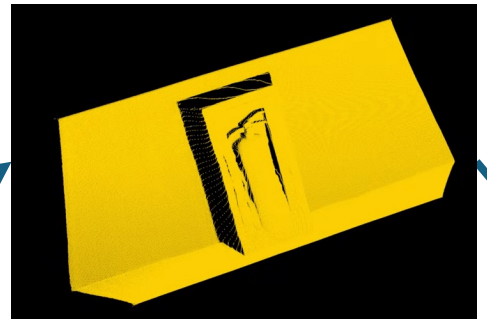


Comparison

Scoop in action

Captured photo
(w/ Depth Provenance)



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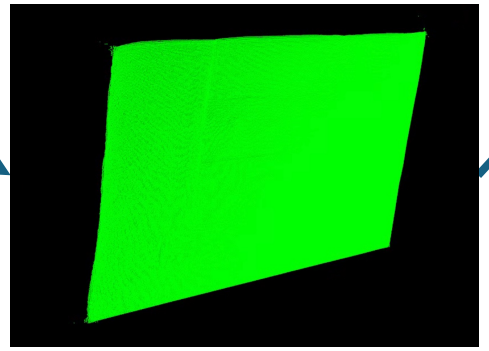

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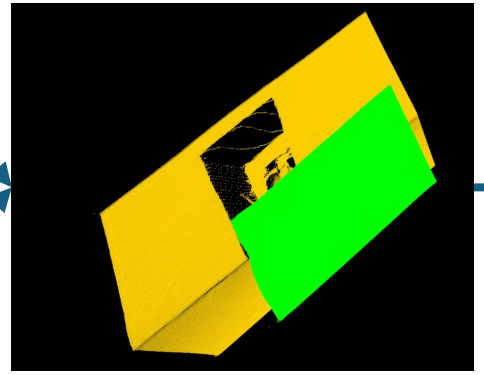


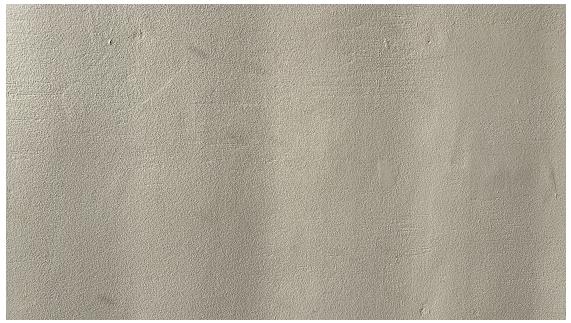
Comparison

Displayed photo
(w/ Highlight)

Scoop in action

Captured photo
(w/ Depth Provenance)

Scoop in action



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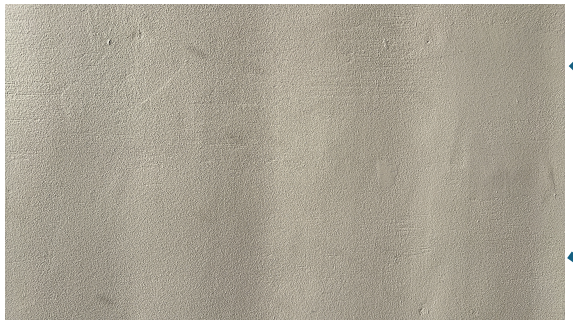

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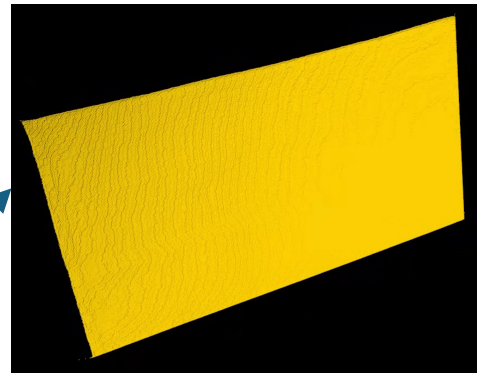

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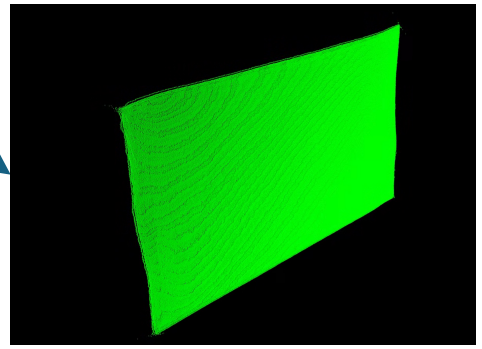

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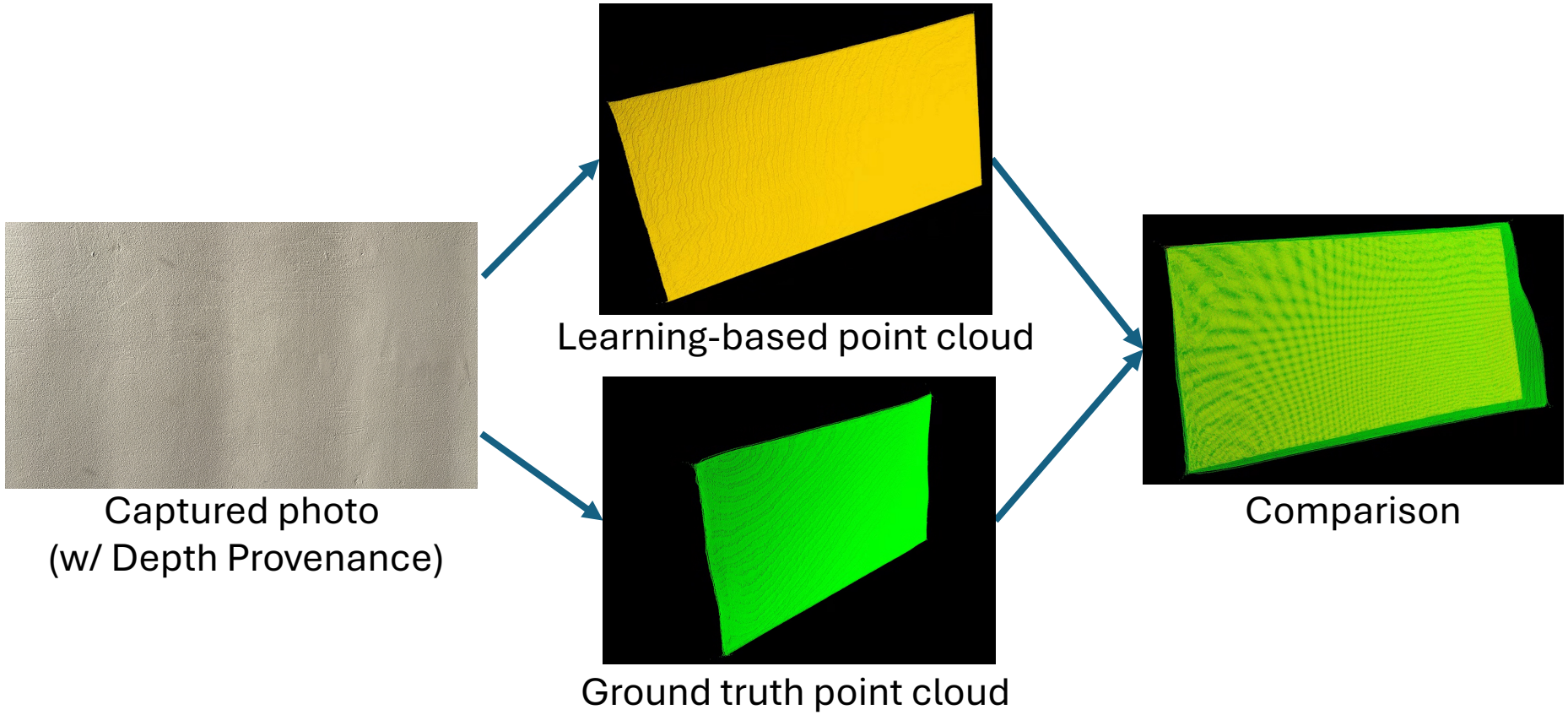

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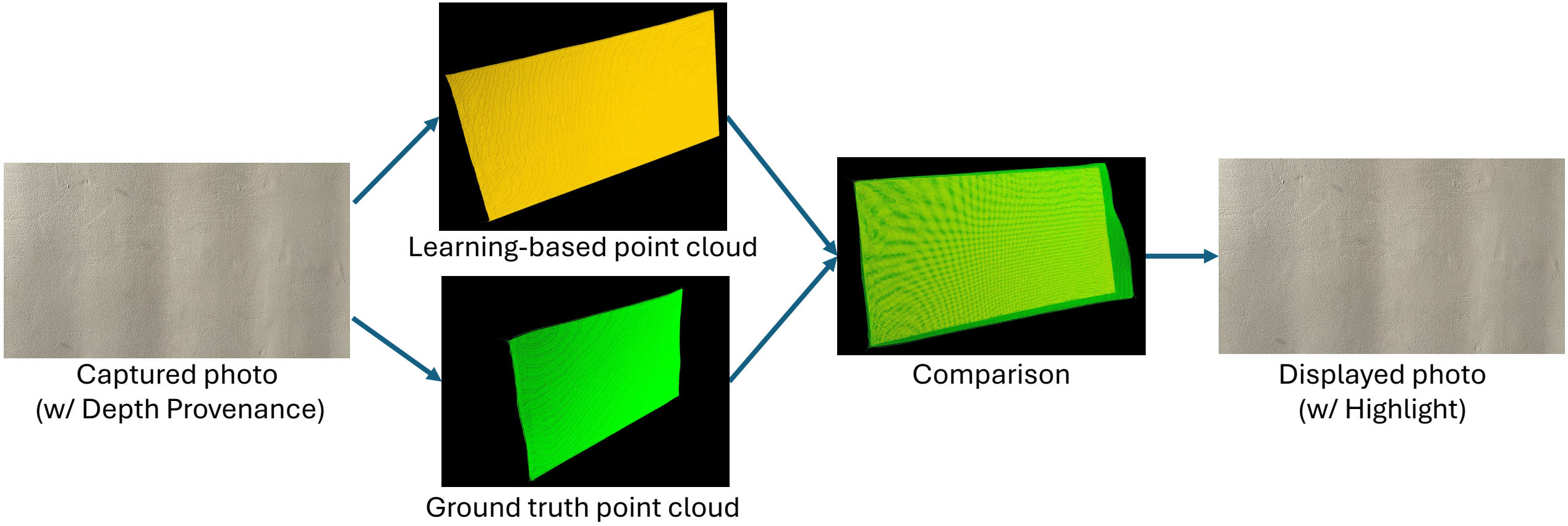

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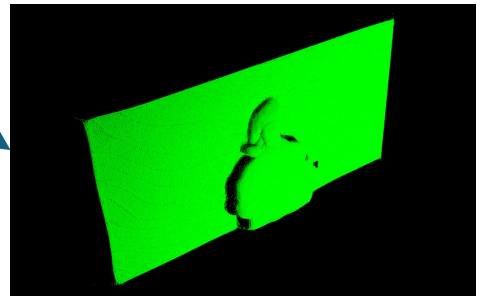

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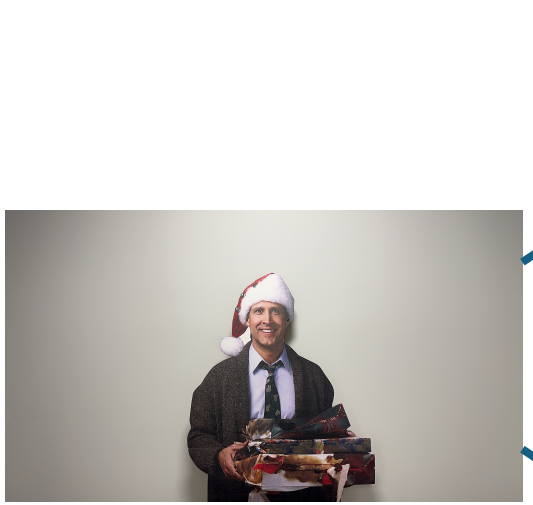

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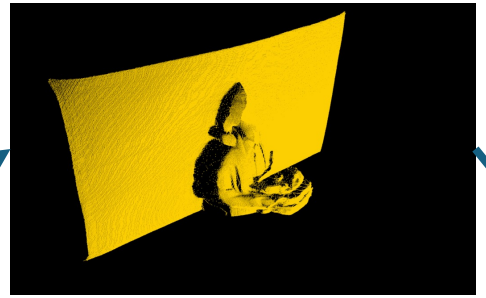
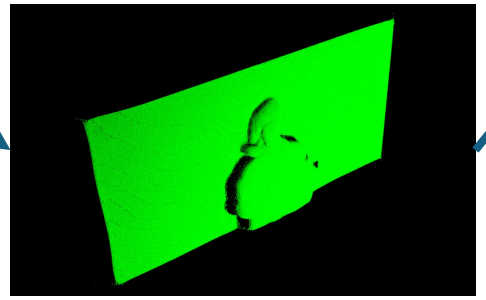
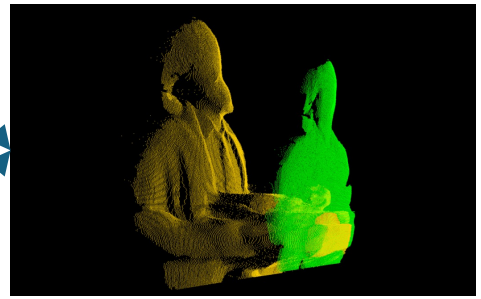


Learning-based point cloud

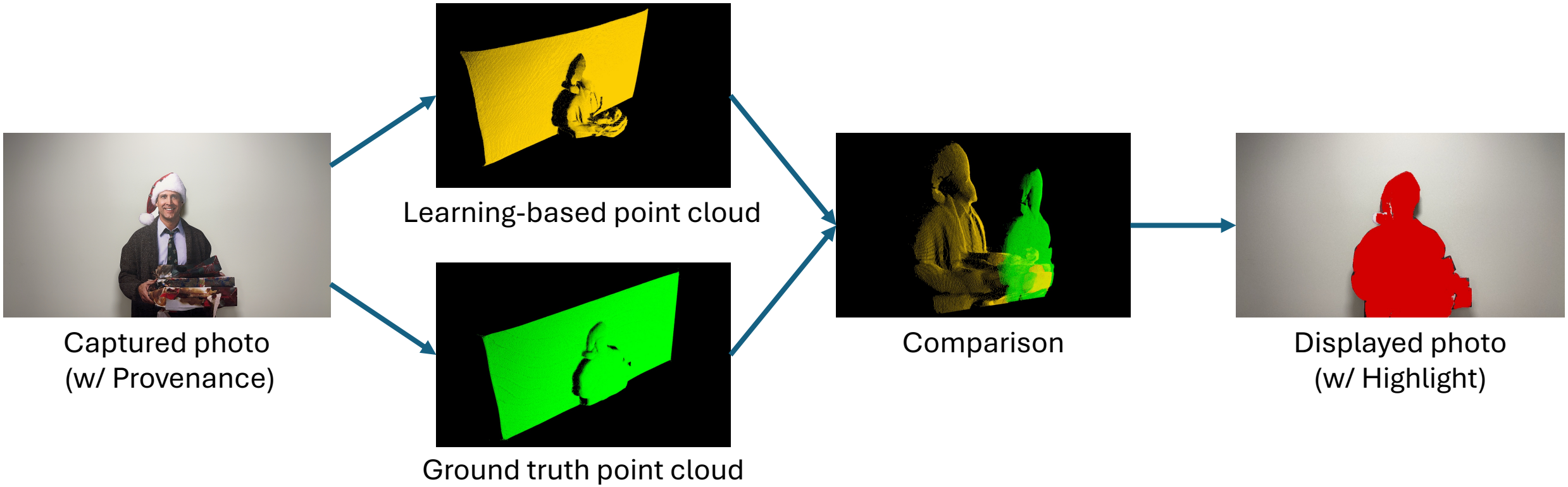


Ground truth point cloud



Comparison

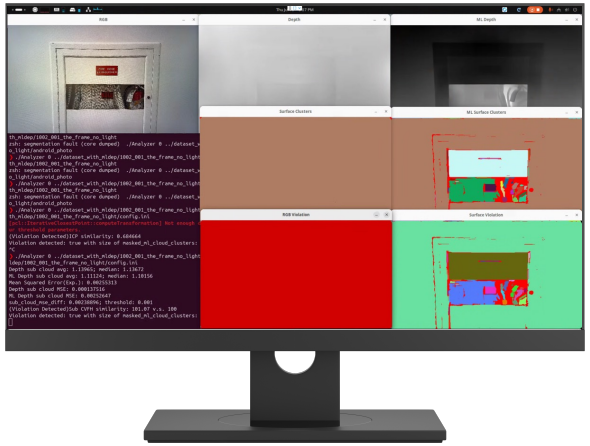
Scoop in action



Prototypes

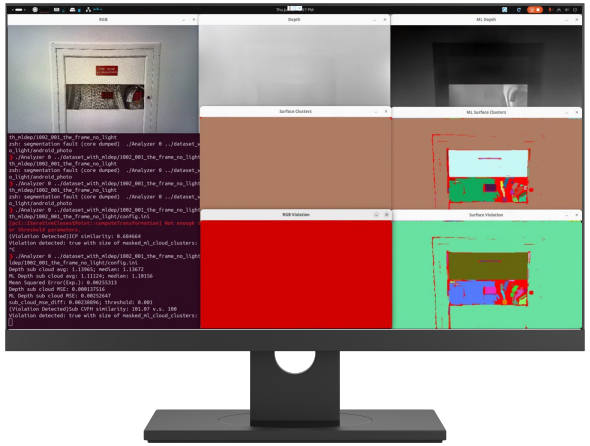
Prototypes

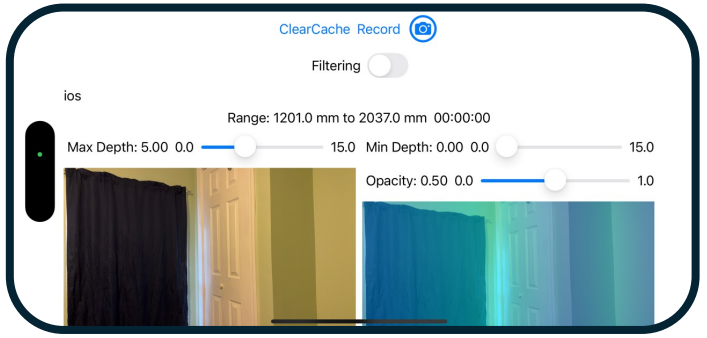
- A desktop Viewer application (OpenCV and Point Cloud Library)



Prototypes

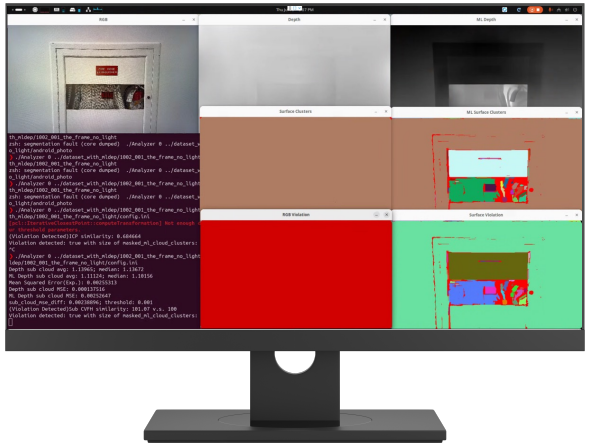
- A desktop Viewer application (OpenCV and Point Cloud Library)
- An iOS camera application

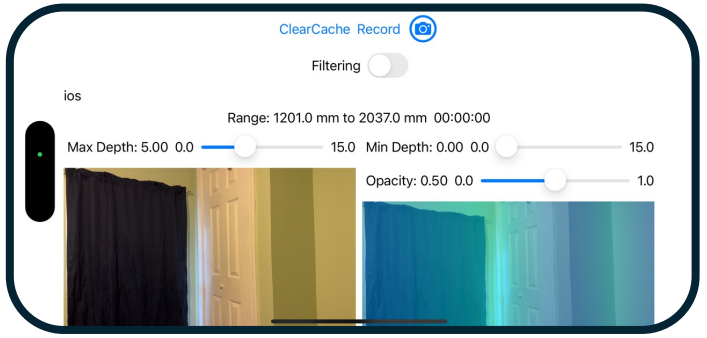


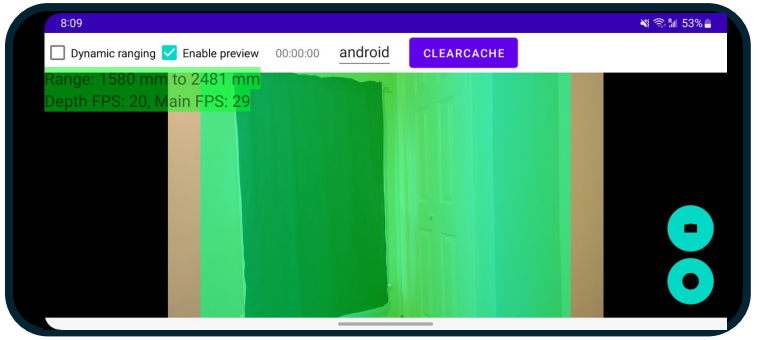


Prototypes

- A desktop Viewer application (OpenCV and Point Cloud Library)
- An iOS camera application
- An Android camera application







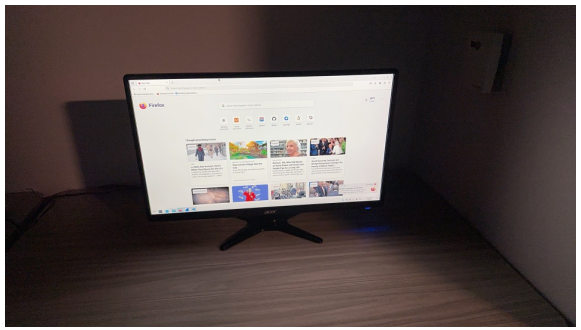
Evaluation

Challenge 3

- No existing dataset designed for evaluating systems like Scoop

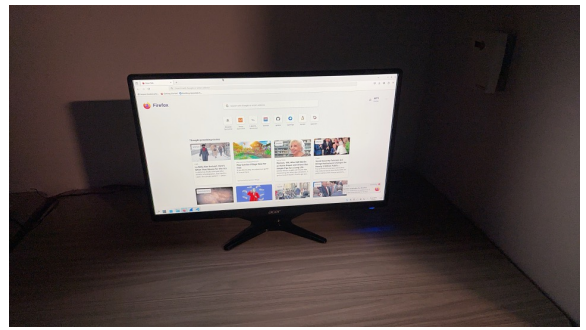
A first-of-its-kind dataset

- Captured using our two smartphone prototypes



A first-of-its-kind dataset

- Captured using our two smartphone prototypes
- 122 unique data points
- 78 recapture scenarios (TVs, cardboard cutouts, projector, and mixed)



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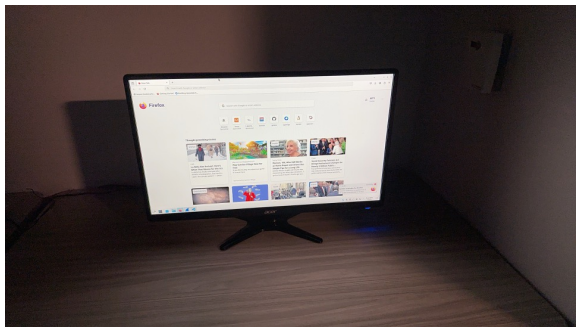
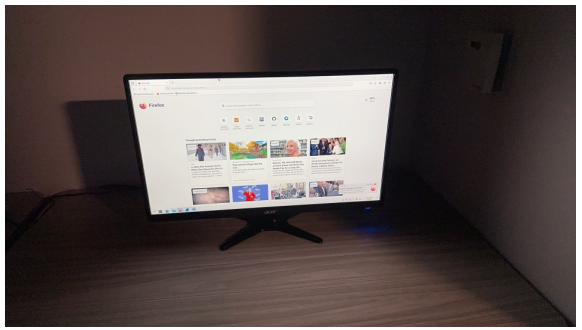


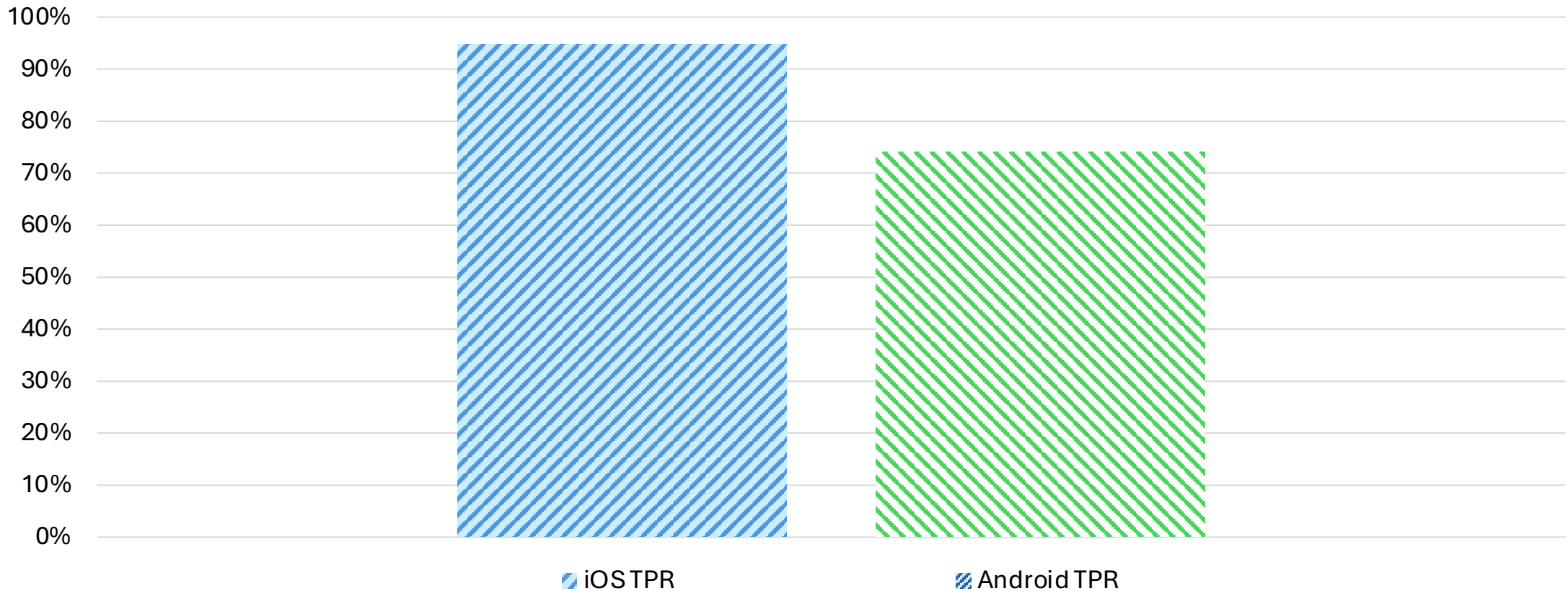
A first-of-its-kind dataset

- Captured using our two smartphone prototypes
- 122 unique data points
- 78 recapture scenarios (TVs, cardboard cutouts, projector, and mixed)
- Both photos and videos
- Cornerstone for evaluating systems such as Scoop



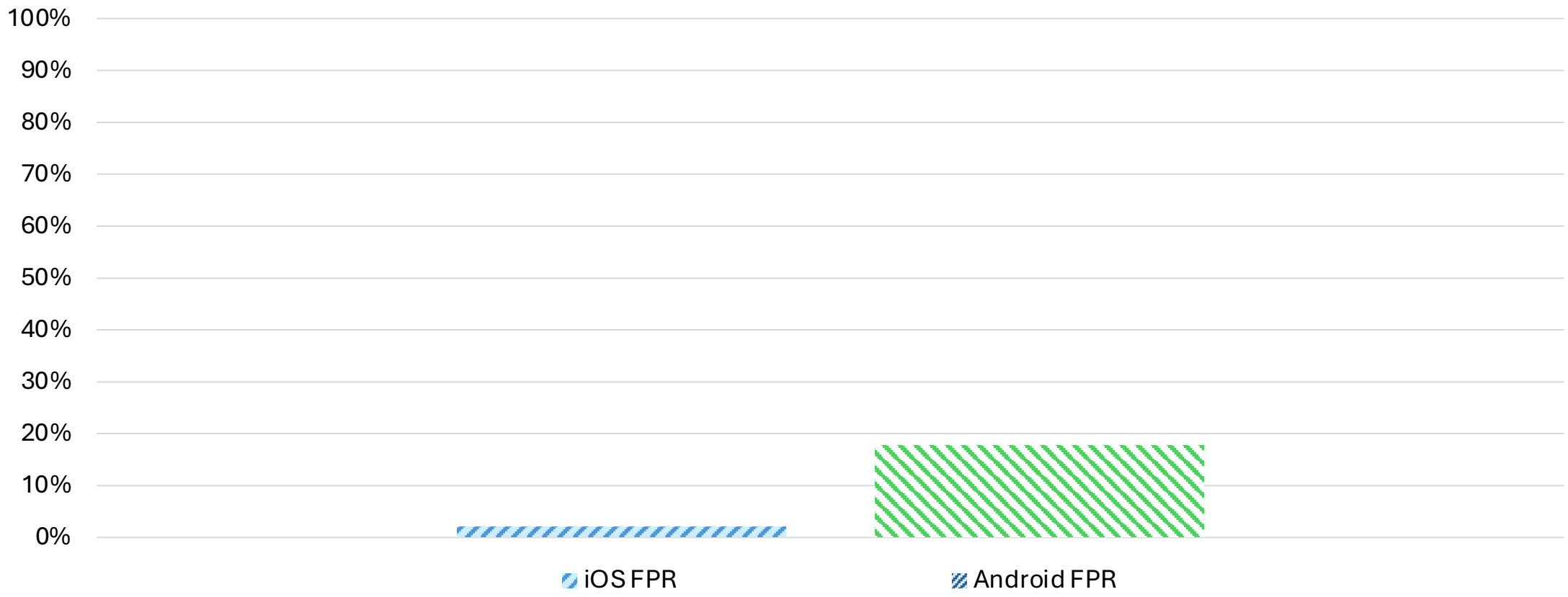
Effectiveness

True positive rate (TPR): Rate of correctly identified misleading recapture

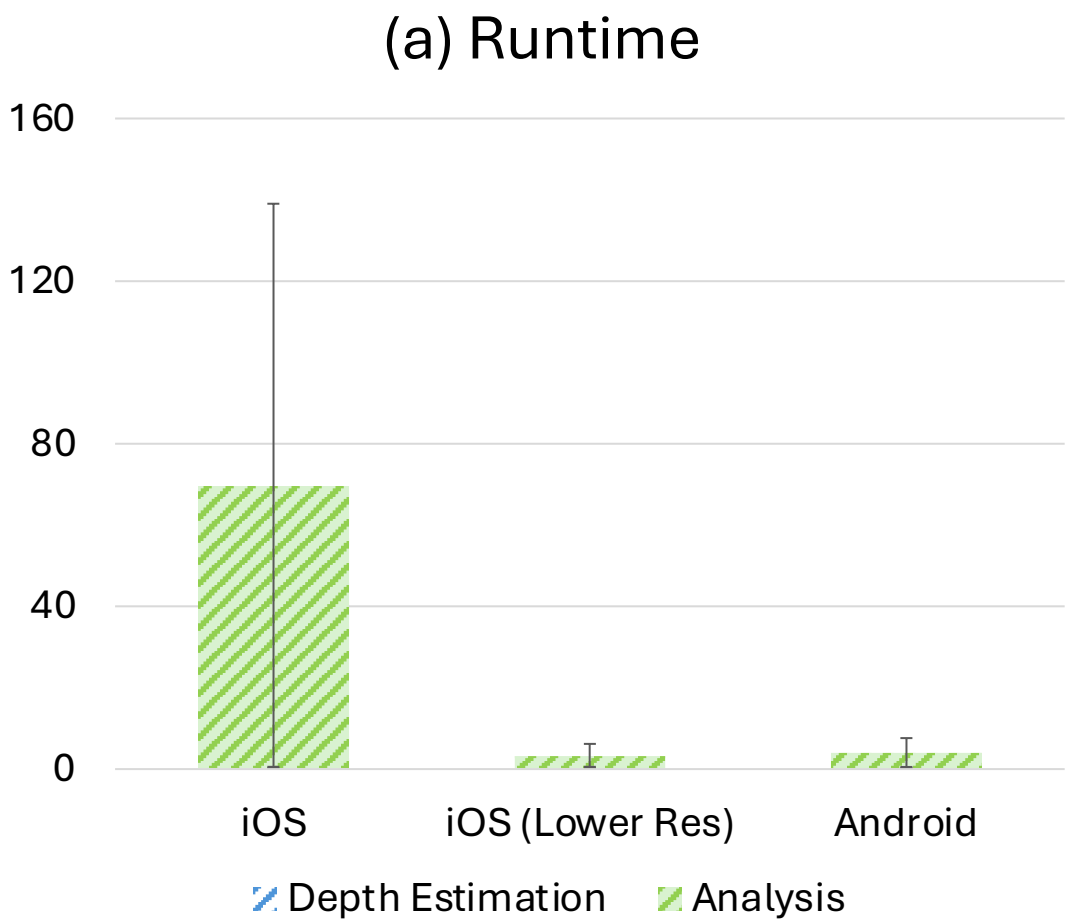


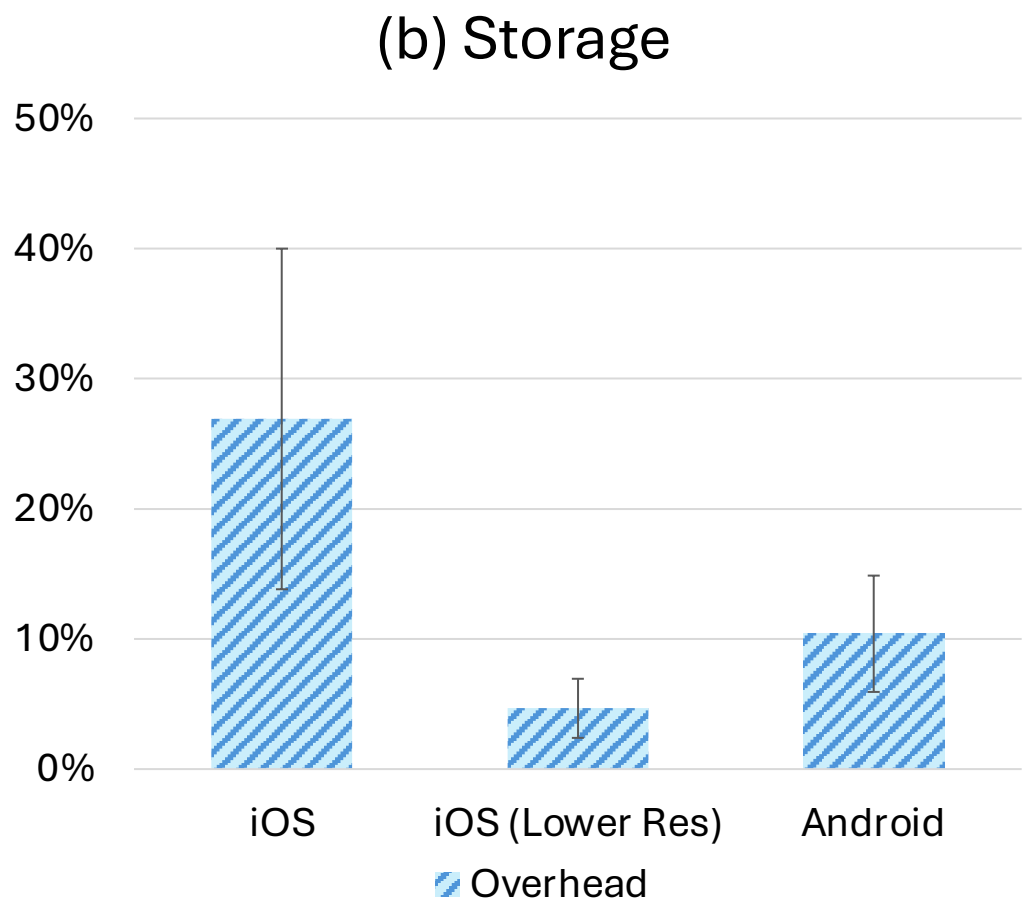
Effectiveness

False positive rate (FPR): Rate of incorrectly identified benign as recapture



Overhead


(a) Runtime
160
120
80
40
0
iOS
iOS (Lower Res)
Android
Depth Estimation
Analysis


(b) Storage
50%
40%
30%
20%
10%
0%
iOS
iOS (Lower Res)
Android
Overhead

Summary

- Shed light on an important vulnerability in existing provenance-based techniques

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- Fully functional Scoop prototype based on commodity devices

Summary

Paper: **Code:**

- Shed light on an important vulnerability in existing provenance-based techniques
- Design of Scoop, an effective countermeasure against recapture attacks
- A first-of-its-kind dataset for evaluating systems like Scoop
- Fully functional Scoop prototype based on commodity devices

Thank you!

Questions? Feel free to email to yuxin.liu@uci.edu