Fourier Features for Low-Light Image Enhancement

Jinyu Liu
Affiliations, University of Toronto

Motivation

- Low-light imaging presents significant challenges in various applications, including **photography**, **surveillance**, and **medical imaging**.
- Images cannot be enhanced with hardware. For low signal images, a higher ISO, **amplifying the noise** as well. Higher exposure may introduce **motion blur**
- Neural networks are a popular post-processing approach to low-light imaging denoising. However, they are susceptible to **bias** towards **low-frequency components** of data towards training [1]. They have difficulty learning the **complex, high frequency details** of an image.
- In this project, we explore the question: **Can encoding Fourier features alongside the image improve model performance in low-light image enhancement?**

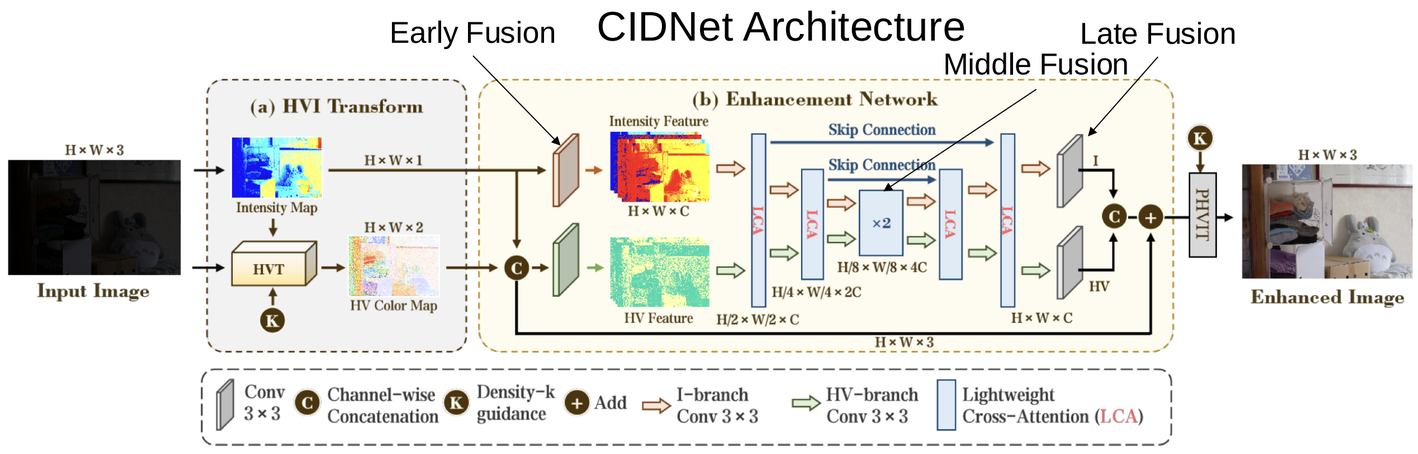
Related Work

- **Fourier Features in Image Denoising** has been attempted before, mostly for their edge detection and ability to capture high-frequency details. Fourier features have been used as a model prior to ensure repeated details such as vents in a spacecraft are preserved through the denoising processes [2,3]. These models use Fourier features to separate noise from the image structure.
- **LOw-Light (LOL) dataset** is comprised of 485 training images and 15 testing pairs for low-light enhancement. **CIDNet** [4] currently has one of the best performances on peak-signal-to-noise ratio on the LOL dataset. CIDNet works by using a novel color space, Horizontal/Vertical-Intensity that decouples brightness from color. It could be an interesting idea to explore the Intensity channel for CIDNet

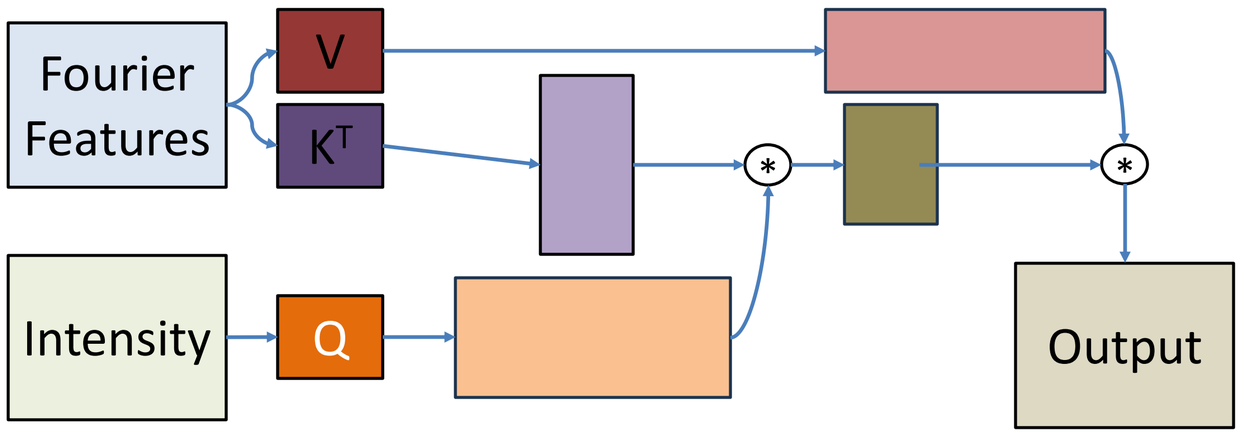
References

[1] Cao, Yuan, et al. "Towards understanding the spectral bias of deep learning." *arXiv preprint arXiv:1912.01198* (2019).
[2] Yang, Jingfan, et al. "Edge Modeling Activation Free Fourier Network for Spacecraft Image Denoising." *arXiv preprint arXiv:2409.07067* (2024).
[3] Li, Xi, et al. "FEUSNet: Fourier Embedded U-Shaped Network for Image Denoising." *Entropy* 25.10 (2023): 1418.
[4] Yan, Qingsen, et al. "You only need one color space: An efficient network for low-light image enhancement." *arXiv preprint arXiv:2402.05809* (2024).

New Technique



Fourier/Intensity Cross Attention Encoding



Architecture Augmentation: We modify the existing architecture of CIDNet by encoding **Fourier features**. Experimentation is done to see where to best encode the Fourier features for the best model results.

Experimental Results

Input Image (Low-light Image)

Ground Truth Image (High-light Image)

Results After Training for 1500 Epochs
Dataset size: 485 Images

Baseline (No modifications)
Avg PSNR: 19.8997
Avg SSIM: 0.8182

Early Fusion
Avg PSNR: 15.3205
Avg SSIM: 0.6869

Middle Fusion
Avg PSNR: 22.1694
Avg SSIM: 0.8382

Late Fusion
Avg PSNR: 15.4061 0.6590
Avg SSIM: 0.6590