Clicking Better Images with Under Display Cameras (UDC) in Smartphones

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Motivation

- Under Display Cameras (UDC) are an emerging technology developed for smartphones where the camera is embedded under the display so that the screen covers the entire surface. This replaces the current top-notch or punch-hole based cameras which break the screen's smoothness.
- However, placing the camera inside the screen introduces degradations such as noise, flare, haze and low-light. Transparent-OLED (T-OLED) and phone Pentile-OLED (P-OLED) screens are often used but have differing levels of degradation.
- The aim of this project is to solve this ill-posed inverse problem and restore the UDC image, through exploration of knowledge distillation and denoising diffusion probabilistic models.

Related Work

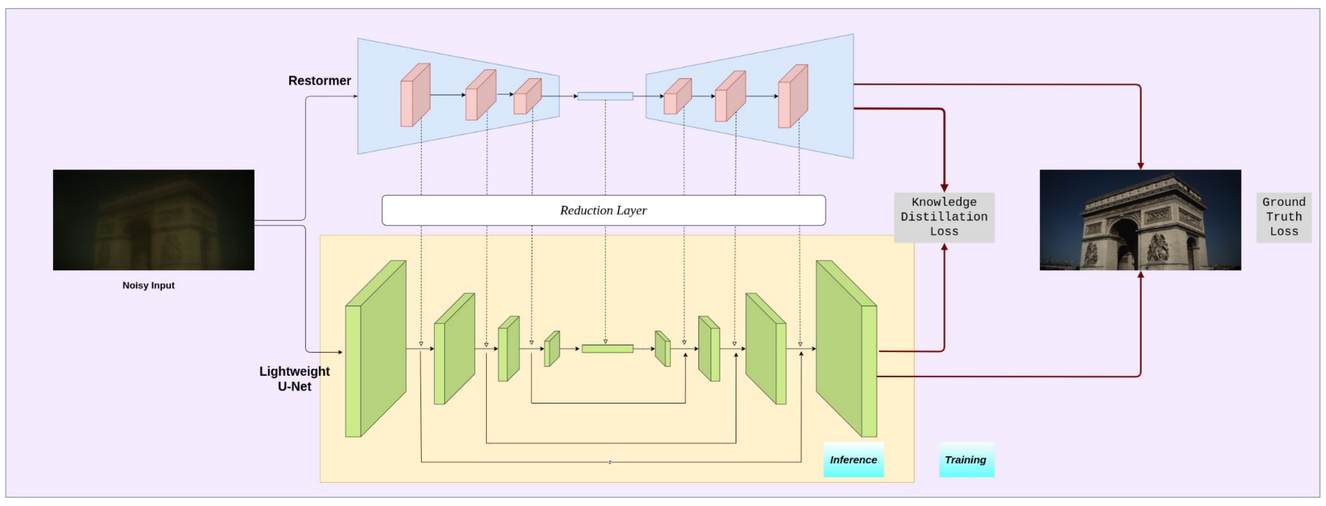
- The first paper that tackled this problem was Zhou et al. [1], introducing techniques to capture the pair of images and then developed model-based and learning-based deconvolution solutions. Following their work, a competition was held in ECCV 2020 which brought the first major wave of attention towards UDC [2]. A similar challenge was held in 2022 and the resultant methods are summarised in [3].
- In terms of efficiency, Conde et.al [4] developed a U-Net model architecture with custom residual attention blocks embedded inside, having 4x less compute operations, while performing competitively.
- Our work extends upon the same idea, utilising some novel approaches and further simplifying the solution.

References

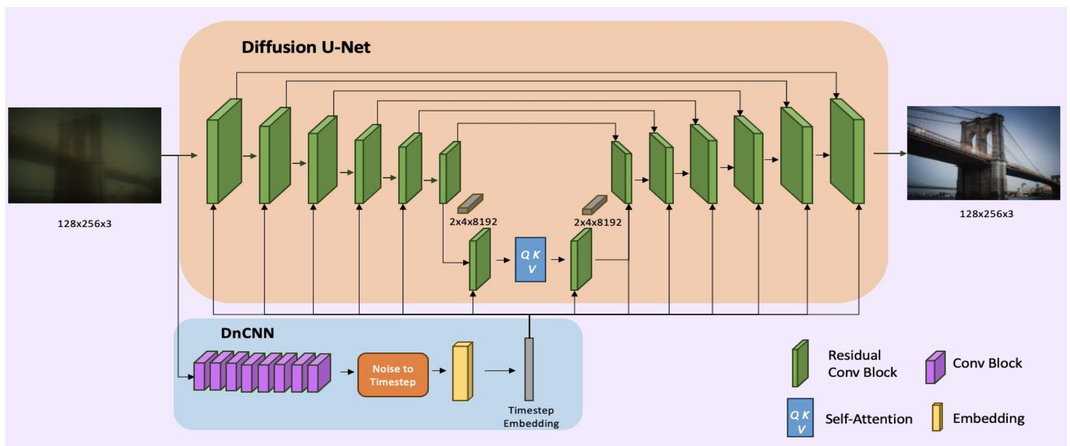
[1] Zhou et al.. Image restoration for under-display camera, 2021.
[2] Udc 2020 challenge on image restoration of under-display camera: Methods and results, 2020.
[3] Feng et al. Mipi 2022 challenge on under-display camera image restoration: Methods and results, 2022.
[4] Conde et al. Real-time under-display cameras image restoration and hdr on mobile devices. In ECCV 2022.

New Technique

- We perform cross-model knowledge distillation to get a lightweight, efficient solution that offers high performance in less parameter count.

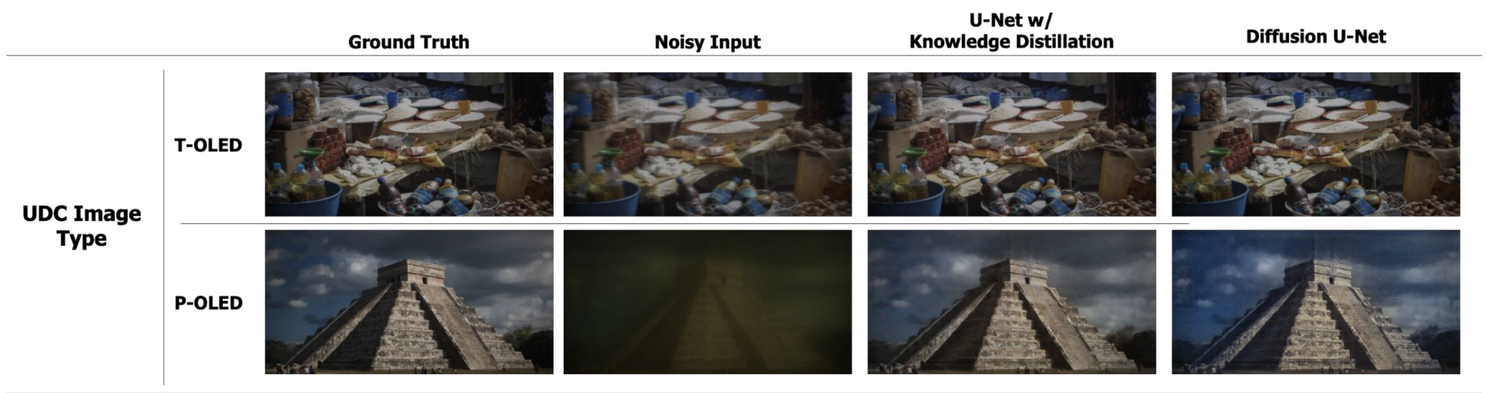


- We experiment with a pre-trained diffusion U-Net model to study the efficacy of denoising diffusion probabilistic methods. An 8-layer DnCNN estimates noise variance for inputs, serving as priors to the model.



Experimental Results & Discussion

- Some qualitative and quantitative results of our models. Note that we achieve this without any additional dataset, using only 240 pairs of UDC images.



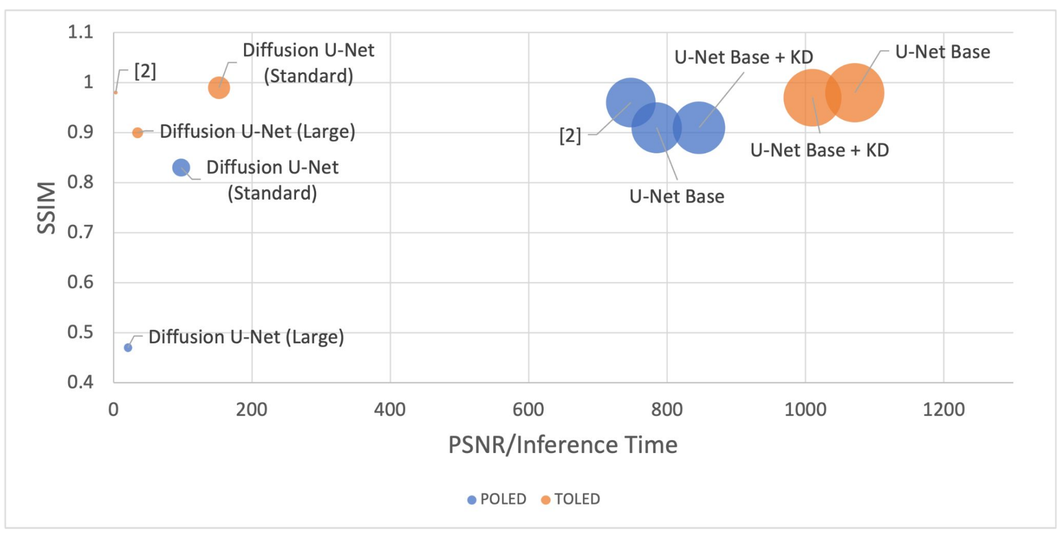
Results on T-OLED

Approach	PSNR (dB)	SSIM	No. of Parameters
Best from [2]	38.23	0.98	–
U-Net Base	37.75	0.98	7.78M
U-Net Base + KD	36.24	0.97	7.78M
Diffusion U-Net (Standard)	42.37	0.99	94M
Diffusion U-Net (Large)	30.33	0.90	553M

Results on P-OLED

Approach	PSNR (dB)	SSIM	No. of Parameters
Best from [2]	32.90	0.96	–
U-Net Base	27.72	0.91	7.78M
U-Net Base + KD	30.59	0.91	7.78M
Diffusion U-Net (Standard)	27.15	0.83	94M
Diffusion U-Net (Large)	18.09	0.47	553M

SSIM vs. PSNR/Inference Time



- U-Net with KD provides most efficient model with higher potential for real-time use.
- Standard diffusion model outperforms ECCV 2020 competition best on T-OLED data in single diffusion step.
- Diffusion approaches tend to change colour/lighting while denoising.