UniDemoiré: Towards Universal Image Demoiréing with Data Generation and Synthesis

Zemin Yang[1,*], Yujing Sun[2,*], Xidong Peng[1], Siu Ming Yiu[2], Yuexin Ma[1,†]

[1]ShanghaiTech University, [2]The University of Hong Kong

AAAI-25
FEBRUARY 25 – MARCH 4, 2025
PHILADELPHIA, USA

Motivation

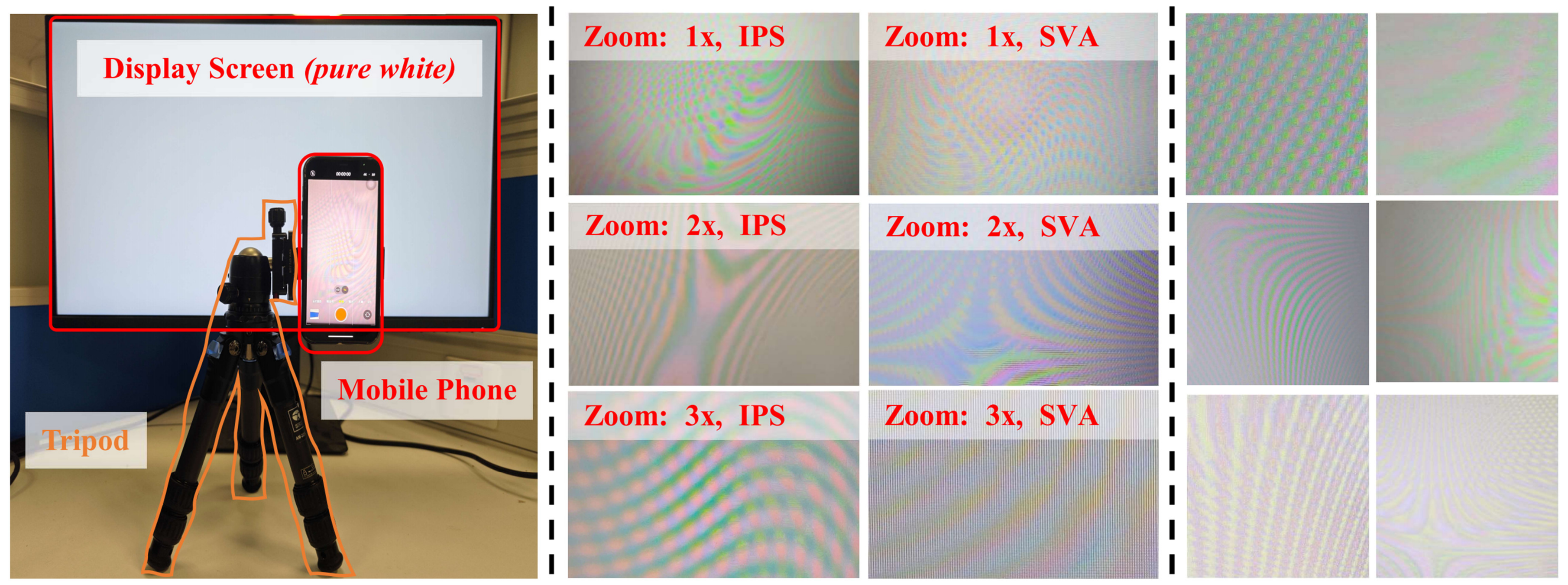
- **Limited Data:** Existing methods overfit to single moiré domains
- **Real-Synthetic Gap:** Handcrafted/retrieved patterns ≠ Real-world complexity
- **Universal Demand:** "A single model for ALL moiré types!"

Core Features of our UniDemoiré:

- 150K+ Pure Moiré Patterns
- Diverse & Realistic Moiré Synthesis
- Diffusion-Based Pattern Generation
- Zero-Shot Generalization

Moiré Pattern Dataset

"White screen + Phone videos → 150K high-res moiré patterns"



Datasets		Avg. Resolution	Size	Capture settings				
Type	Name			Phone	Screen	Multi-zooming rate	Multi-camera / CMOS	Screen Panel
Moiré Image Dataset	TIP2018(R)	256 × 256	135000	3	3	✗(1x-only)	✗(Main-only)	IPS-only
	FHDMi(R)	1024 × 1024	12000	3	2	✗(1x-only)	✗(Main-only)	IPS-only
	UHDM(R)	4328 × 3248	5000	3	3	✗(1x-only)	✗(Main-only)	IPS-only
	LCDMoiré(S)	1024 × 1024	10200	-	-	-	-	-
Moiré Pattern Dataset	MoireSpace(R)	2160 × 1286	18147	3	3	✗(1x-only)	✗(Main-only)	IPS-only
	Ours(R)	**3840 × 2160**	**150000**	**6**	**6**	**✓(1x,2x,3x)**	**✓(Main,Telephoto)**	**IPS, SVA**

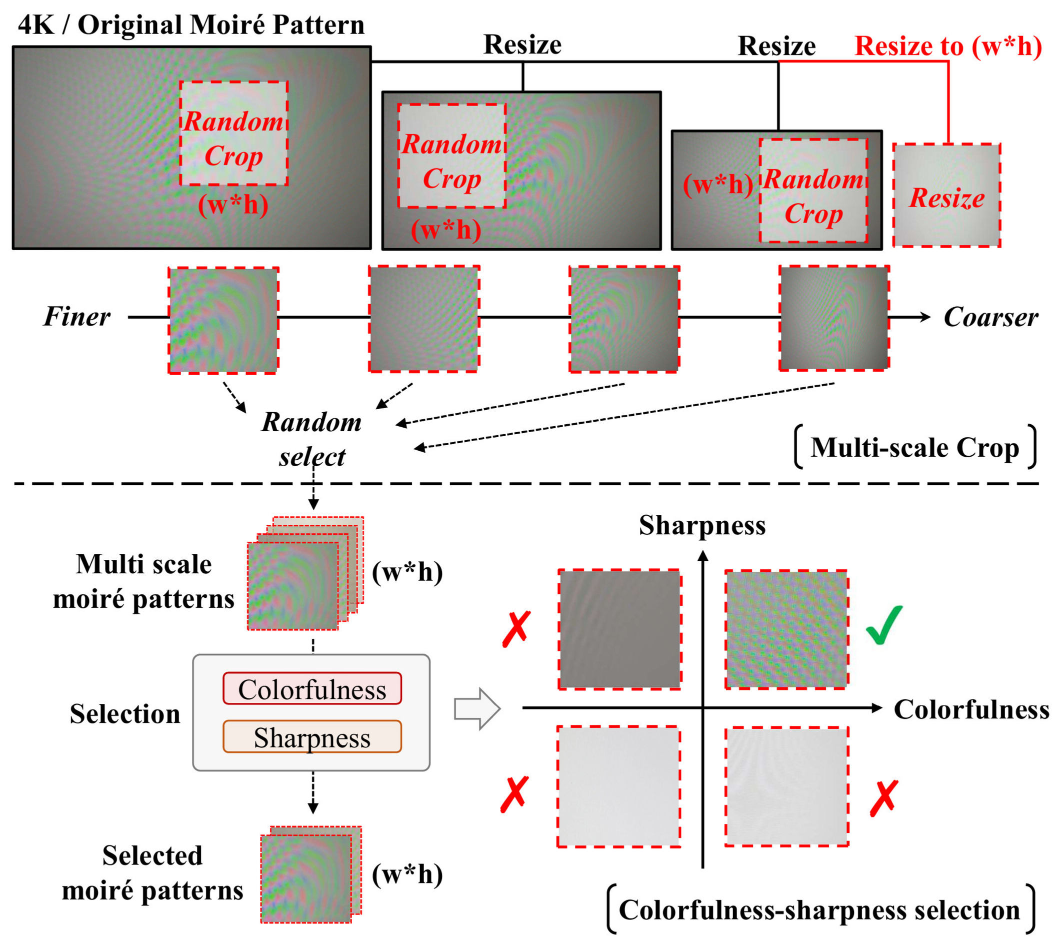
Moiré Pattern Generation

Stage 1: Multi-scale cropping + Colorfulness-Sharpness Selection

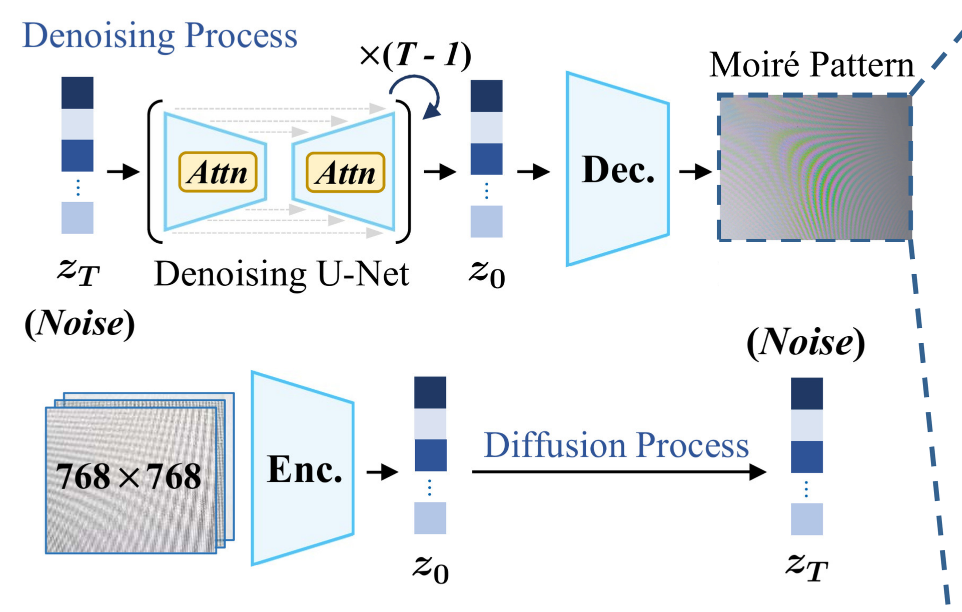
Algorithm 1: Data Preprocessing in MPG.

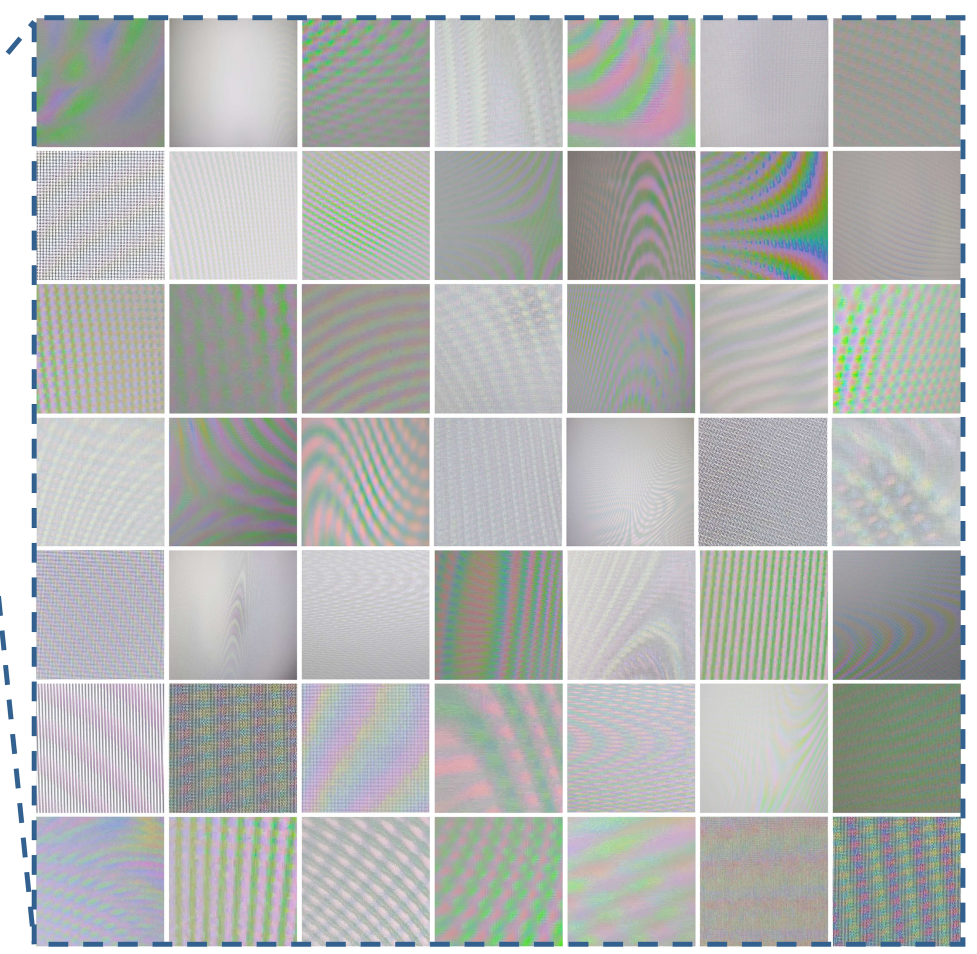
Input: 4K Moiré Pattern Dataset $\mathcal{D}_{mp}$, patch size (w, h).
Output: Selected moiré pattern patch I_{mp}.

while *True* **do**
  Randomly select a 4K moiré pattern $\mathcal{I} \in \mathcal{D}_{mp}$.
  for $i = 1$ *to* n **do**
    1. Multi-Scale Cropping:
      Randomly select probability p_1, p_2.
      if $p_1 \leq 50\%$ **then**
        $I_{mp} \leftarrow \text{Random Crop}(\mathcal{I}, w, h)$.
      else if $p_2 \leq 33.33\%$ **then**
        $\mathcal{I} \leftarrow \text{Resize}(\mathcal{I}, 2560, 1440)$,
        $I_{mp} \leftarrow \text{Random Crop}(\mathcal{I}, w, h)$.
      else if $33.33\% < p_2 \leq 66.66\%$ **then**
        $\mathcal{I} \leftarrow \text{Resize}(\mathcal{I}, 1920, 1080)$,
        $I_{mp} \leftarrow \text{Random Crop}(\mathcal{I}, w, h)$.
      else $I_{mp} \leftarrow \text{Resize}(\mathcal{I}, w, h)$.
    2. Sharpness-Colorfulness selection:
      $G_{mp} \leftarrow \text{RGB\_to\_Gray}(I_{mp})$,
      $L_{mp}, A_{mp}, B_{mp} \leftarrow \text{RGB\_to\_LAB}(I_{mp})$,
      $\text{Sharpness} \leftarrow \sigma(\mathcal{F} * G_{mp})$,
      $\text{Colorfulness} \leftarrow \sqrt{\sigma(A_{mp})^2 + \sigma(B_{mp})^2}$,
      if *Sharpness* $\geq \delta_s$ *and Colorfulness* $\geq \delta_c$ **then**
        return I_{mp}.
  end
end



Stage 2: Latent Diffusion Model → Diverse moiré textures





- **For VAE, we have:**

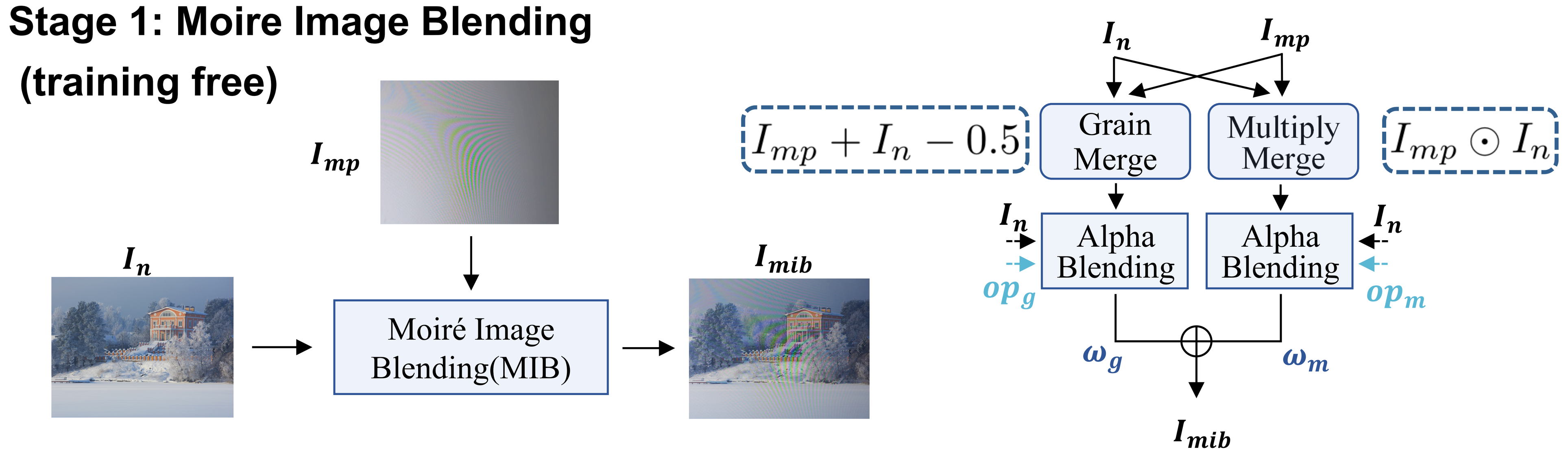
$$\mathcal{L} = \min_{\mathcal{E},\mathcal{D}} \max_{\psi} (\mathcal{L}_{rec}(I_{mp}, \mathcal{D}(\mathcal{E}(I_{mp}))) + \log D_\psi(I_{mp}) - \mathcal{L}_{adv}(\mathcal{D}(\mathcal{E}(I_{mp}))) + \mathcal{L}_{reg}(I_{mp}; \mathcal{E}, \mathcal{D}))$$

- **For Diffusion, we have:**

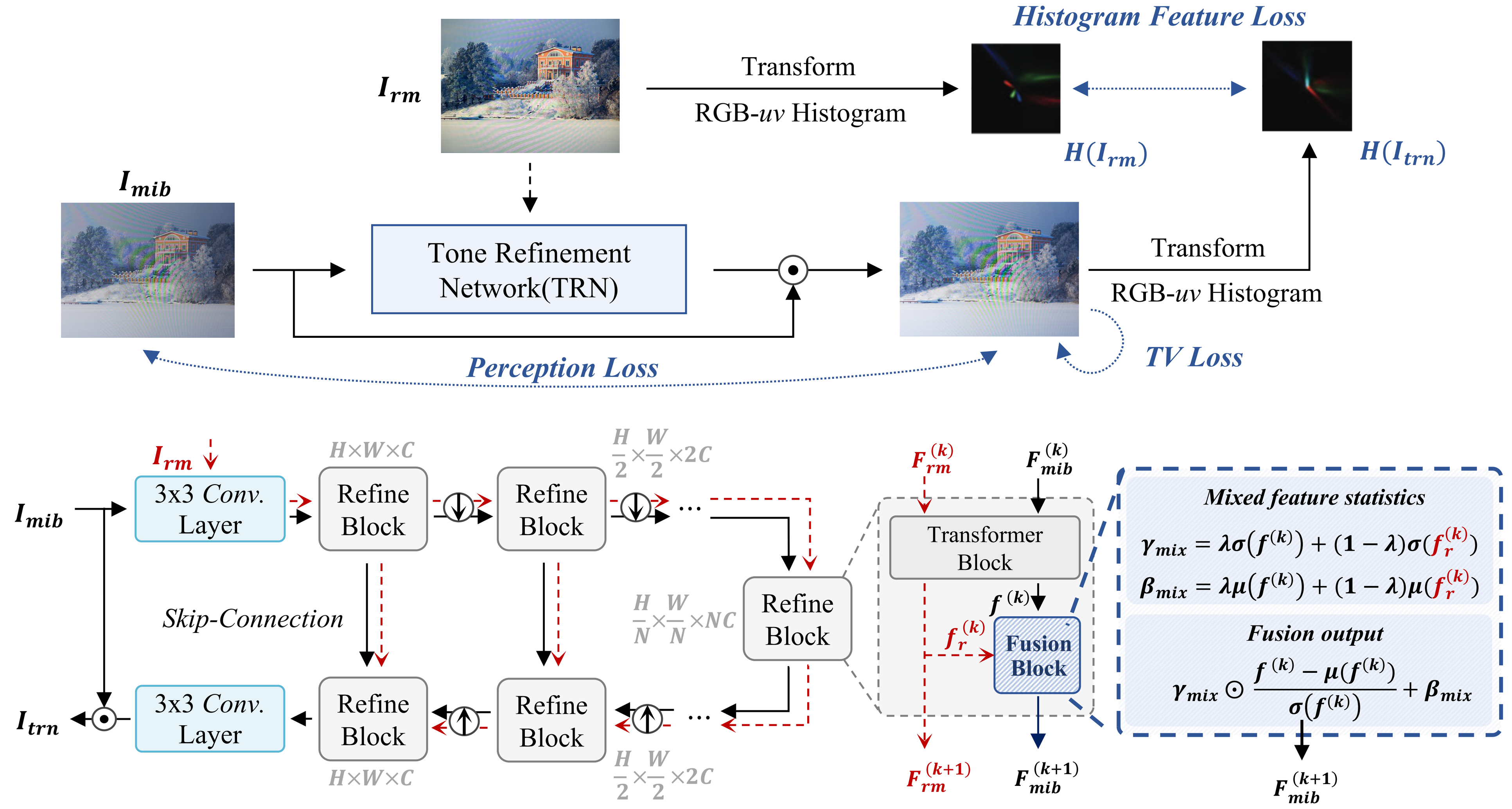
$$\mathcal{L} = \mathbb{E}_{\mathcal{E}(I_{mp}),\epsilon,t} [\|\epsilon - \epsilon_\theta(\alpha_t \mathcal{E}(I_{mp}) + \sigma_t \epsilon, t\|_1]$$

Moiré Image Synthesis

Stage 1: Moire Image Blending (training free)

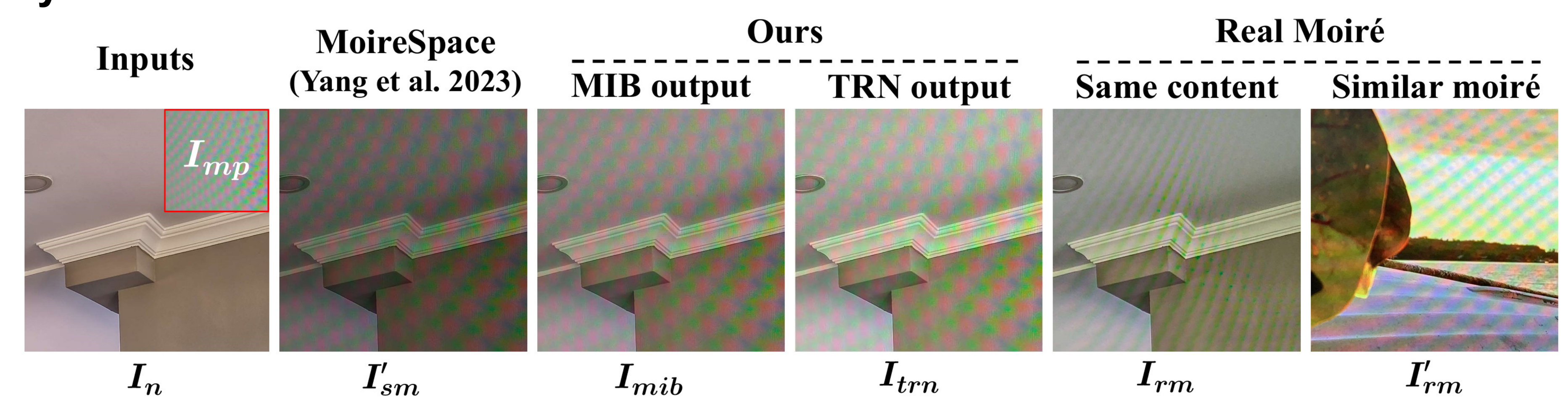


Stage 2: Tone Refinement Network

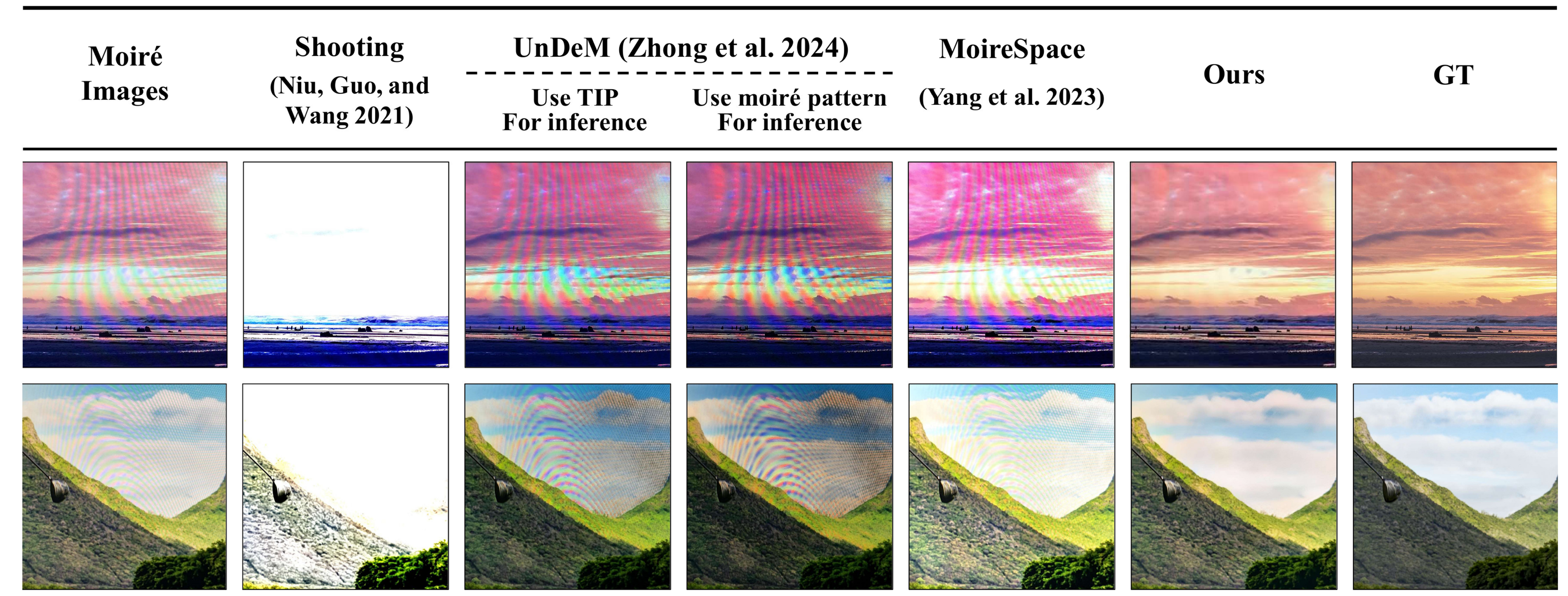


Qualitative Results

Synthesis Result:



Demoiréing Result:



Experiment Results

Zero-Shot Demoiréing Comparison:

Test Dataset	Metric	Demoiréing Network: MBCNN					Demoiréing Network: ESDNet-L				
		Shooting	UnDeM†	UnDeM‡	MoireSpace	Ours	Shooting	UnDeM†	UnDeM‡	MoireSpace	Ours
UHDM	PSNR ↑	9.2284	13.4256	14.5237	14.7826	**17.9162**	10.2568	15.2269	15.2947	14.7989	**17.2524**
	SSIM ↑	0.5180	0.3973	0.4425	0.4724	**0.6280**	0.5664	0.5873	0.5777	0.4859	**0.6454**
	LPIPS ↓	0.6664	0.6489	0.6332	0.5568	**0.4162**	0.5130	0.4190	0.4241	0.5254	**0.3238**
FHDMi	PSNR ↑	10.6750	17.8355	18.1652	18.5523	**19.0094**	11.6022	18.4335	18.5390	18.0763	**19.8128**
	SSIM ↑	0.4478	0.6802	0.6999	0.7094	**0.7137**	0.5425	0.6900	0.6812	0.7189	**0.7319**
	LPIPS ↓	0.5978	0.2606	0.2472	0.2742	**0.2390**	0.4515	0.2877	0.2986	0.2616	**0.2134**

Cross-Dataset Demoiréing Comparison:

Cross Dataset		Metric	Demoiréing Network: MBCNN					Demoiréing Network: ESDNet-L				
Source	Target		Baseline	Shooting	UnDeM	MoireSpace	Ours	Baseline	Shooting	UnDeM	MoireSpace	Ours
UHDM	FHDMi	PSNR ↑	19.3848	19.2032	19.4676	19.4531	**19.8625**	20.3422	20.2407	20.4014	20.2806	**20.7543**
		SSIM ↑	0.7436	0.7459	0.7455	0.7496	**0.7525**	0.7599	0.7579	0.7510	0.7603	**0.7653**
		LPIPS ↓	0.3002	0.2975	0.2964	0.2993	**0.2842**	0.2525	0.2632	0.2509	0.2324	**0.2136**
	TIP	PSNR ↑	17.8107	18.3730	18.6674	18.9214	**19.3922**	18.8040	18.4543	19.3545	19.3964	**19.5009**
		SSIM ↑	0.6627	0.6888	0.6911	0.6996	**0.7022**	0.6921	0.6930	0.6998	0.7111	**0.7149**
		LPIPS ↓	0.3580	0.3886	0.3909	0.3829	**0.3781**	0.3524	0.3849	0.3601	0.3522	**0.3495**
FHDMi	UHDM	PSNR ↑	17.1331	17.5326	17.4870	17.6050	**18.7931**	18.0049	18.4189	17.9574	17.9751	**18.9240**
		SSIM ↑	0.6159	0.6334	0.6331	0.6642	**0.7186**	0.5755	0.5780	0.5857	0.5548	**0.6658**
		LPIPS ↓	0.4470	0.4350	0.4285	0.4020	**0.3508**	0.4420	0.4279	0.4460	0.4579	**0.3405**
	TIP	PSNR ↑	20.2161	20.7793	20.8261	20.1194	**21.0694**	20.6647	20.8678	20.4663	20.8107	**21.5786**
		SSIM ↑	0.7340	0.7304	0.7381	0.7347	**0.7494**	0.7504	0.7606	0.7278	0.7582	**0.7668**
		LPIPS ↓	0.2979	0.2884	0.2891	0.2961	**0.2832**	0.2459	0.2450	0.2998	0.2468	**0.2310**
TIP	UHDM	PSNR ↑	17.3409	17.4011	17.4407	17.4987	**18.2937**	17.4332	16.1836	16.8402	16.6296	**18.4978**
		SSIM ↑	0.6144	0.6062	0.6066	0.6059	**0.6913**	0.5523	0.5511	0.5692	0.5748	**0.6866**
		LPIPS ↓	0.4726	0.4487	0.4473	0.4412	**0.3990**	0.4987	0.4723	0.4532	0.4387	**0.3231**
	FHDMi	PSNR ↑	18.9458	19.2731	19.0336	19.1101	**20.1053**	19.2368	18.1936	19.2112	18.8385	**19.9971**
		SSIM ↑	0.7369	0.7399	0.7215	0.7321	**0.7725**	0.7354	0.7297	0.7499	0.7389	**0.7580**
		LPIPS ↓	0.2494	0.2447	0.2452	0.2382	**0.2315**	0.2316	0.2320	0.2130	0.2228	**0.1915**