Fast Bilateral Filtering

Group 1

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Contents

Papers

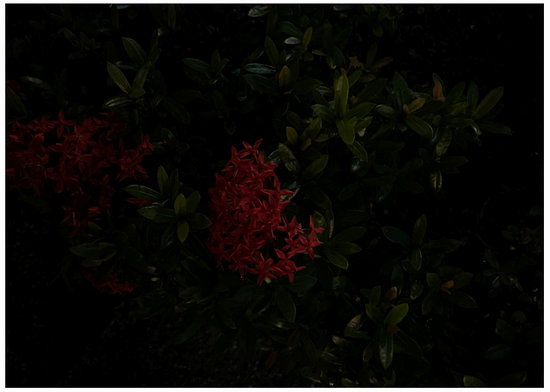
Combining bilateral filtering on all kinds of image enhancement at once

- S. Ghosh and K. N. Chaudhury, “Fast bright-pass bilateral filtering for low-light enhancement”, Proc. IEEE International Conference on Image Processing (ICIP), pp. 205-209, Taipei, Taiwan, 2019
- R. G. Gavaskar and K. N. Chaudhury, "Fast Adaptive Bilateral Filtering of Color Images," 2019 IEEE International Conference on Image Processing (ICIP), Taipei, Taiwan, 2019, doi: 10.1109/ICIP.2019.8802987

Motivation

- Capture undesired image ex. too dark, unfocused, blur...
- No second chance to retake

Automatic enhancement and quick response



Motivation

Fast Bright-Pass Bilateral Filtering for Low-Light Enhancement

- low-light conditions
- retinex model can estimate the illumination and reflectance
- Bright-Pass Bilateral Filtering (BPBF) is used for illumination estimation, but is computation intensive and takes long processing time

➡ Fourier approximation on BPBF to accelerate filtering

Motivation

Fast Adaptive Bilateral Filtering of Color Images

- Enhancement capacity of the filter can be boosted by adapting the width of the range kernel at each pixel.
- Adaptive bilateral filtering of grayscale images.
- Goal: Enable the use of adaptive bilateral filtering for real-time applications on color images

➡ approximating the histogram by an uniform distribution

Problem Definition

Combine two types of bilateral filtering on image enhancement

- effectively enhance an image in one operation
- automatically detect the needed adjustment
  - low-light
  - detail enhancement
- short processing time
  - fast bilateral filter process
- generally optimized result in all cases

Algorithm

Fast Bright-Pass Bilateral Filtering for Low-Light Enhancement

1. convert to HSV channel and extract the V channel to modify the illumination
2. find the best tone-mapping parameter with Fourier expansion and sigmoid function
3. compute the compressed channel with Fourier approximation term with gaussian filter
4. get the ratio between original channel and compressed channel
5. compute the gamma correction on compressed channel
6. reconstruct the enhanced V channel by multiplying the ratio and gamma correction
7. convert the HSV channel back to RGB image to get the enhanced result

Tuning parameters:

- Kmax: maximum order of approximation
- sigma s: spatial kernel radius for the Gaussian filter, controls the smoothing range
- sigma r: controls how much the pixel intensities or colors influence the filtered output

Algorithm

Fast Adaptive Bilateral Filtering of Color Images

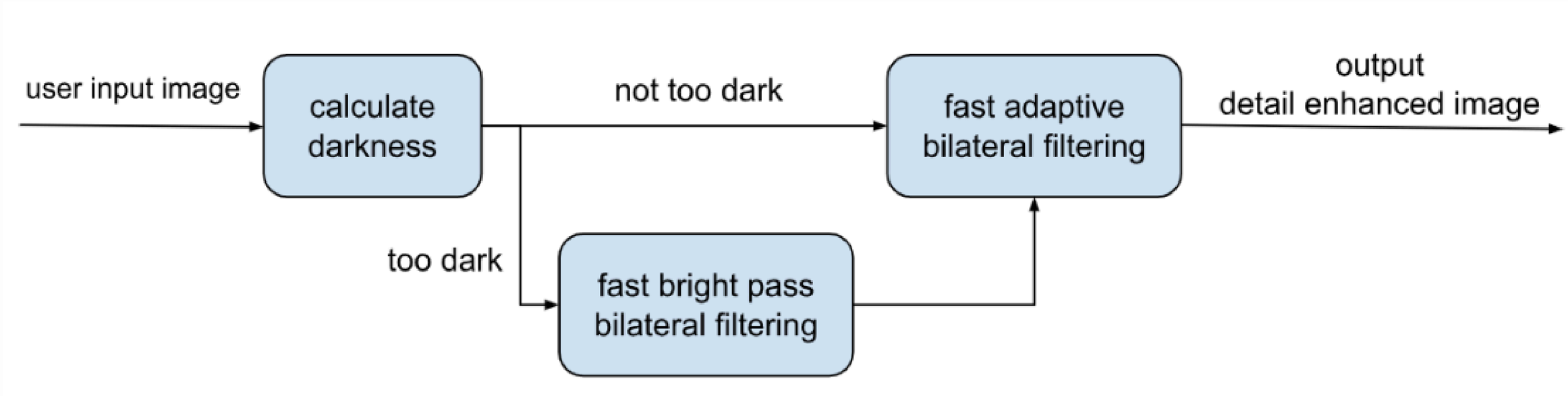
1. Using the local covariance to determine this optimal direction efficiently.
2. Approximate the local histogram by a uniform distribution along the direction of the dominant eigenvector.
3. Histogram approximation transform the equations into integrals.
4. Derive closed-form solutions for the integrals, enabling fast computation of the filtered output.

Tuning parameters:

- rho (float): Standard deviation of Gaussian spatial kernel OR radius of box kernel
- sigma_r (np.ndarray): m-by-n matrix of pixelwise standard deviations of Gaussian range kernels)

Algorithm

Combination



Result

low light enhancement

- Evaluation
  - process time
  - PSNR: compare signal and noise; higher value better quality
  - PIQE: visibility of details and edges; higher value better quality

Result

different parameter: Kmax

time: 1.27s
PIQE: 0.3811

Kmax = 5

time: 11.56s
PIQE: 0.3643

Kmax = 15

time: 37.57s
PIQE: 0.3638

Kmax = 25

time: 67.19s
PIQE: 0.3637

Kmax = 35

Result

different parameter: sigma s

time: 0.89s
PSNR: 29.64 / PIQE: 0.52

sigma s = 1

time: 1.28s
PSNR: 29.73 / PIQE: 0.55

sigma s = 5

time: 3.17s
PSNR: 29.90 / PIQE: 0.53

sigma s = 20

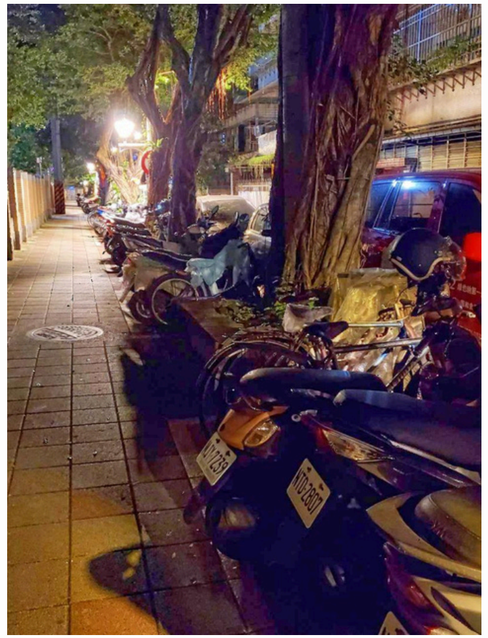
time: 7.42s
PSNR: 29.88 / PIQE: 0.52

sigma s = 50

Result

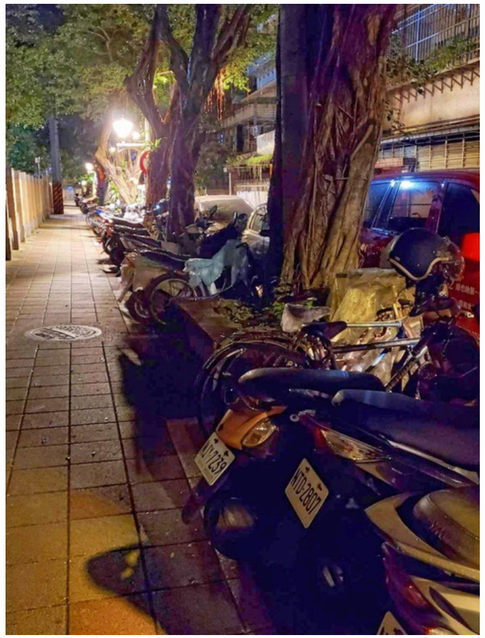
different parameter: sigma r

PSNR: 27.66 / **PIQE: 0.63**



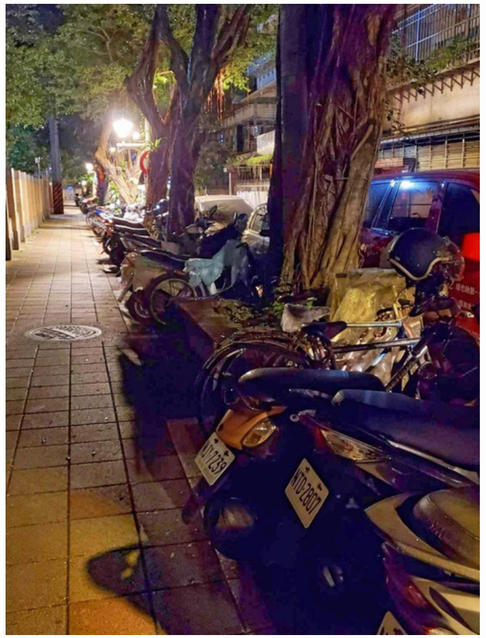
sigma r = 10

PSNR: 27.68 / PIQE: 0.62



sigma r = 30

PSNR: 27.68 / PIQE: 0.61

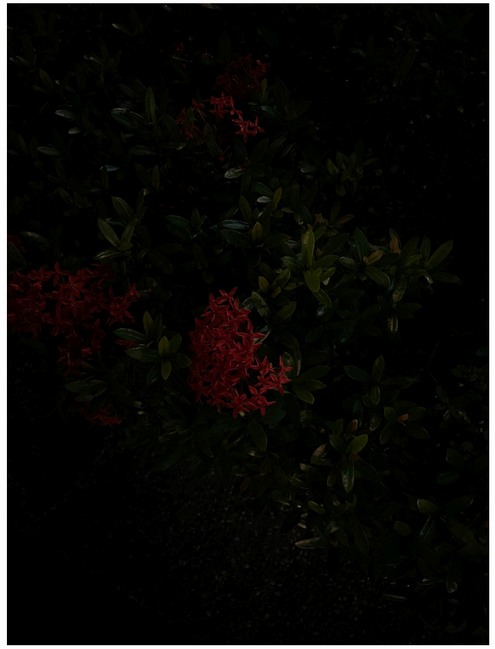


sigma r = 50

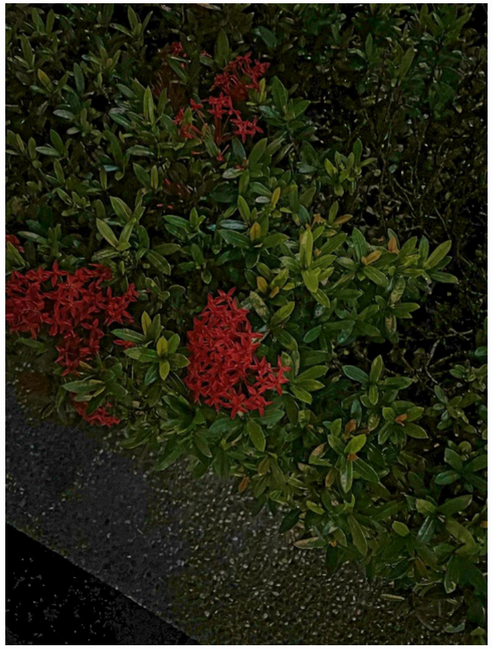
Result

low light enhancement

time: 1.44s / PSNR: 28.56 / PIQE: 0.7309



before



after

time: 1.86s / PSNR: 29.73 / PIQE: 0.5532

before

after

Result

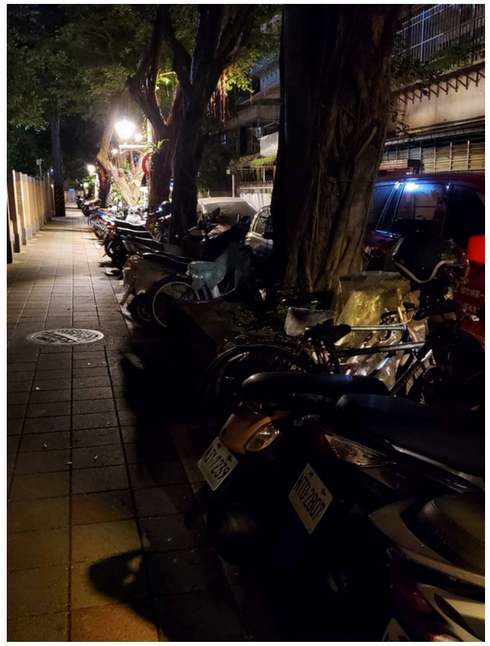
low light enhancement

time: 1.27s / PSNR: 27.59 / PIQE: 0.3811

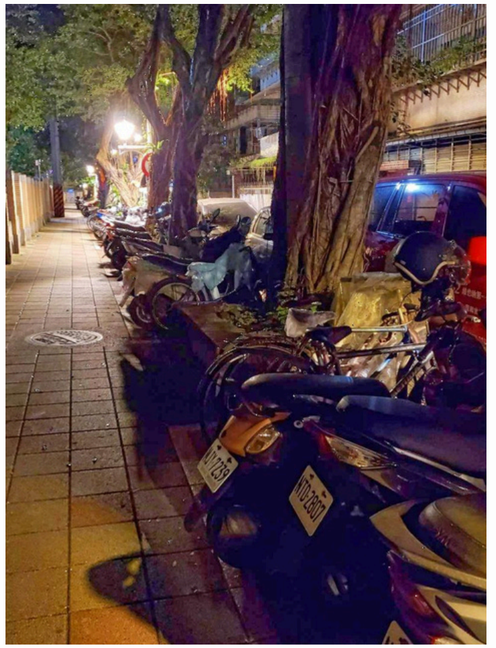
before

after

time: 1.66s / PSNR: 27.68 / PIQE: 0.6229



before



after

Result

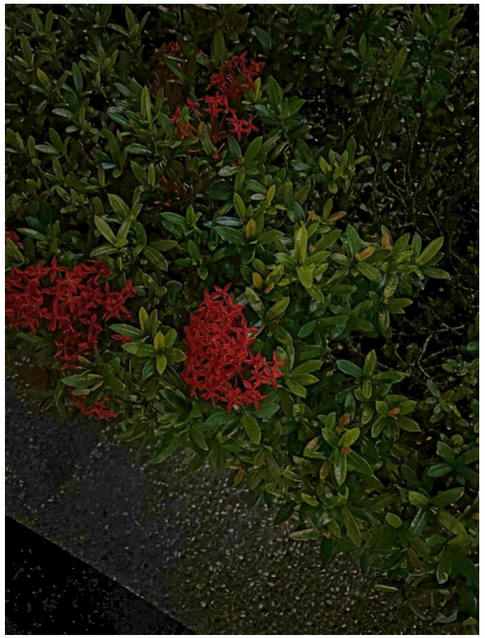
compare with other low light enhancement approaches

- Appoach
  - Fast BPBF: fourier approximation on filtering
  - Brute force BPBF: traditional bilateral filtering
  - BPDHE: brightness preserve of dynamic histogram equalization
  - LIME: low light enhancement with illumination map estimation

Result

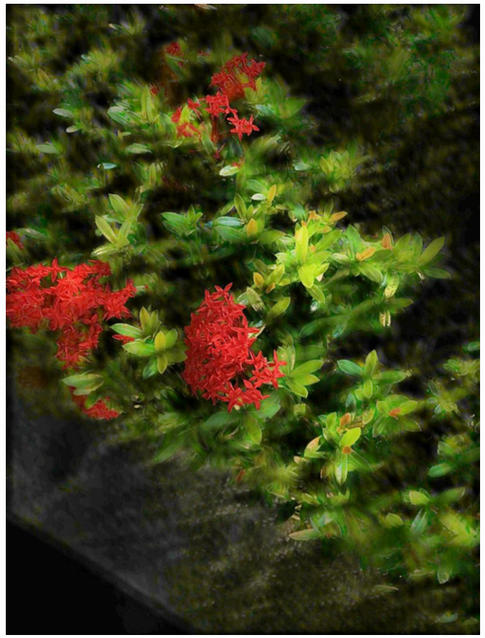
compare with other low light enhancement approach

time: 1.48s
PSNR: 28.56 / PIQE: 0.73



fast BPBF

time: 12.56s
PSNR: 28.04 / PIQE: 0.54

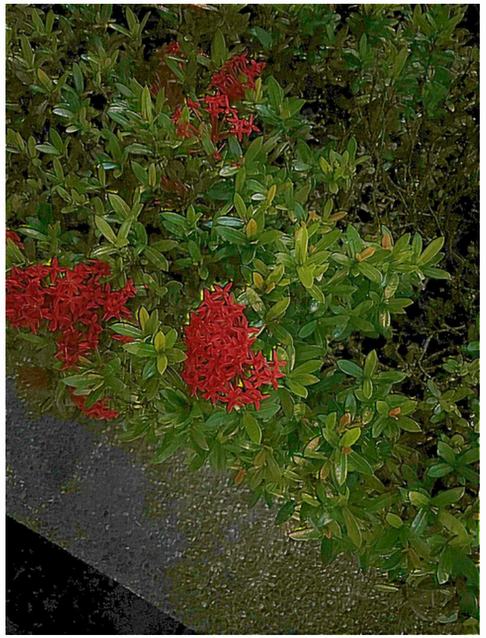


brute force BPBF

time: 0.12s
PSNR: 29.24 / PIQE: 0.76

BPDHE

time: 5.54s
PSNR: 28.46 / PIQE: 0.86



LIME

Result

compare with other low light enhancement approach

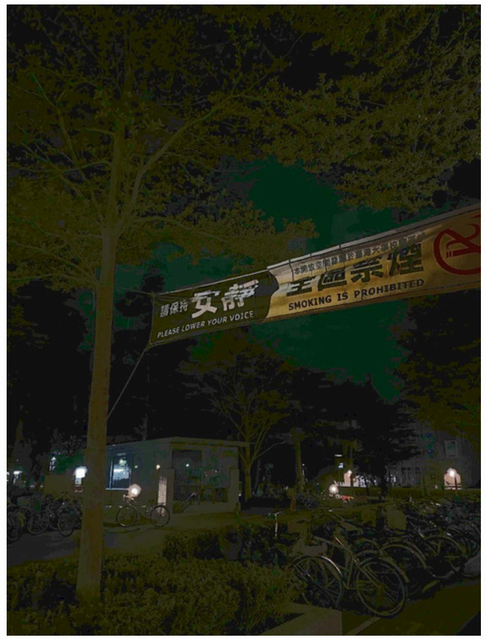
time: 1.76s
PSNR: 29.73 / PIQE: 0.55

fast BPBF

time: 12.38s
PSNR: 28.61 / PIQE: 0.18

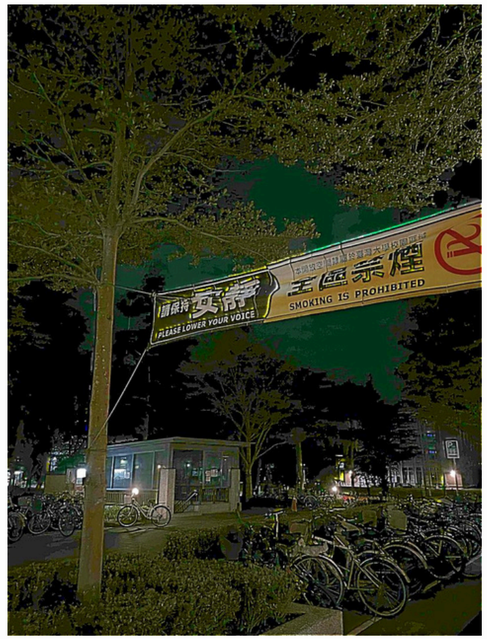
brute force BPBF

time: 0.12s
PSNR: 28.52 / PIQE: 0.42



BPDHE

time: 5.54s
PSNR: 29.69 / PIQE: 0.65



LIME

Result

compare with other low light enhancement approach

time: 1.30s
PSNR: 27.59 / PIQE: 0.38

fast BPBF

time: 12.54s
PSNR: 27.75 / PIQE: 0.34

brute force BPBF

time: 0.13s
PSNR: 28.09 / PIQE: 0.52

BPDHE

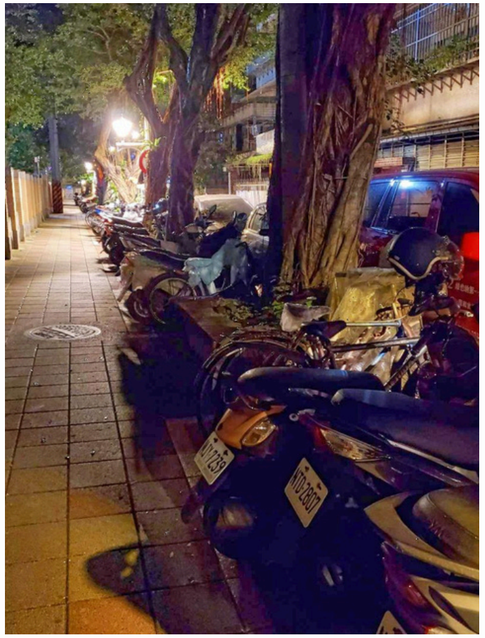
time: 5.67s
PSNR: 27.50 / PIQE: 0.60

LIME

Result

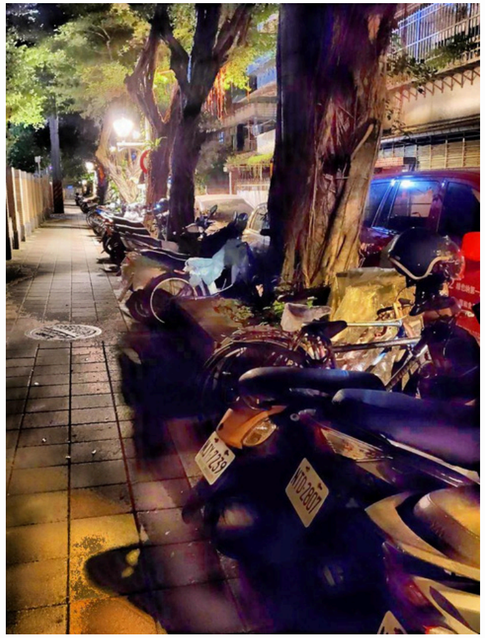
compare with other low light enhancement approach

time: 1.29s
PSNR: 27.68 / PIQE: 0.62



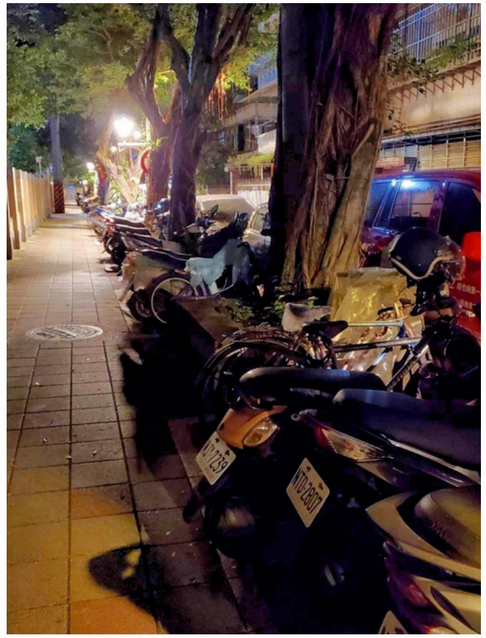
fast BPBF

time: 14.29s
PSNR: 28.30 / PIQE: 0.56



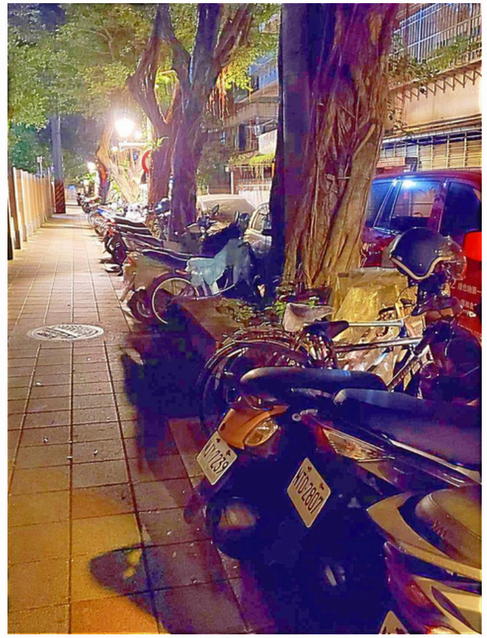
brute force BPBF

time: 0.12s
PSNR: 28.62 / PIQE: 0.54



BPDHE

time: 5.50s
PSNR: 27.56 / PIQE: 0.72



LIME

Result

compare with other low light enhancement approach

time: 0.79s
PSNR: 27.81 / PIQE: 0.35

fast BPBF

time: 8.98s
PSNR: 28.03 / PIQE: 0.50

brute force BPBF

time: 0.08s
PSNR: 30.94 / PIQE: 0.28

BPDHE

time: 2.36s
PSNR: 27.51 / PIQE: 0.44

LIME

Result

combine-deblock

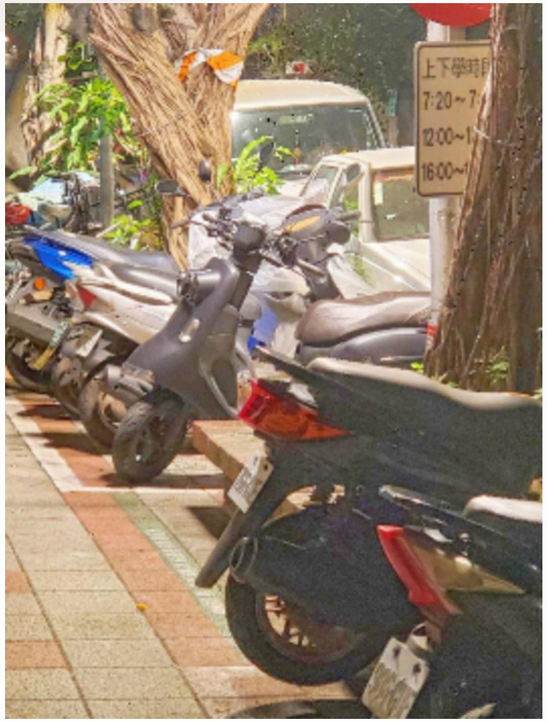
FastABF

- Time taken: 19.28527593612671 sec
- PSNR: 35.314751891629115

Brute-force ABF

- Time taken: 41.56327986717224 sec
- PSNR: 36.13560896876534

Original



Fast ABF

Bruteforce ABF

Result

combined

FastABF

- Time taken: 13.85993766784668 sec
- PSNR: 34.668635767029265

Brute-force ABF

- Time taken: 25.165709972381592 sec
- PSNR: 34.992776182265985

Original

Fast ABF

Bruteforce ABF

Result

combined

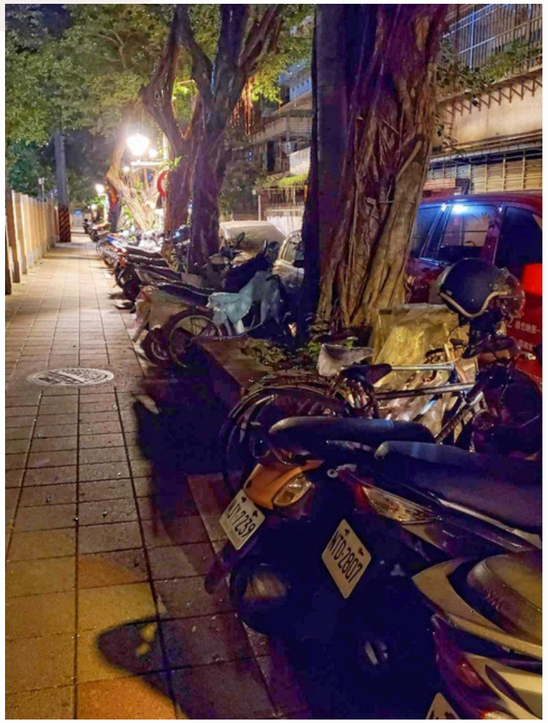
FastABF

- Time taken: 29.478028535842896 sec
- PSNR: 32.45620372024169

Brute-force ABF

- Time taken: 46.89840841293335 sec
- PSNR: 32.77076775638831

Original



Fast ABF

Bruteforce ABF

Result

combined

FastABF

- Time taken: 26.53427529335022 sec
- PSNR: 34.70526666405951

Brute-force ABF

- Time taken: 46.43718218803406 sec
- PSNR: 34.624226671899564

Original

Fast ABF

Bruteforce ABF

Result

combined

FastABF

- Time taken: 25.94984483718872 sec
- PSNR: 32.01508416176675

Brute-force ABF

- Time taken: 47.94389343261719 sec
- PSNR: 32.757752996193716

Original

Fast ABF

Bruteforce ABF

Result

combined

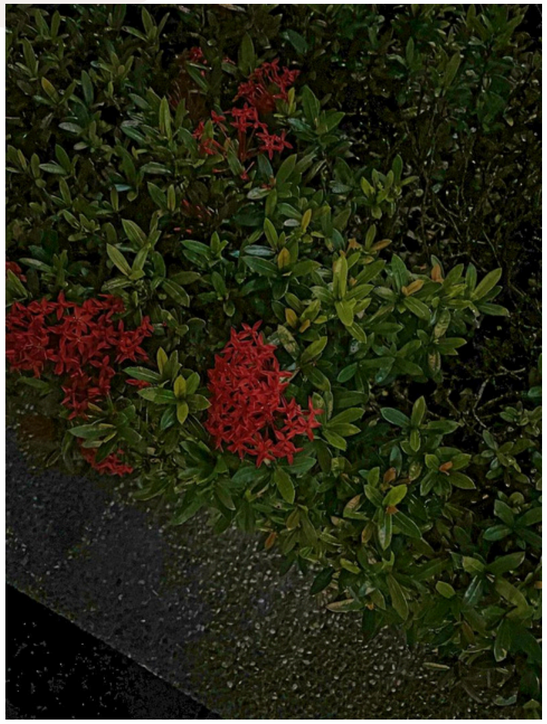
FastABF

- Time taken: 29.478028535842896 sec
- PSNR: 32.45620372024169

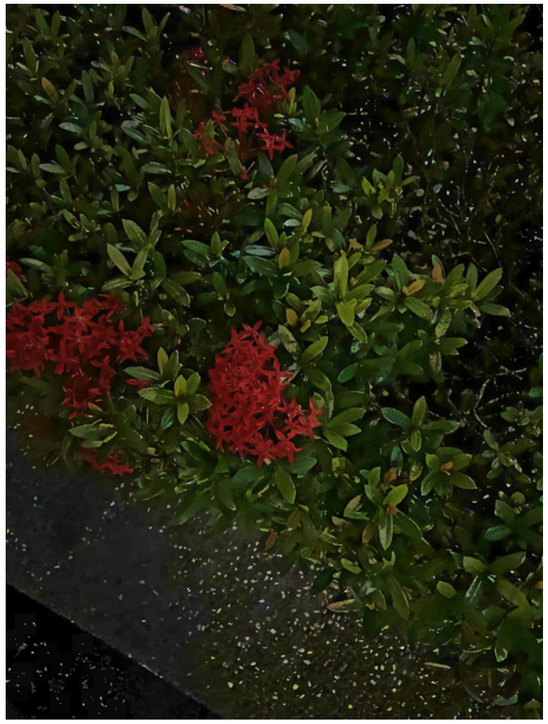
Brute-force ABF

- Time taken: 46.89840841293335 sec
- PSNR: 32.77076775638831

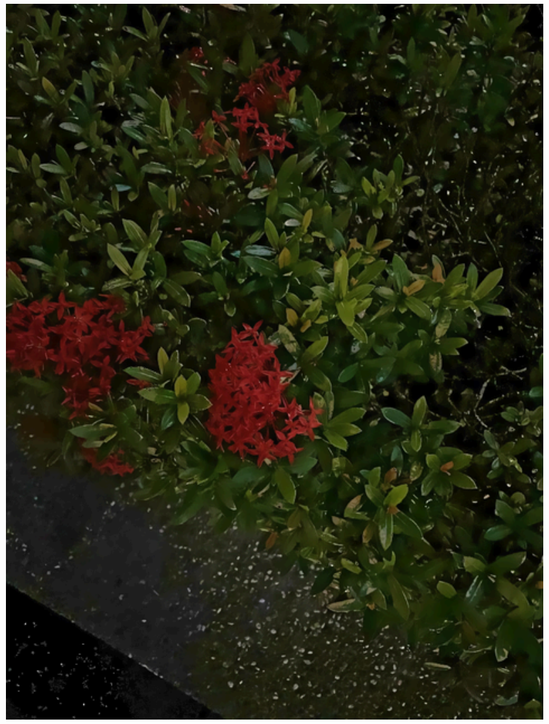
Original



Fast ABF



Bruteforce ABF



Reference

- S. Ghosh and K. N. Chaudhury, "Fast Bright-Pass Bilateral Filtering for Low-Light Enhancement," 2019 IEEE International Conference on Image Processing (ICIP), Taipei, Taiwan, 2019, pp. 205-209, doi: 10.1109/ICIP.2019.8802986. keywords: {Lighting;Approximation algorithms;Kernel;Fourier series;Filtering;Estimation;Acceleration;low-light enhancement;retinex;bilateral filter;Fourier approximation;fast algorithm},
- R. G. Gavaskar and K. N. Chaudhury, "Fast Adaptive Bilateral Filtering of Color Images," 2019 IEEE International Conference on Image Processing (ICIP), Taipei, Taiwan, 2019, pp. 180-184, doi: 10.1109/ICIP.2019.8802987. keywords: {Histograms;Kernel;Color;Image color analysis;Approximation algorithms;Image edge detection;Gray-scale;color processing;bilateral filter;fast algorithm;histogram;covariance},

Reference

- H. Ibrahim and N. S. Pik Kong, "Brightness Preserving Dynamic Histogram Equalization for Image Contrast Enhancement," in IEEE Transactions on Consumer Electronics, vol. 53, no. 4, pp. 1752-1758, Nov. 2007, doi: 10.1109/TCE.2007.4429280.keywords: {Brightness;Histograms;Image enhancement;Dynamic range;Consumer electronics;TV;Pixel;Digital images;Filters},
- X. Guo, Y. Li and H. Ling, "LIME: Low-Light Image Enhancement via Illumination Map Estimation," in IEEE Transactions on Image Processing, vol. 26, no. 2, pp. 982-993, Feb. 2017, doi: 10.1109/TIP.2016.2639450.keywords: {Lighting;Estimation;Image enhancement;Visualization;Atmospheric modeling;Histograms;Image color analysis;Illumination estimation;illumination (light) transmission;low-light image enhancement},
- C. Tomasi and R. Manduchi, "Bilateral filtering for gray and color images," Sixth International Conference on Computer Vision (IEEE Cat. No.98CH36271), Bombay, India, 1998, pp. 839-846, doi: 10.1109/ICCV.1998.710815. keywords: {Filtering;Color;Low pass filters;Photometry;Imaging phantoms;Pixel;Shape measurement;Smoothing methods;Computer science;Humans},