Learning to Enhance Visual Quality via Hyperspectral Domain Mapping (Student Abstract)

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Abstract

Deep learning based methods have achieved remarkable success in image restoration and enhancement, but most such methods rely on RGB input images. These methods fail to take into account the rich spectral distribution of natural images. We propose a deep architecture, SPECNET, which computes spectral profile to estimate pixel-wise dynamic range adjustment of a given image. First, we employ an unpaired cycle-consistent framework to generate hyperspectral images (HSI) from low-light input images. HSI is further used to generate a normal light image of the same scene. We incorporate a self-supervision and a spectral profile regularization network to infer a plausible HSI from an RGB image. We evaluate the benefits of optimizing the spectral profile for real and fake images in low-light conditions on the LOL Dataset.

Introduction

Human visual perception is acquainted with high-contrast images that are characterized by high contrast, good visibility, and minimal noise. Thus researchers have focused extensively on developing computer-vision techniques to improve the visual perception of images. Such algorithms have broad applicability, such as all-weather autonomous vehicles and illumination-invariant face detection.

Low-light image enhancement is a well-studied problem, and researchers have proposed several methods to address this problem. These methods include histogram equalization, dehazing-based approaches, and retinex theory. Although these representative state-of-the-art methods produce good results, they are limited in terms of model capacity for illumination and reflectance decomposition. Such constraints are hand-crafted and require careful hyperparameter-optimization. To mitigate this problem, researchers have used CNNs for low-level image processing. Owing to the extensive success of GANs for the problem of image-to-image translation, we build a framework that can generate visually-pleasing images through spectral guidance.

In this paper, we propose SPECNET which optimizes a spectral profile to achieve superior results. We first use a cycle-consistent framework to reconstruct hyperspectral images from RGB images which is further used to restore proper illumination for the given low-light or dark image. The primary GAN framework used for hyperspectral reconstruction has been carefully modified to incorporate a spectral-profile optimization framework, ultimately aimed at generating visually-pleasing images. Finally, we perform extensive set of experiments to evaluate the effectiveness of the model.

Dark Image | Reconstructed HSI | Enh. Output | Ground Truth

Figure 1: A sample dark image along with the reconstructed HSI and the output obtained using SPECNET.

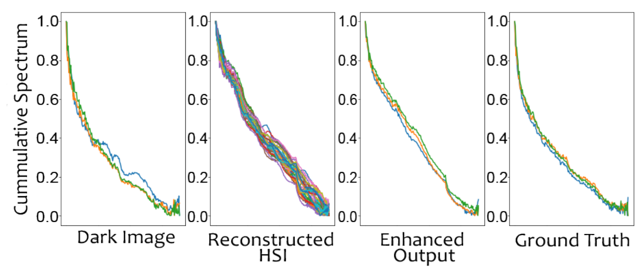

Figure 2: Multi-channel cumulative spectral profile of sample dark image along with the reconstructed HSI and the output obtained using SPECNET

Proposed Method

To propose SPECNET, we hypothesize that multi-band information in the reconstructed hyperspectral images can improve the perceptual quality of images. First of all, we create a spanned 31-channel RGB image matrix to imitate the 31-channel HSI, to ease the under-constrained problem of HSI reconstruction from RGB images. The framework can be viewed as a cascaded GAN approach. The first GAN takes an unsupervised cycle-consistent approach to recon-

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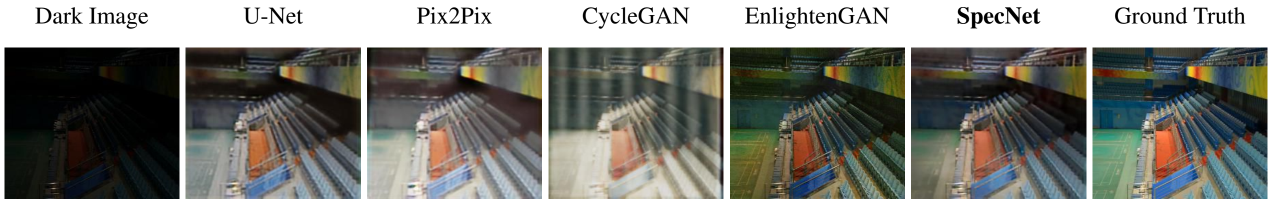

Figure 3: Qualitative comparison for different models as described in Table 1.

struct HSI, which is fed into another cGAN to generate the final enhanced output image. To solve the under-constrained problem of HSI reconstruction we make use of several guiding principles such as task-aided supervision and spectral-profile optimization.

Aided Supervision The lack of large-scale hyperspectral image datasets poses a problem in learning an output distribution that can imitate the underlying original hyperspectral values. A task-aided supervision addresses this distributional discrepancy. We use our original low-light enhancement task as an auxiliary optimization task to aid hyperspectral reconstruction. We modify the cycle-consistency loss as

$$\mathcal{L}_{cyc} = \|y - G_h(G_x(x))\|_2^2 + \|h - G_x(G_h(h))\|_2^2. \quad (1)$$

where (x, y) refers to dark and ehanced RGB images respectively, G_x, G_h refer to dual generators used for cycle-consistency and h refers to HSI.

Spectral-profile Optimization As the primary task of the framework is to produce enhanced images, we incorporate a network to generate spectral-profile using multi-channel power spectrum from 2D Fourier transform (Durall, Keuper, and Keuper 2020). The network was used to regularize the spectral distribution of reconstructed HSI. The motivation is to induce alignment in spectral distributional discrepancy in the reconstructed HSI. This is achieved by jointly optimizing the algorithm with a spectral-profile generator that discriminates between spectral profiles of reconstructed HSI and real RGB images. By minimizing the mean squared error, the algorithm encourages spectrally-enduring HSI.

Multi-layer Colorization Space The multi-layer colorization space is constructed using different color models such as HSV, YCrCb, and LAB concatenated together with RGB which results in a 12-channel input image (Mehta et al. 2020). This is fed into cGAN along with the reconstructed HSI.

Experimental Evaluation

The experimental results in terms of PSNR and SSIM on LOL dataset (Wei et al. 2018) are compiled in Table 1. SPECNET outperforms the existing state-of-the-art techniques in terms of PSNR and SSIM.

The proposed SPECNET consists of several components which add to performance through cumulative effort.To delineate the contributions of different components, several models were trained apart from the final model. The comparative performance is summarized in Table 2.

Method	SSIM	PSNR
U-Net	0.7397	21.500
Pix2Pix	0.7307	20.483
CycleGAN	0.6850	20.348
EnlightenGAN	0.7694	23.202
SPECNET	**0.8052**	**22.330**

Table 1: Comparative results on LOL dataset

Method	Components		SSIM
	Spectral Profile Optimization	Multi-Layer Colorization Space	
Model-1			0.6784
Model-2	✓		0.7244
SPECNET	✓	✓	**0.8052**

Table 2: Ablation Models

Conclusions

This work demonstrates the use of spectral-profile optimization for low-light image enhancement using a cascaded GAN framework, referred to as SPECNET. It reconstructs HSI from low-light RGB images and an enhanced cGAN generates enhanced output images using reconstructed hyperspectral images. The model utilizes color spaces by concatenating a 12-channel multi-layer color space with the reconstructed HSI. Further, an ablation study is conducted which substantiates the contribution of individual components in the framework.

References

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