Learning to Enhance Visual Quality via Hyperspectral Domain Mapping

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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.

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 reconstruct HSI, which is fed into another eGAN to generate the
Figure 3: Qualitative comparison for different models as described in Table 1.

| 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 |
|------------|-----------------------------|------|
| Model-1    | Spectral Profile Optimization | 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.

Supplementary Material

Architectural Details

The proposed work adapts an unpaired cycle-consistency framework (Zhu et al. 2017) to exploit supervision at the level of sets. The objective is to learn a mapping function $G_x: X_{31} \rightarrow Y$, where $X_{31}$ represents the stacked RGB image and $Y$ refers to the reconstructed HSI. In context to the adversarial loss, the reconstruction module can be expressed as
Figure 4: Qualitative comparison with different models.
Figure 5: The schematic diagram for the proposed SpecNet

The generators in $G_x$, $G_y$ and $G_z$ adopt a U-Net with skip connections while PatchGAN is adopted for the corresponding discriminators. We use L1 cycle consistency losses and identity losses (Zhu et al. 2017) to further improve the reconstructed HSI.

The generator $G_s$ uses a ResNet-based architecture to compute the spectral profile of input image. Deriving inspiration from recent work by Durall, Keuper, and Keuper, we extend the analysis to hyperspectral images. The network aims to regularize the generated HSI with respect to spectral distribution of real images.

Datasets

To facilitate HSI reconstruction, HSCycle is trained using ICVL BGU Hyperspectral Dataset (NTIRE 2018) (Arad and Ben-Shahar 2016; Arad, Ben-Shahar, and Timofte 2018) and the NTIRE 2020 dataset. The dataset is composed of 200 natural images with various indoor and outdoor scenes. The dataset provides sampled images which each having 31 spectral bands. Adjacent bands have an incremental difference of 10 nm. In addition, preprocessing like random cropping and flip is utilized to increase the total number of images upto 6000.

To train the proposed network for low light image enhancement, we use low/normal-light pairs in the LOL Dataset. The LOL Dataset consists of 500 image pairs, which is pre-divided into training and evaluation datasets.

Additional Results

In Figure 4 we show additional qualitative comparison of SPECNET with several deep learning based models. U-Net, Pix2Pix and CycleGAN, being general computer vision models, were re-trained on the train dataset used by SPECNET.

In Figure 6 we visually show the performance of SPECNET with respect to other ablated models. The red box highlights the improvement our model gets due Spectral Profile optimization and multi-layer colorization.

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