Joint Motion Deblurring and Low-Light Image Enhancement on Raw Images

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Motivation

The Challenge

Low-light enhancement requires solving three problems simultaneously: extreme sensor noise, color restoration, and motion blur (caused by either camera shake or moving scenes).

The Gap

- Raw bypasses the non-linear in-camera ISP pipeline
- Raw is stored as a high–bit-depth signal compared to 8-bit sRGB
- Raw includes rich metadata (e.g. exposure time) that can guide image restoration.
- DarkIR tackles joint deblurring and denoising only in the sRGB domain.

Our Approach

- Synthetic Dataset: We constructed a new Raw benchmark derived from Seeing in the Dark that simulates realistic motion.
- Metadata-Guided Network: We propose a novel architecture injecting EXIF metadata for joint restoration.
- ExposureDiffusion Adaptation: We propose injecting blur into the model training process.

Related Work

Noise Modeling: ELD [3] introduces a physics-based noise formation model. We utilize this to synthesize realistic noise for our Raw training data.

Raw Enhancement: ExposureDiffusion [1] is the state-of-the-art for low-light enhancement in the Raw domain. However, it does not explicitly account for motion blur.

Joint Restoration: DarkIR [2] handles simultaneous deblurring and enhancement. Unlike our method, it operates in the sRGB domain, which limits dynamic range recovery compared to Raw pipelines.

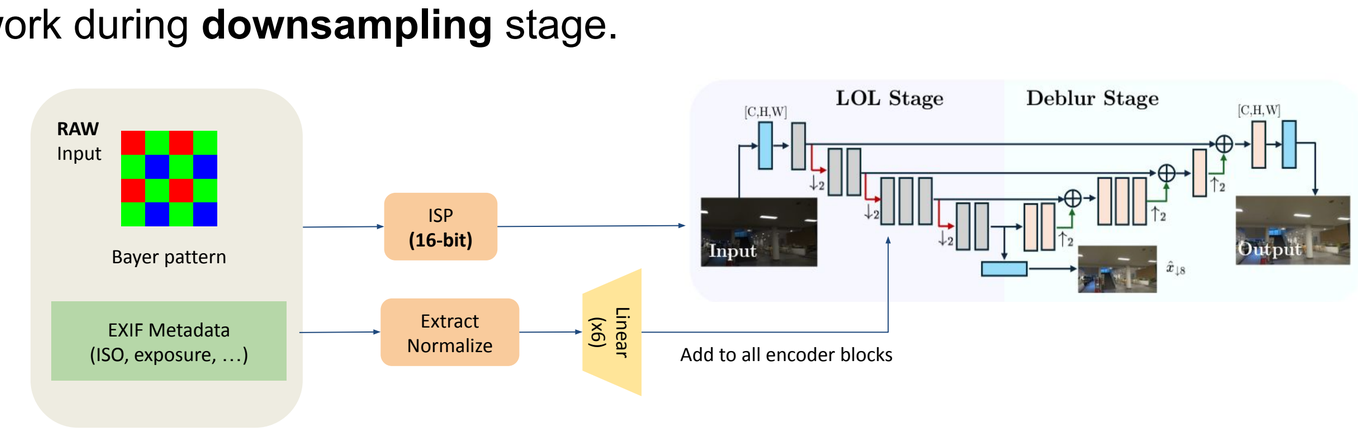
References

[1] Y. Wang et al., "ExposureDiffusion: Learning to Expose for Low-light Image Enhancement," arXiv preprint arXiv:2307.07710, 2023.
[2] D. Feijoo et al., "DarkIR: Robust Low-Light Image Restoration," arXiv preprint arXiv:2412.13443, 2025.
[3] K. Wei et al., "A Physics-Based Noise Formation Model for Extreme Low-Light Raw Denoising," in CVPR, 2020.

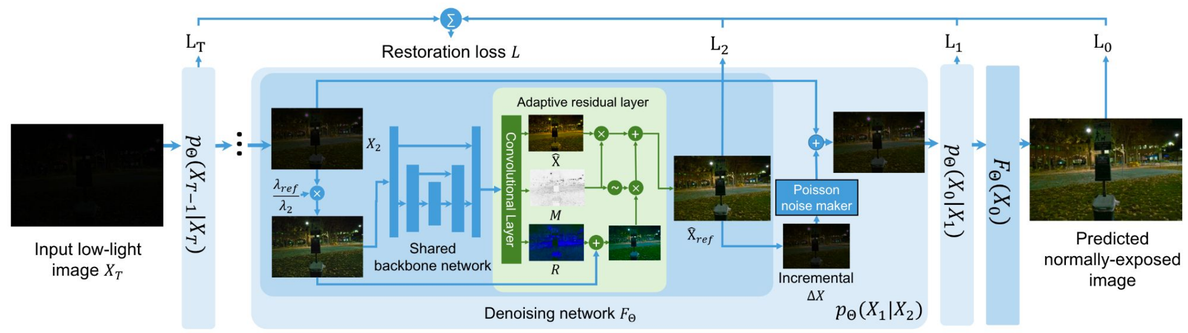
New Technique

Synthetic Dataset: Utilizing the exposure time information, we can know what the clean dark image would be like from the light image and what is the true noise. Then, we apply random motion kernel and add the noise back.

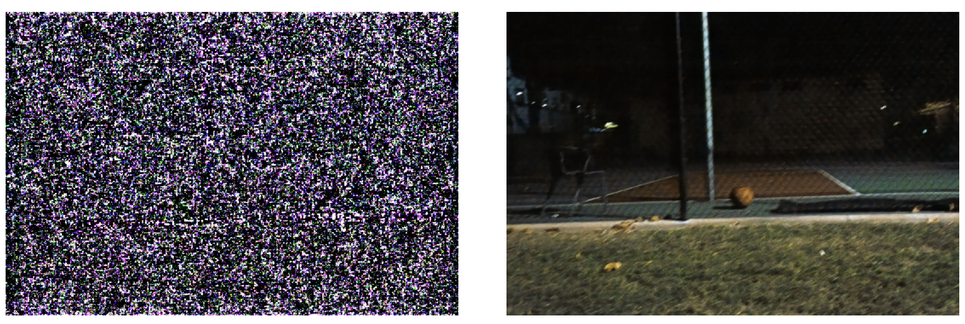
Metadata-Guided Network: We build our model based on DarkIR[2], but with Raw data (ISO, F/N, White balance level, Exposure, etc.) injected into the network during **downsampling** stage.



ExposureDiffusion Network: We fine-tune our model using training samples augmented with injected blur



Experimental Results



Metrics of Different Models

	Dataset	PSNR	SSIM
DarkIR - original	SID-Blurred	11.36	0.2340
DarkIR - FT w/ EXIF	SID-Blurred	18.65	0.6240
DarkIR - FT w/o EXIF	SID-Blurred	17.83	0.6117
ED - original	SID	36.54	0.8823
ED - original	SID-Blurred	33.15	0.8377
ED - Fine Tuned	SID-Blurred	28.57	0.7345

Discussion

- The original DarkIR model amplifies the noise, which can be resolved by fine-tuning on the SID dataset
- The original ED model does not account for image blur
- Limited to a single camera model: Sony A7S2
- Handle more complicated blur, such as out-of-focus blur