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https://reality.ssu.ac.kr/

SIDL: A Real-World Dataset for Restoring Smartphone Images with Dirty Lenses



Sooyoung Choi, Sungyong Park, Heewon Kim
Soongsil University
{csy010921, ejqdl}@soongsil.ac.kr, hwkim@ssu.ac.kr

Motivation

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- Smartphone cameras have become an essential tool in everyday life.
- However, their lenses are often exposed to various contaminants.

Dust particle

Scratched

Fingerprint

Water drop

Can current restoration models *effectively handle lens contamination problems?*

Motivation

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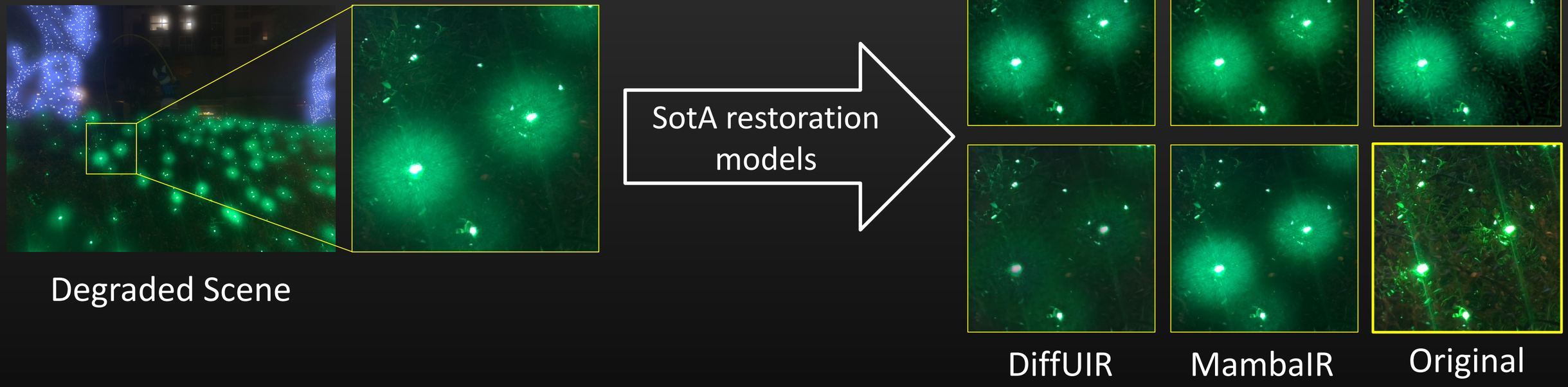
- State-of-the-art restoration models struggled to handle the lens contamination in the real-world.



Why do current models *fail with lens contamination problems?*

→ ***The first step is to create datasets that capture lens contamination images.***

Motivation

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- Previous research has introduced numerous datasets to address various types of image degradation and environmental conditions.

Type	Dataset	Resolution	Device	Real/Synthetic	Multiple Distortions	RAW Data Available	Ref images	Distort images
Deblurring	GOPRO	1280 x 720	Digital camera	Synthetic	✗	✗	3,214	3,214
	HIDE	1280 x 720	Digital camera	Synthetic	✗	✗	8,422	8,422
	RealBlur	680 x 773	Digital camera	Synthetic	✗	✗	232	4,738
Denoising	SIDD	5312 x 2988	Smartphone	Real	✗	✓	200	30,000
	DND	7360 x 4912	Smartphone	Real	✗	✓	50	50
Environmental conditions	O-HAZE	5456 x 3632	Digital camera	Real	✗	✓	45	45
	Dense-Haze	5456 x 3632	Digital camera	Real	✗	✓	33	33
	MPID	1920 x 990	Digital camera	Both	✓	✗	4,543	4,543
	LOL	400 x 600	Digital camera	Real	✗	✗	500	500
Dirty lens	Wang et al. 2023	1920 x 1080	Digital camera	Real	✗	✗	1,251	1,251
	Let's see clearly	384 x 384	Digital camera	Synthetic	✓	✗	18,000	18,000
	SIDL (Ours)	4032 x 3024	Smartphone	Real	✓	✓	300	1,588

However, the previous dirty lens datasets are *limited in scope.*

→ This makes it difficult to develop effective restoration methods.

Proposed SIDL Dataset

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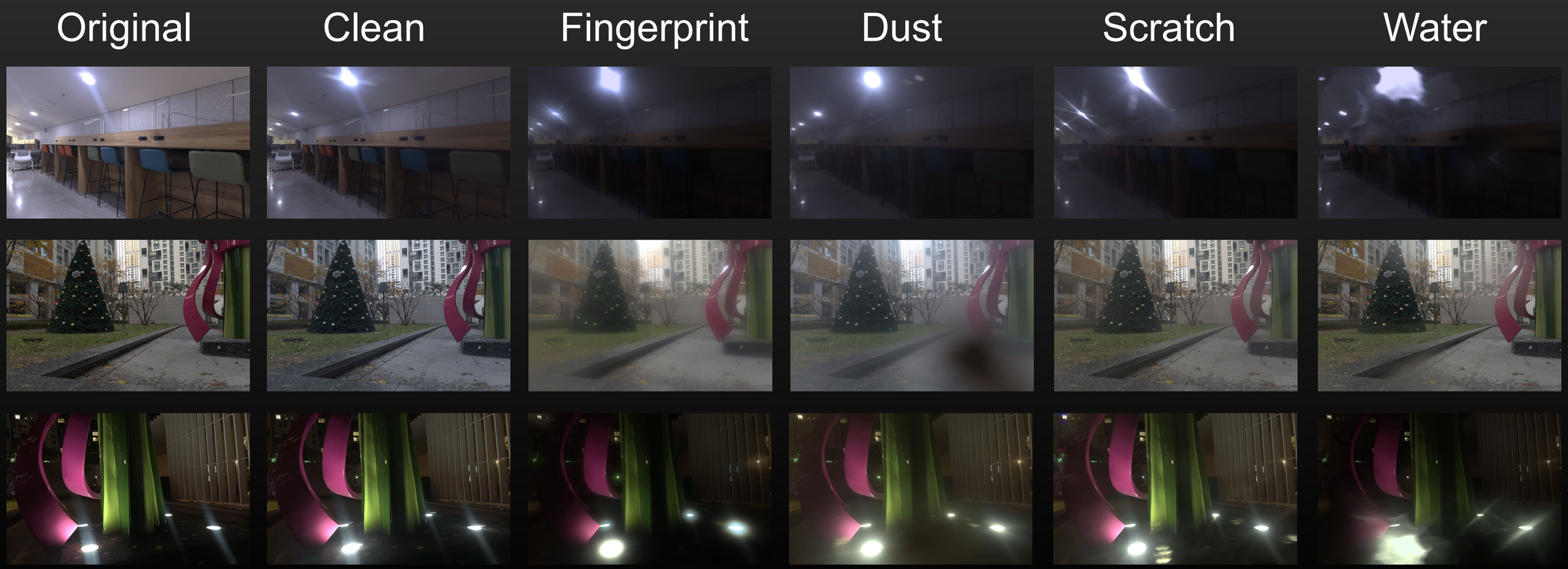
- ***1,588*** image pairs from ***300*** scenes.
- Includes six types of lens contamination.
- Captured under various conditions: day, night, indoor, outdoor, lighting intensity



Proposed SIDL Dataset

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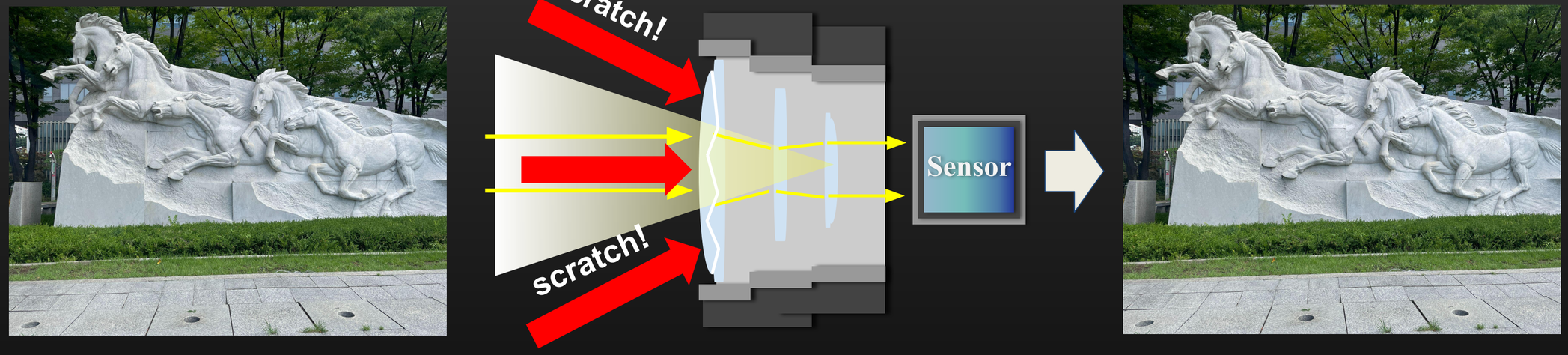
- **General Smartphone Image Capture Process**
  - ***Directly damaging the lens is impractical and expensive.***



How can we replicate real-world contamination during the image acquisition process?

Proposed SIDL Dataset

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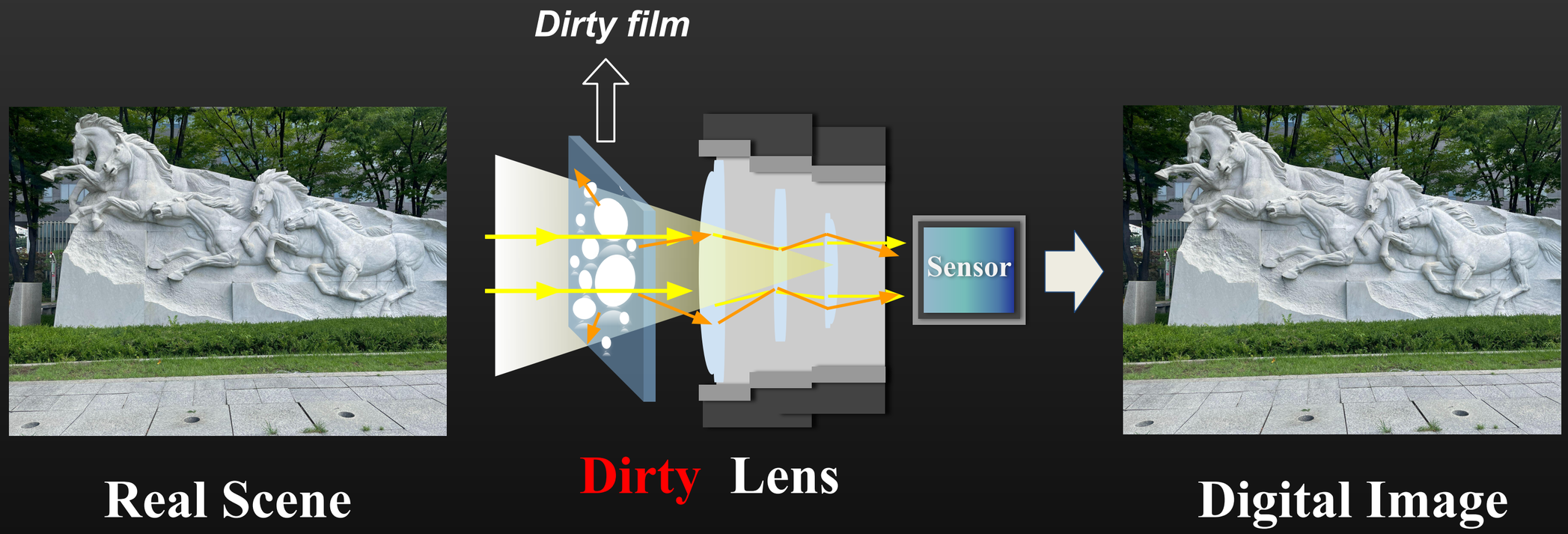
- SIDL (Smartphone Image with Dirty Lens) Capture Process



This approach allows us to create a diverse range of contamination scenarios for the SIDL dataset.

Proposed SIDL Dataset

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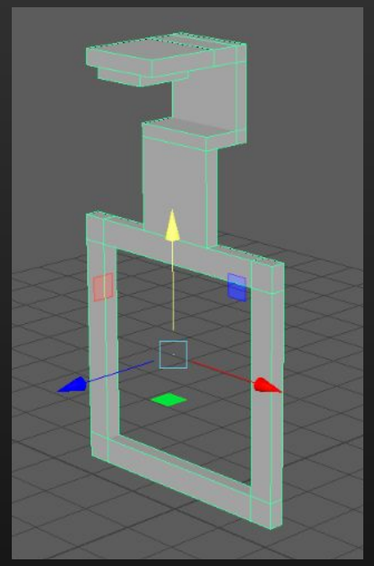
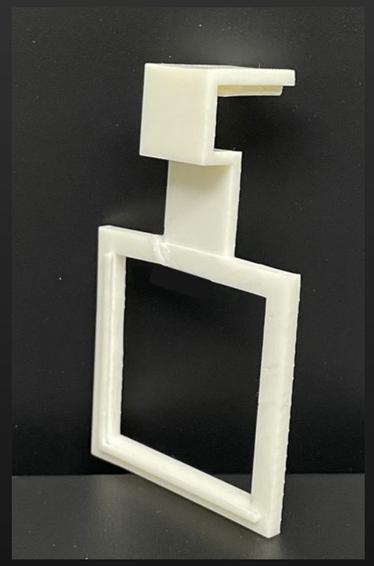
- **Image Acquisition Setup**

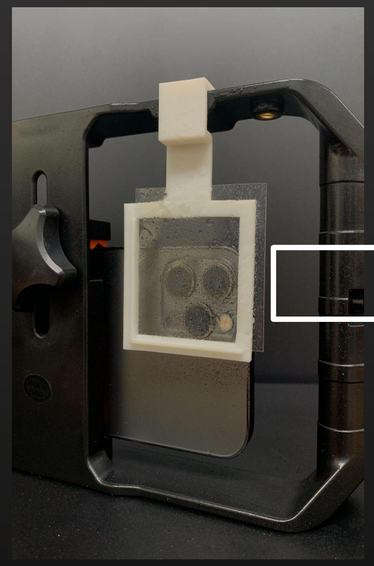


3D modeling using Maya

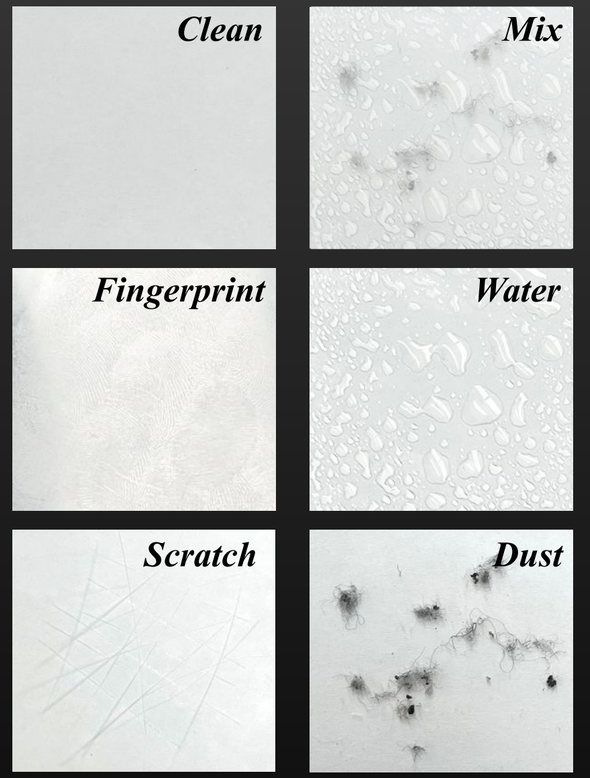
3D Printer



Film holder



Setting



Dirty films

Created new dirty films for each scene to *prevent pattern memorization.*

Proposed SIDL Dataset

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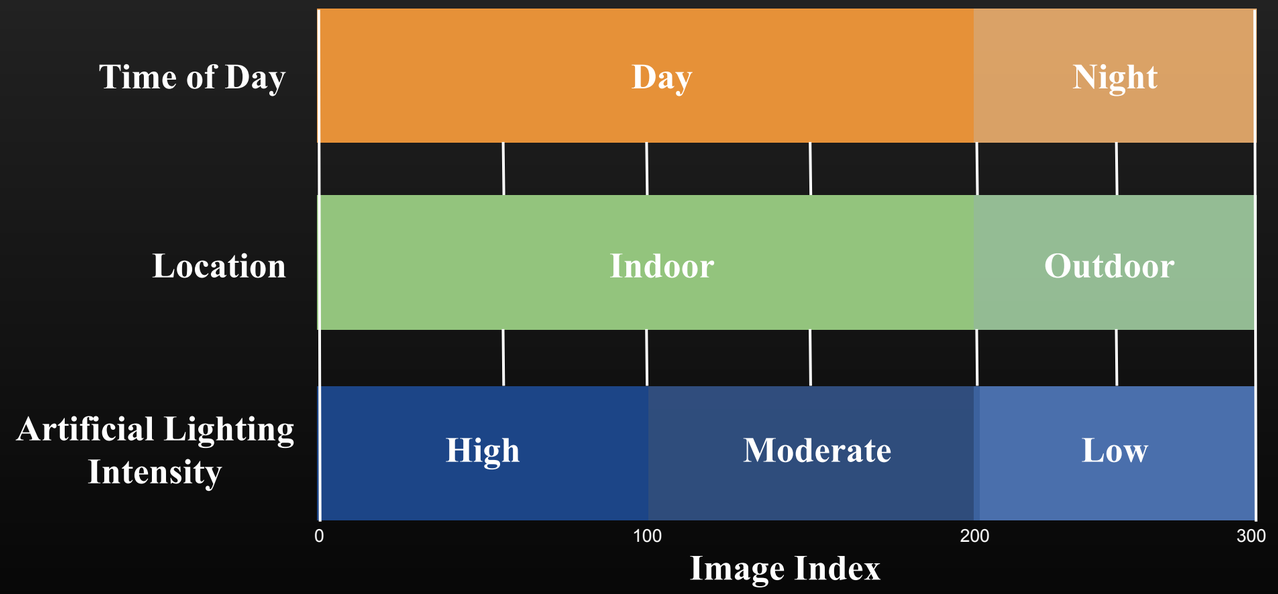
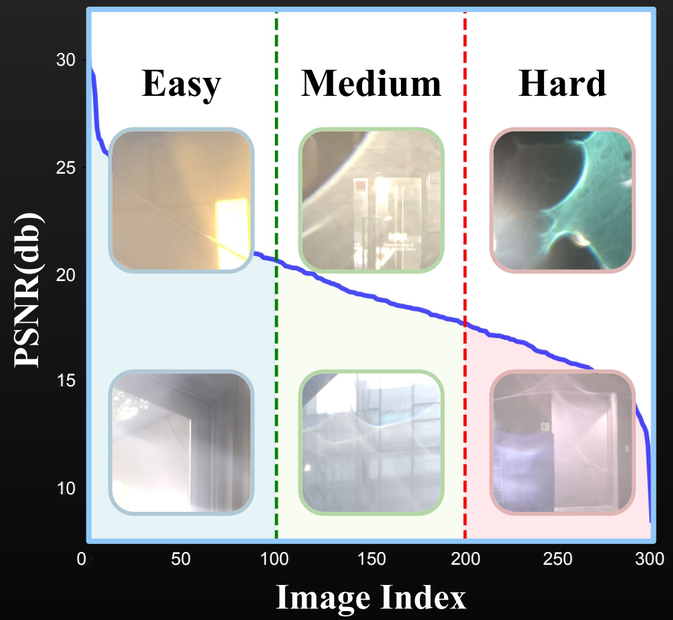
- **Benchmark & Statics**
  - **For each degradation type**, the dataset is split into **240** scenes for training, **20** for validation, and **40** for testing.
  - **Difficulty levels for evaluation:** ***Easy, Medium, Hard*** **(based on PSNR).**





Experiments

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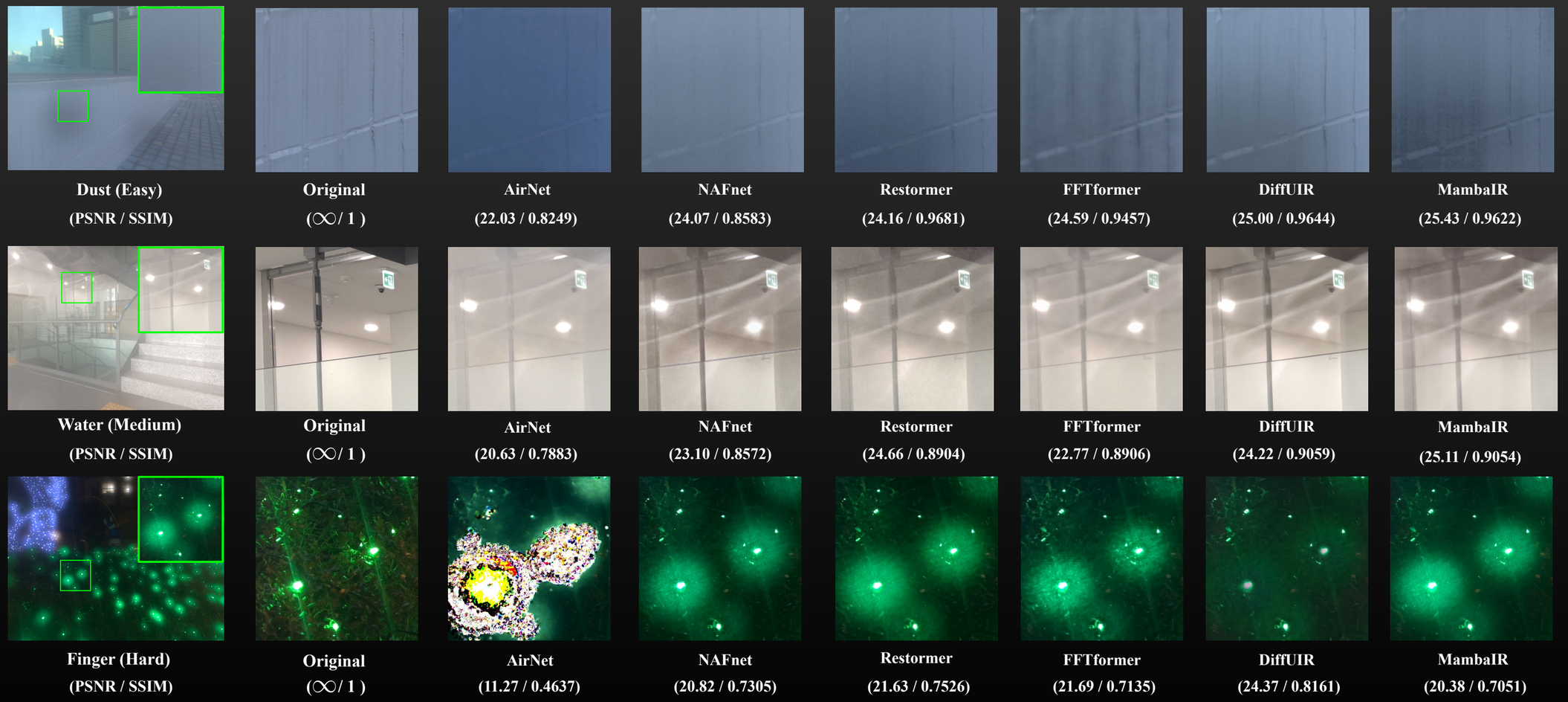
- **Quantitative comparison of restoration methods on SIDL datasets**

Method	Network		Clean PSNR/SSIM	Dust PSNR/SSIM	Fingerprint PSNR/SSIM	Water PSNR/SSIM	Scratch PSNR/SSIM	Mixed PSNR/SSIM	Average PSNR/SSIM
CNN	AirNet	Easy	27.10 / 0.9329	23.40 / 0.8669	25.10 / 0.8708	24.85 / 0.8658	25.84 / 0.8917	25.30 / 0.8422	25.26 / 0.8784
		Medium	26.13 / 0.8899	19.69 / 0.7577	22.53 / 0.8191	20.36 / 0.7656	21.24 / 0.8051	16.79 / 0.7542	21.12 / 0.7986
		Hard	23.79 / 0.8527	16.18 / 0.7350	15.83 / 0.6432	16.64 / 0.7449	18.13 / 0.7975	14.48 / 0.7047	17.50 / 0.7463
	NAFNet	Easy	36.37 / 0.9682	23.19 / 0.8197	28.12 / 0.8987	25.21 / 0.8609	27.55 / 0.8829	22.90 / 0.7569	27.22 / 0.8646
		Medium	32.25 / 0.9312	21.60 / 0.7367	25.45 / 0.8470	22.53 / 0.7834	25.16 / 0.8282	20.16 / 0.7579	24.53 / 0.8141
		Hard	28.56 / 0.9093	19.34 / 0.6985	17.59 / 0.6614	19.61 / 0.7256	20.24 / 0.7734	17.75 / 0.7411	20.51 / 0.7516
Transformer	Restormer	Easy	38.12 / 0.9786	25.65 / 0.9083	28.77 / 0.9186	26.25 / 0.8984	27.00 / 0.9230	22.62 / 0.8435	28.06 / 0.9117
		Medium	34.07 / 0.9368	23.39 / 0.8235	26.08 / 0.8701	24.11 / 0.8400	26.32 / 0.8912	22.41 / 0.8345	26.06 / 0.8660
		Hard	30.49 / 0.9338	21.41 / 0.8349	19.38 / 0.7708	20.85 / 0.8417	21.57 / 0.8528	18.86 / 0.8054	22.09 / 0.8399
	FFTformer	Easy	34.58 / 0.9621	22.79 / 0.8742	28.34 / 0.9053	25.09 / 0.8925	22.59 / 0.8665	21.80 / 0.6909	25.86 / 0.8653
		Medium	31.45 / 0.9137	21.23 / 0.7786	25.22 / 0.8536	22.81 / 0.8162	21.38 / 0.8315	20.64 / 0.7974	23.78 / 0.8318
		Hard	28.29 / 0.9024	19.22 / 0.7935	16.55 / 0.6808	18.21 / 0.7727	18.45 / 0.7891	18.06 / 0.7886	19.80 / 0.7879
Diffusion	DiffUIR	Easy	34.51 / 0.9785	26.96 / 0.9276	28.82 / 0.9331	27.42 / 0.9220	30.14 / 0.9375	28.22 / 0.9021	29.34 / 0.9335
		Medium	33.25 / 0.9375	22.11 / 0.8325	26.16 / 0.8856	24.65 / 0.8647	27.07 / 0.9105	20.32 / 0.8368	25.36 / 0.8786
		Hard	29.47 / 0.9366	20.38 / 0.8602	18.93 / 0.7763	19.91 / 0.8500	21.27 / 0.8599	18.97 / 0.8409	21.71 / 0.8533
Mamba	MambaIR	Easy	36.96 / 0.9807	24.92 / 0.9125	29.26 / 0.9235	26.93 / 0.9488	29.34 / 0.9322	25.30 / 0.8819	28.78 / 0.9299
		Medium	34.62 / 0.9498	23.48 / 0.8298	26.62 / 0.8785	24.23 / 0.8489	27.29 / 0.8955	22.18 / 0.8365	26.40 / 0.8728
		Hard	31.37 / 0.9481	21.87 / 0.8388	19.27 / 0.7750	21.02 / 0.8480	21.98 / 0.8615	19.53 / 0.8249	22.51 / 0.8494

Experiments

- **Qualitative comparison of restoration methods on SIDL datasets**
  - **Severe degradation remains a *challenge for future research***



Experiments: Ablation Studies

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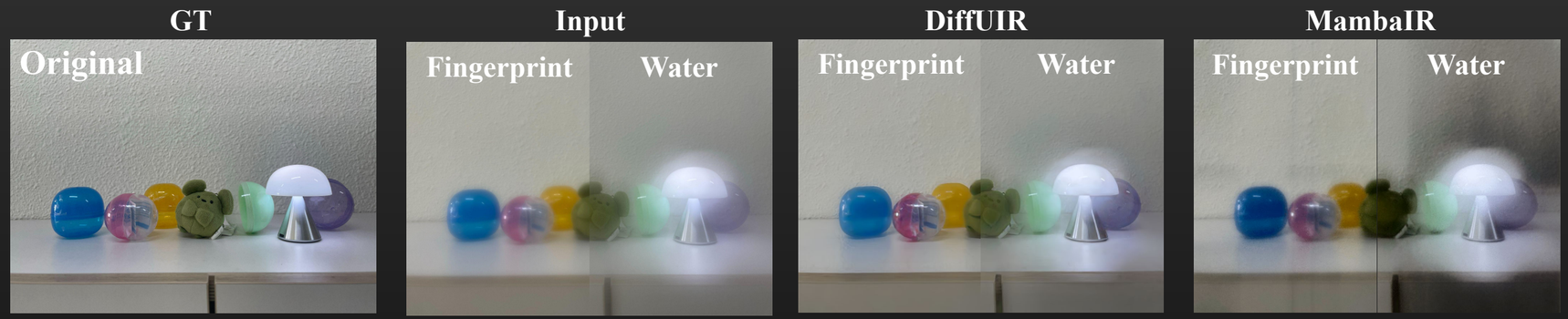
- **Validation with Real Dirty Lenses**
  - **SIDL successfully replicates the visual characteristics of real dirty lens images.**



(a) Real Dirty Lens Image

(b) SIDL Image

Experiments: Ablation Studies

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- **Performance comparison of Pretrained *vs.* Trained models on the SIDL test set.**

Method	Type	Pretrained	Trained	Difference
DiffUIR	Dust	20.38 / 0.8130	23.15 / 0.8734	+2.77 / 0.0604
	Water	21.88 / 0.8408	23.99 / 0.8789	+2.11 / 0.0381
FFTformer	Dust	19.74 / 0.7926	21.08 / 0.8154	+1.34 / 0.0228
	Water	21.15 / 0.8075	22.04 / 0.8271	+0.89 / 0.0196
MambaIR	Dust	19.33 / 0.7461	23.42/ 0.8604	+4.09 / 0.1143
	Water	21.21 / 0.7572	24.06 / 0.8819	+2.85 / 0.1247

- **Comparison of NAFNet models trained on different dirty lens datasets and evaluated on the SIDL test set.**

Method / Train Set	Easy	Medium	Hard
NAFNet / Wang et al.	25.55 / 0.8239	21.61 / 0.7235	**18.16 / 0.7598**
NAFNet / SIDL (scratch)	**27.55 / 0.8829**	**25.16 / 0.8282**	**20.24 / 0.7734**

Summary

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- **SIDL** provides a realistic dataset of ***1,588*** **image pairs** specifically designed for smartphone lens contamination restoration.
- Our experiments validate that SIDL effectively represents **real-world lens contamination problems.**
- SIDL will be a valuable benchmark for **developing better restoration methods** for everyday smartphone camera problems.
- We hope SIDL leads to diverse future research in this **underexplored area of image restoration.**

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Thank You

Benchmark website → *https://sidl-benchmark.github.io*