# Frequency Domain Image Relighting Enhancement

Tianyang Hu, An Cao, Jie Zhang
Department of Computer Science, University of Toronto

## Motivation

This project explores incorporating Fourier transforms into existing relighting methods. Light is considered as low-frequency information (Figure 1), suggesting that Fourier analysis could possibly enhance a model's ability to capture and manipulate illumination patterns effectively. By introducing Fourier transform into the deep learning model, we hypothesize that the relighting process can be improved in two key aspects:

(1) Image Quality — capturing illumination-related features and manipulate them to make the output has more smooth background while preserving high-frequency details

Figure 1

(2) Efficiency — potentially reducing computational complexity by working in the frequency domain.


Figure 2

## Related Work

- In recent papers of the area, researchers often focused on adding auxiliary data such as depth map [1] to the network to achieve better outcomes.
- A latest study on the one to one image relighting task reveals that although auxiliary data give the network a better way to deal with shadows, the lighting condition such as light bloom are yet not reconstructable by the existing methods [2].
- Past studies on CNN reveals that early hidden layers of the network usually perform edge and corner detections [3]; however, in a relighting task the light condition is better represented by low frequency informations.
- In recent paper about low-light image enhancement [4], we saw that adding fourier domain features to a network has the potential of enhance the performance of the network.

## References

[1] Z.-L. Zhu, Z. Li, R.-X. Zhang, C.-L. Guo, and M.-M. Cheng, "Designing an illumination-aware network for deep image relighting," IEEE Transactions on Image Processing, vol. 31, p. 5396–5411, 2022.
[2] Y. Yang, H. A. Sial, R. Baldrich, and M. Vanrell, "Relighting from a single image: Datasets and deep intrinsic-based architecture," 2024.
[3] M. D. Zeiler and R. Fergus, "Visualizing and understanding convolutional networks," 2013.
[4] C. Wang, H. Wu, and Z. Jin, "Fourllie: Boosting low-light image enhancement by fourier frequency information," 2023.

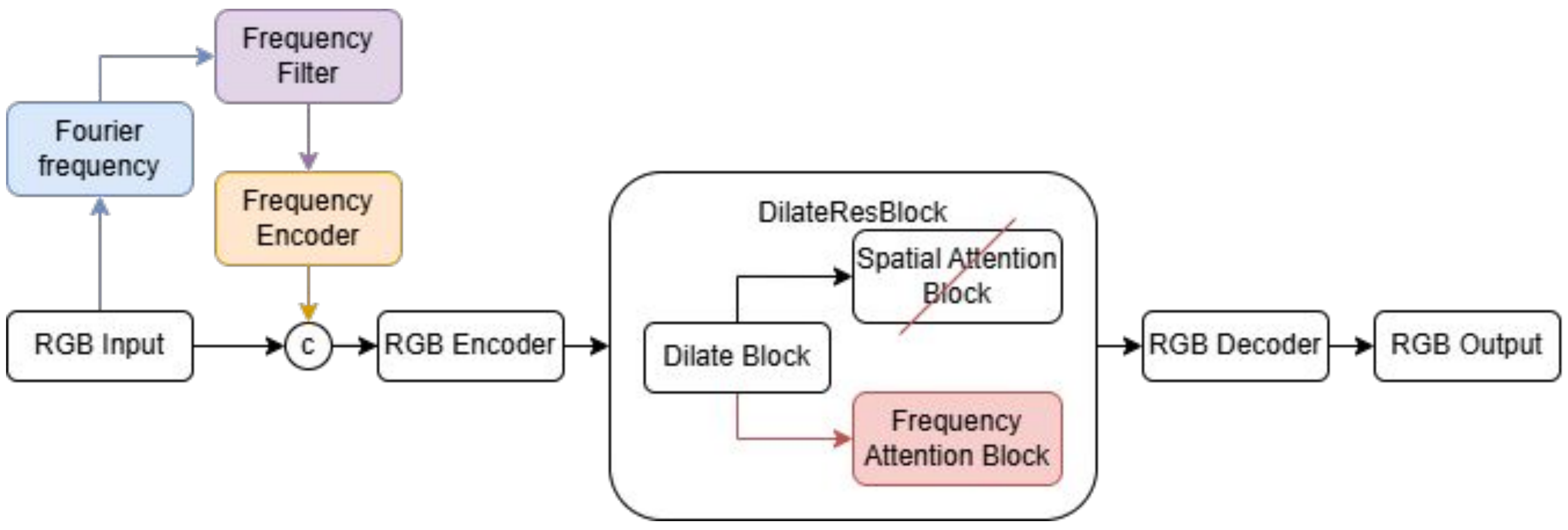
## New Technique

Fourier Channel:
In addition to RGB channels, we concat FFT results of each channel with inputs

Fourier Filter:
We concat low-pass filtered FFT results of each RGB channel with inputs

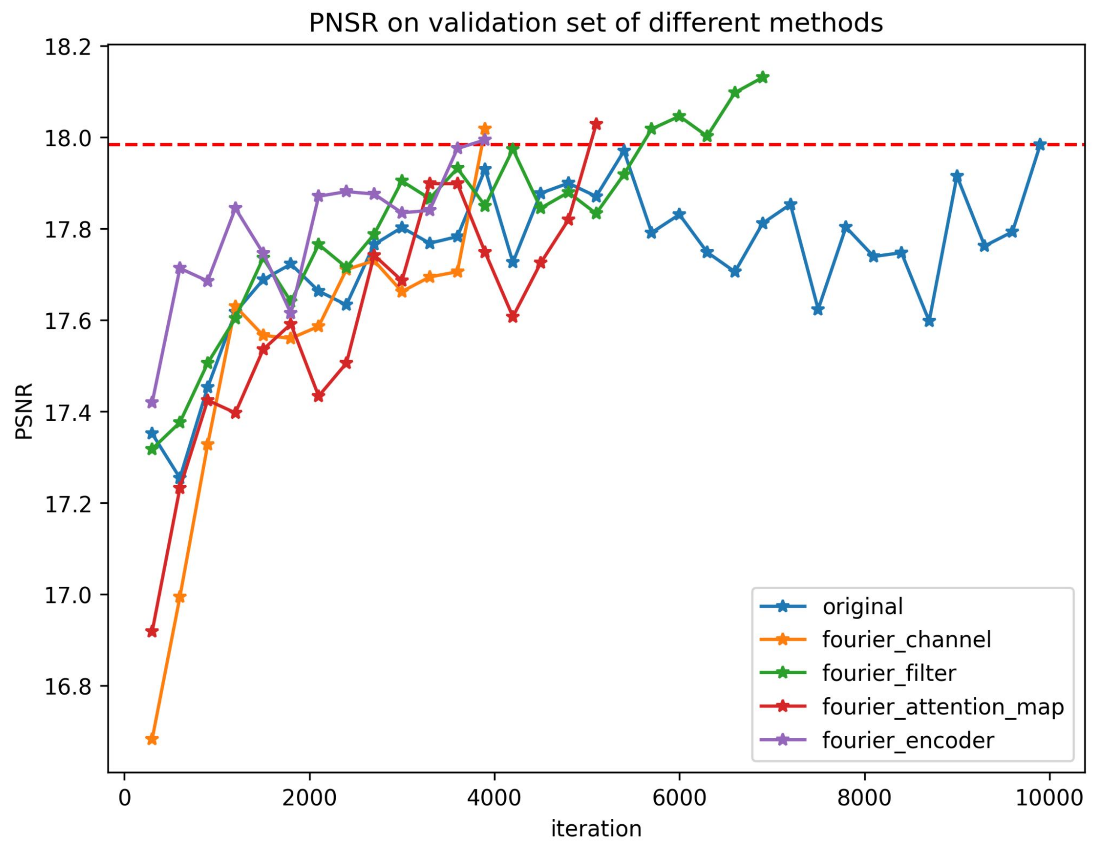
Fourier Attention Map:
Instead of spatial attention map, we use frequency attention map to determine which frequency is more important.

Fourier Encoder:
Add a CNN-based encoder taking input of image in the Fourier domain and add the output back to the input of the RGB layers



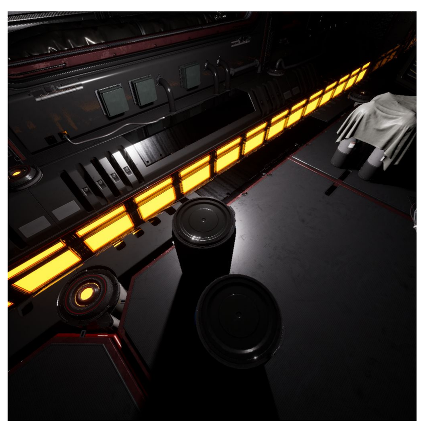

## Experimental Results

We have tested the performance of all the four modified Fourier methods we proposed as well as the original model with the same model settings on the validation set of VIDIT ECCV 2020 AIM dataset.

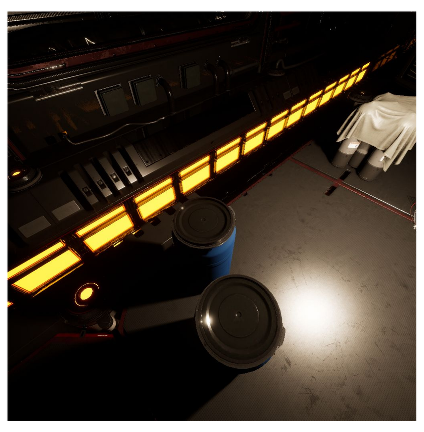



With several forms of Fourier are integrated into the project, the model could focus on the information related to relighting and achieve a better performance than the original model within fewer iterations.

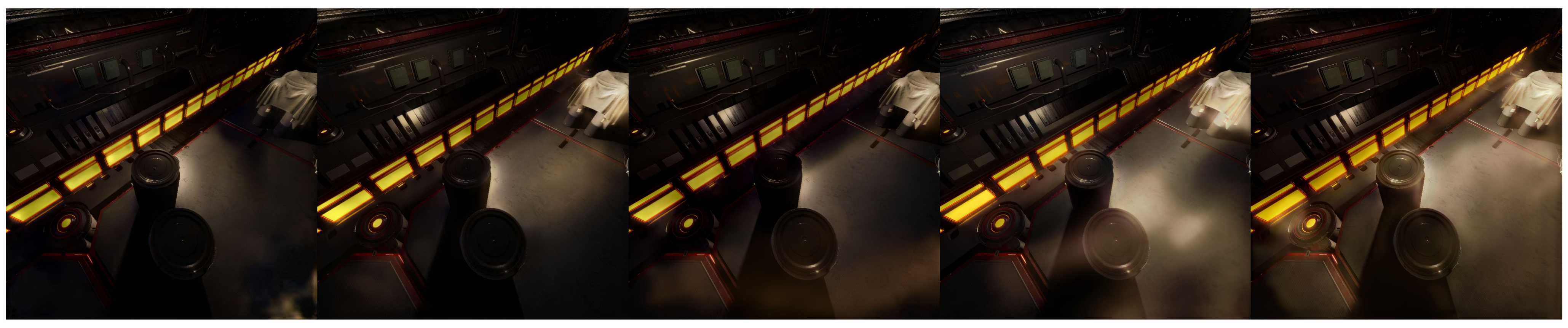
| Method | original | Fourier Channel | Fourier Filter | Fourier Attention Map | Fourier Encoder |
|---|---|---|---|---|---|
| PSNR | 17.9837 | 18.0184 | 18.1311 | 18.0287 | 17.9945 |
| Iteration | 9900 | 3900 | 6900 | 5100 | 3900 |



Input



Target



Fourier Channel | Fourier Filter | Fourier Attention | Fourier Encoder | Original