Improving Face Recognition in Lensless Imaging Systems

Junho Kim, Salman S. Khan, Ashok Veeraraghavan
Rice University, Houston, TX

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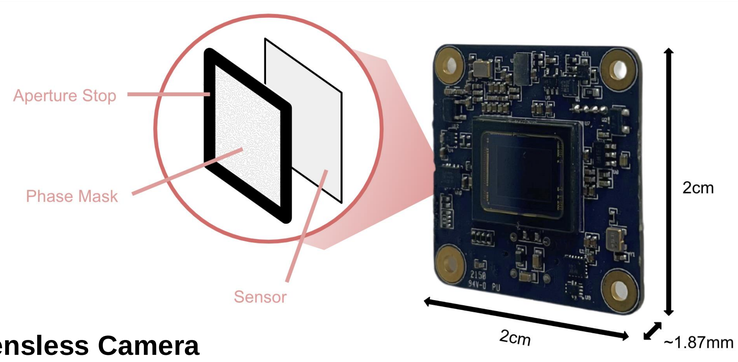
Background



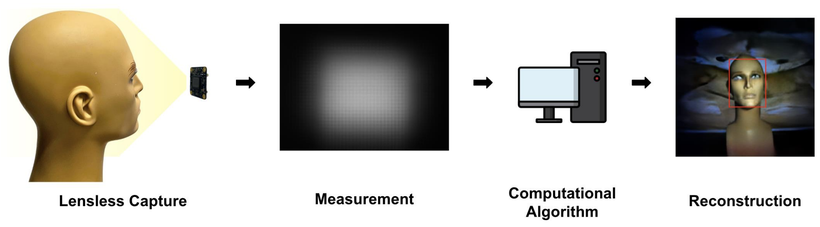
Lensless Camera

- Ultra-thin, compact, and lightweight design.
- Captures encoded measurements instead of direct images.
- Offers cost-effective and scalable imaging solutions for various applications.

Face Recognition

- Applications in security, surveillance, and privacy-preserving imaging.
- Growing maturity in real-world applications.

Overview



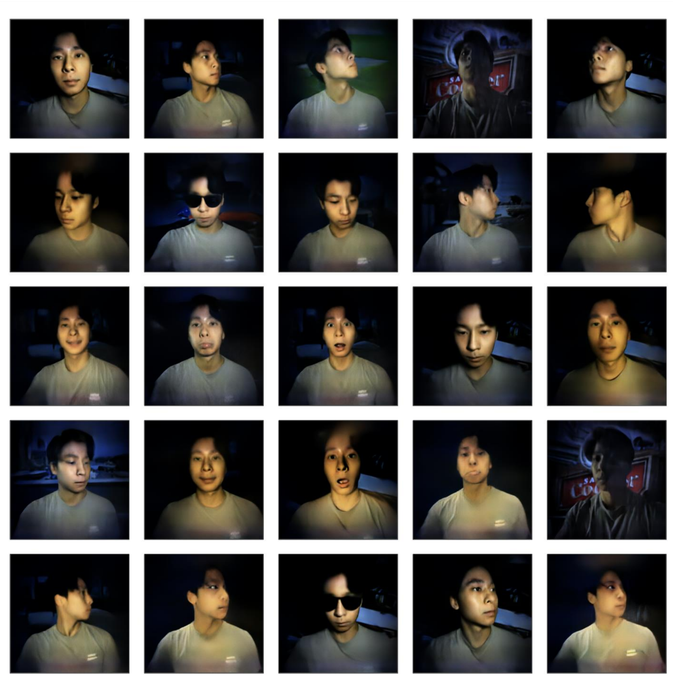
Objective

- Collect a large-scale, real-world face dataset for face recognition using a lensless camera (PhlatCam).
- Enhance the accuracy of face recognition in lensless imaging systems across different lensless camera prototypes.

Contribution

- ➢ Introduced a real-world face dataset (~17,108 images, 90+ participants).
- ➢ Demonstrated model weight transferability across different lensless camera prototypes (PhlatCam → DiffuserCam).
- ➢ Enhanced face recognition in trainable networks with real-world data.

Data Collection

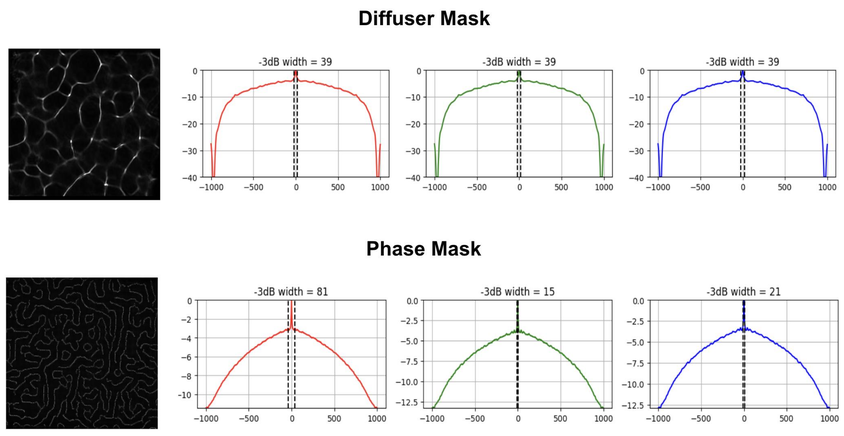


Subjects	91	Lighting	9
Total Images	17108	Angles	12
Expressions	5	Location	Indoor, Outdoor
Occlusion	Sunglasses	Pose	Sitting, Standing

Key Concepts

Point Spread Function (PSF)

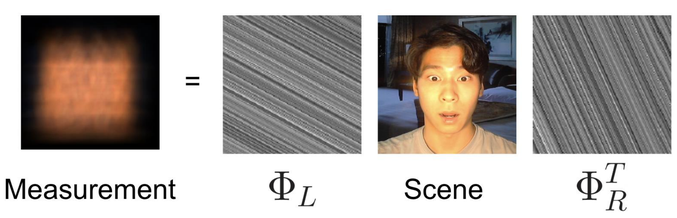
- Describes how a point source spreads or blurs in an image.
- Autocorrelation evaluates self-similarity, with a sharp peak indicating high shift sensitivity.



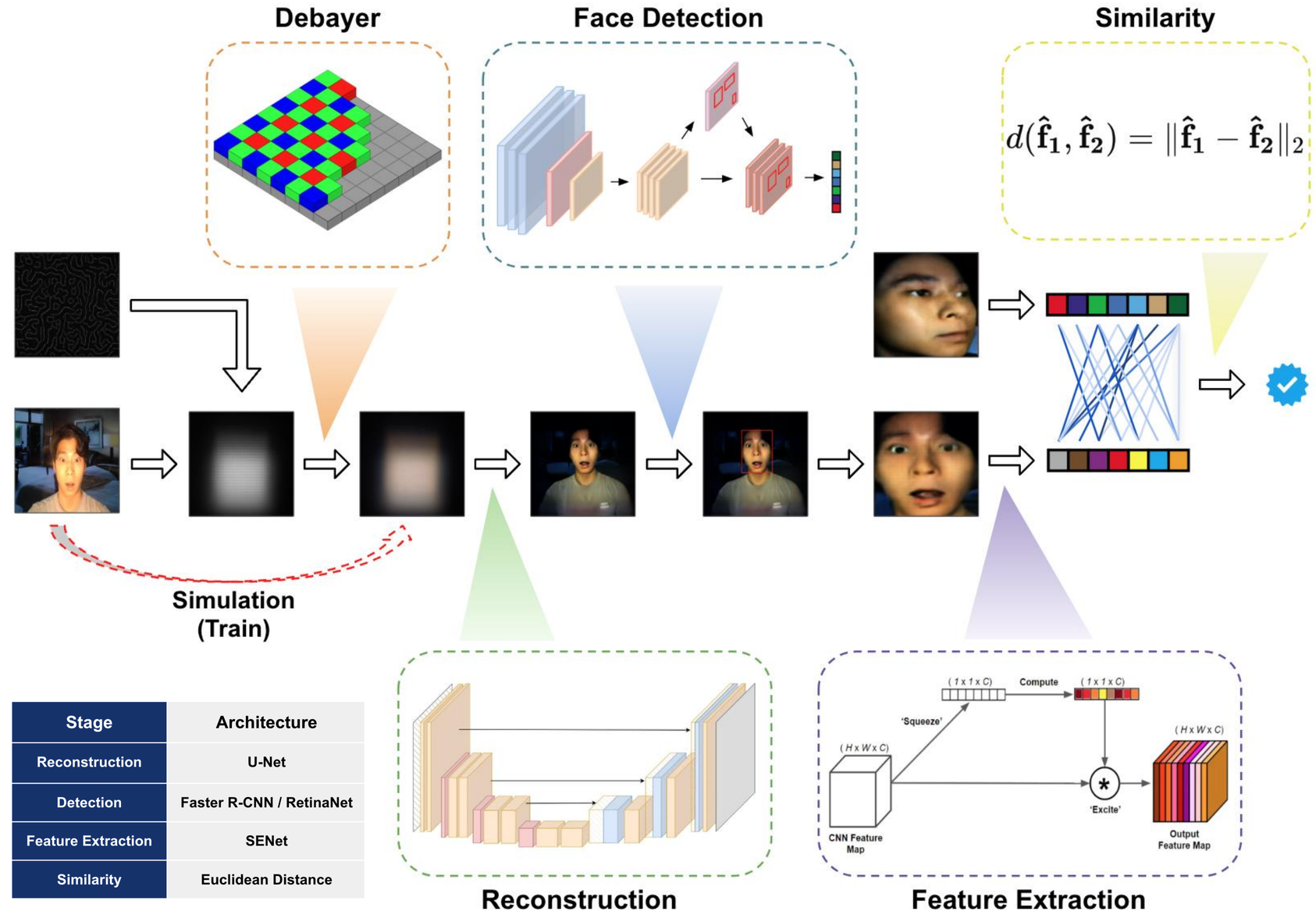
Simulation

- Convolution in spatial domain ↔ Multiplication in Fourier space.
- Efficient and scalable for generating large training datasets.
- Limited accuracy due to sim-to-real gap in real-world captures.

$$Y = \Phi_L X \Phi_R^T + N$$

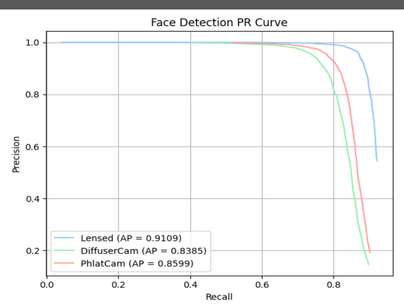


Computational Architecture

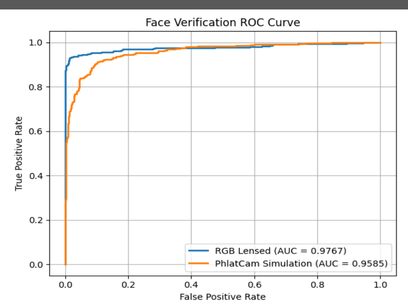


Stage	Architecture
Reconstruction	U-Net
Detection	Faster R-CNN / RetinaNet
Feature Extraction	SENet
Similarity	Euclidean Distance

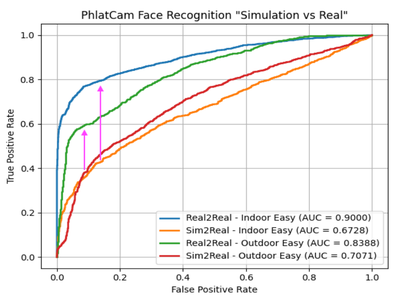
Evaluation & Results



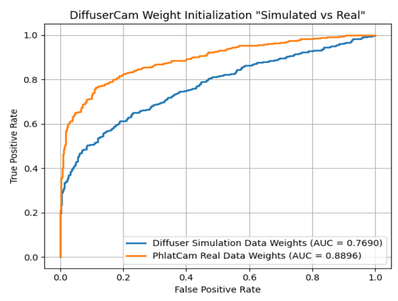
Result [1] – Lensed images outperform lensless on FDDB face detection.



Result [2] – Lensed and simulated lensless images show similar performance on LFW.



Result [3] – Finetuning with real-world data improves face verification.



Result [4] – Initializing face verification networks with real face data improves performance.

1. Face Detection Results on FDDB Dataset

Variation	F1 Score (%)	Accuracy (%)
DiffuserCam	83.66	71.91
PhlatCam	85.96	75.38
Lensed	91.30	83.99

Reconstruction and Detection Impact Recognition Performance

2. Face Verification Results on LFW Dataset

Variation	FPR=1%	FPR=0.1%	Accuracy
DiffuserCam Simulation	39.4%	0.0%	76.9%
PhlatCam Simulation	63.6%	0.0%	90.5%
RGB Lensed	90.4%	0.0%	95.7%

3. Face Verification Results on Real World Dataset

Variation	FPR=1%	FPR=0.1%	Accuracy
Real2Real - Indoor Easy	59.04%	41.35%	84.2%
Real2Real - Outdoor Easy	19.22%	1.28%	75.77%
Sim2Real - Indoor Easy	13.84%	1.81%	64.94%
Sim2Real - Outdoor Easy	4.77%	0.67%	66.53%

Conclusion

1. Lens-based images achieve higher accuracy in both detection and verification tasks compared to lensless images.
2. Lensless images demonstrate competitive performance in detection and verification relative to lens-based images, despite inherent differences.
3. PhlatCam exhibits higher shift sensitivity, as evidenced by autocorrelation analysis, while also outperforming DiffuserCam in both detection and verification tasks.
4. The sim2real gap remains significant across both indoor and outdoor imaging conditions.
5. A real-world training dataset captured with the PhlatCam prototype can be effectively transferred to DiffuserCam through weight initialization.