NeRF as a Denoiser

EE367 Project Proposal

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Motivation:

Traditional image signal processing usually uses the information from a single image for denoising, such as, Gaussian filter, Median filter, Bilateral filter, and Non-Local means. From the Guest lecture by Dr. Orly Liba, we also learned that by combining a burst of underexposed photos, we can also create a clean image in a low-light environment.

NeRF has been a hot area in recent years because it enables people to perform novel view synthesis of a complex scene from a sparse set of input views. This task was only achievable by a light field camera before. After reading several NeRF-related papers, we realized that NeRF has the potential to denoise images because, similar to the burst denoiser, both methods integrate information from multiple images. For this project, we want to investigate whether we can utilize NeRF as a denoiser and, at the same time, perform novel view synthesis, especially when the input images are noisy.

Related work:

Nerf [1] was proposed to use the input image information and the volume rendering technique to train a neural radiance field. The radiance field takes spatial location (x, y, z) and viewing direction (θ, φ) as inputs and then uses an MLP to map inputs to color and density. Novel view images can be rendered from the same radiance field. If the input images are noisy, we might still be able to train a noise-free radiance field, so all the new images rendered from the radiance field are noise-free.

NeRF in the Dark [2] showed NeRF's potential as a Denoiser. The authors show that NeRF is highly robust to the zero-mean distribution of raw noise and the post processing pipeline from Raw to JPG will distort the noise distribution of raw sensor data. Maybe we should also use Raw to train the NeRF. This paper also provides datasets of 17 low light static scenes, images are in both Raw and JPEG, so we should have enough data.

Besides training NeRF on Raw images, Naama et al. [3] leverages the inter-view and spatial information in NeRF to reduce the noise. The output of the radiance field in this paper is not only color and density but a feature set including inter-view and spatial information. It then uses two more MLPs to convert these feature sets to color and density. With more information provided, the NeRF network is more robust to noise.

Project Overview:

Due to the time limitation, this project is not about implementing a NeRF network but investigating how we can use NeRF as a denoiser. We will first find an existing NeRF network that trains faster than the original NeRF. Then, as a baseline, we will train the NeRF on low-light JPG inputs. The evaluation metrics could include qualitative checks, PSNR, and SSIM.

Getting the intuition from RawNerf [2], we aim to make any required changes to train the network on raw inputs. We will also capture our own raw data to investigate if the assumption (Raw images have zero-mean noise) made in RawNerf is valid. Will compare Raw NeRF output with JPG NeRF output.

Given the intuition of NAN [3], we will then investigate if we can further modify the NeRF network to denoise one level more. Then, we will evaluate the metrics and analyze the effectiveness.

Milestone:

2/26 - 2/29:

- Find an existing NeRF codebase that is suitable for our use case.
- Make sure it can run on Colab or a local Linux computer.
- Without any modification, train the network using low-light JPGs from the dataset and analyze the result

3/01 - 3/04:

- Modify the NeRF network to train on Raw inputs.
- Create our own raw images datasets of low light scenes.
- Compare Raw NeRF output with JPG NeRF output.

3/05 - 3/10:

- Investigate if we can modify the NeRF network to improve its denoising performance further.

3/11 - 3/13:

- Work on the final report and the poster.

References

[1] Mildenhall, Ben, et al. "Nerf: Representing scenes as neural radiance fields for view synthesis." *Communications of the ACM* 65.1 (2021): 99-106.

[2] Mildenhall, Ben, et al. "Nerf in the dark: High dynamic range view synthesis from noisy raw images." *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*. 2022.

[3] Pearl, Naama, Tali Treibitz, and Simon Korman. "Nan: Noise-aware nerfs for burst-denoising." *Proceedings of the IEEE/CVF Conference on Computer Vision and Pattern Recognition*. 2022.