Local area processing / Local area contrast enhancement

1. Contrast limited adaptive histogram equalization (CLAHE)
2. Image pyramid
3. A multiscale morphology
4. Adaptive contrast enhancement using histogram equalization
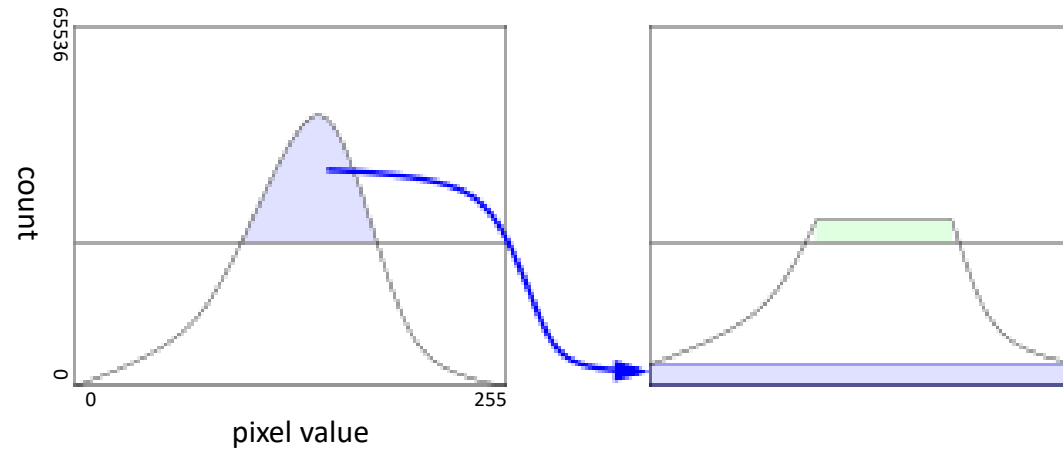5. Shannon's entropy

By Sang Moon

1. Contrast limited adaptive histogram equalization (CLAHE)
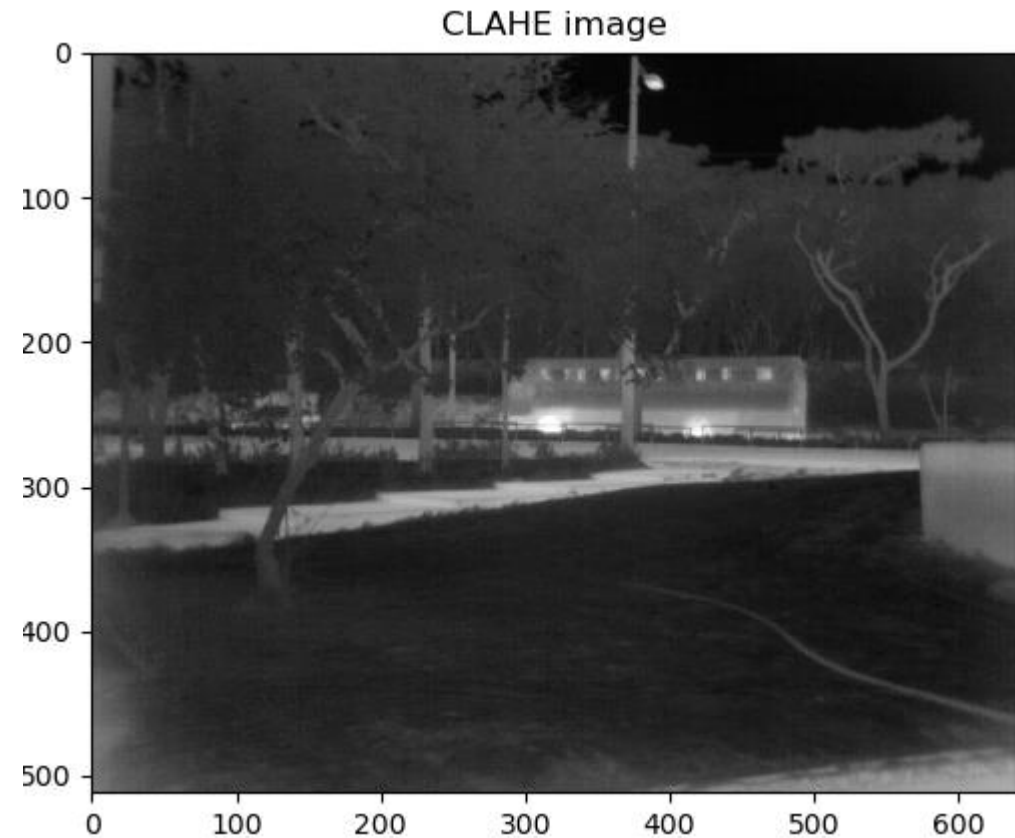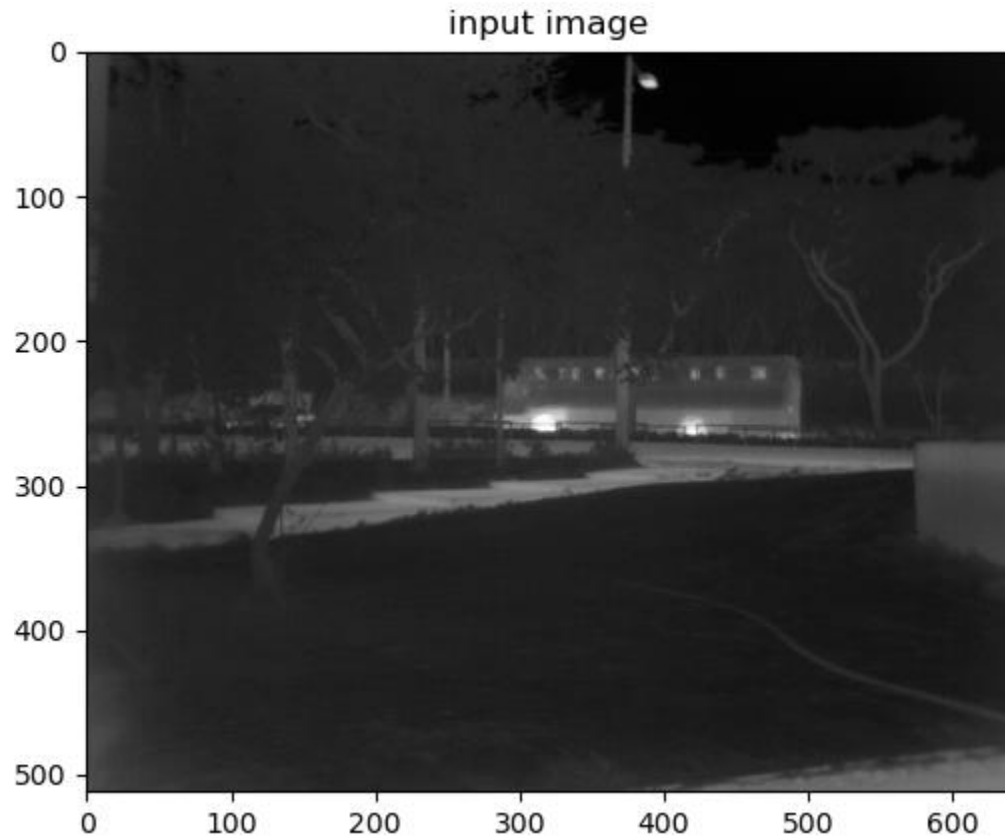
- Local area contrast enhancement.

Summary of the algorithm
1. Divide an input image into small blocks. (16 blocks)
2. Calculate histograms of each blocks.
3. Distribute the part of the histogram which exceeded the limit equally over all histogram bins.
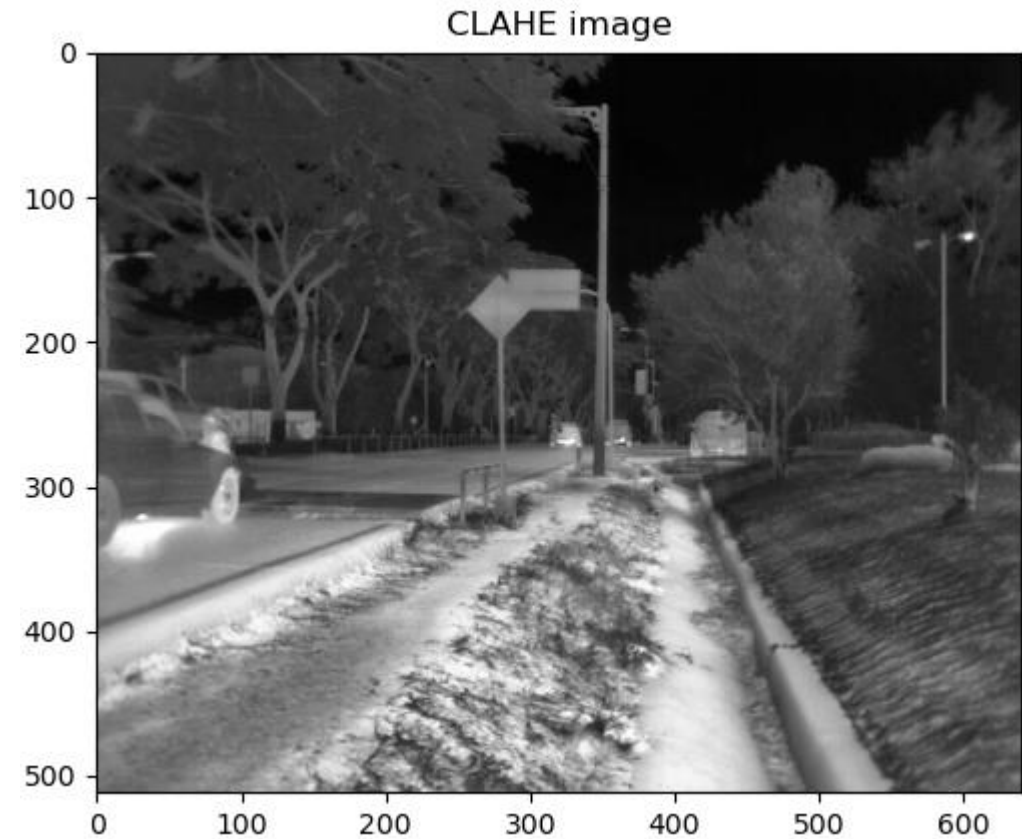

4. Find CDF and stretch the contrast.

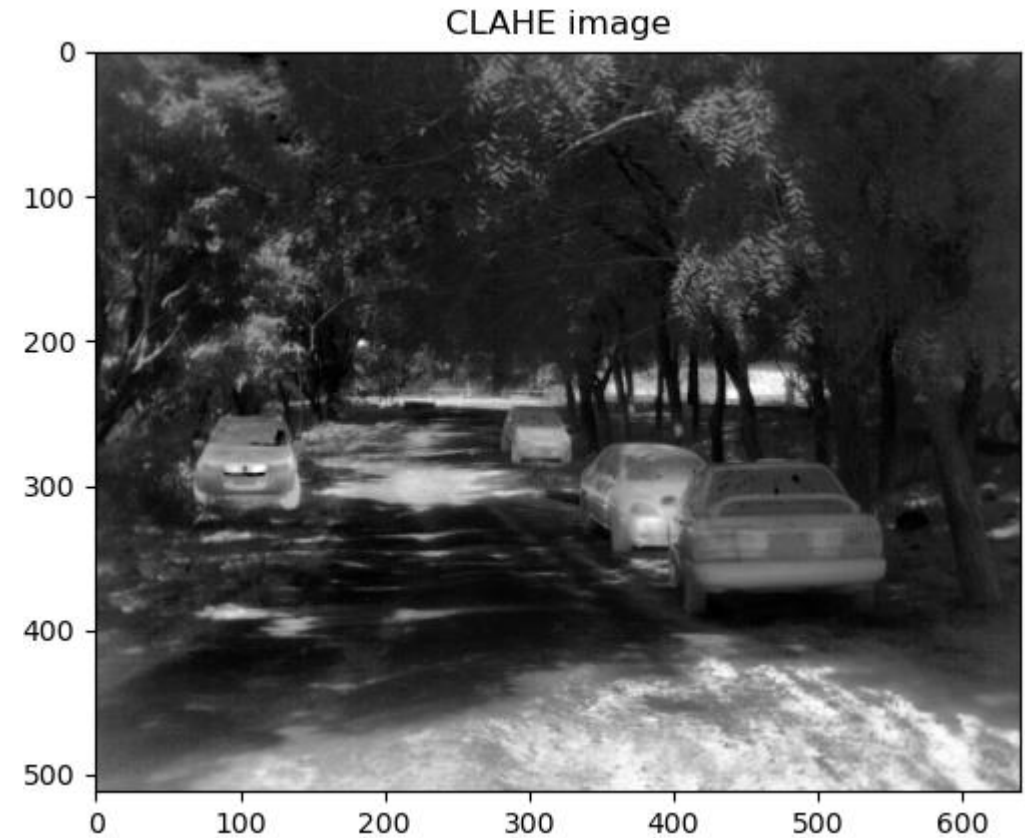# 1. Contrast limited adaptive histogram equalization (CLAHE)
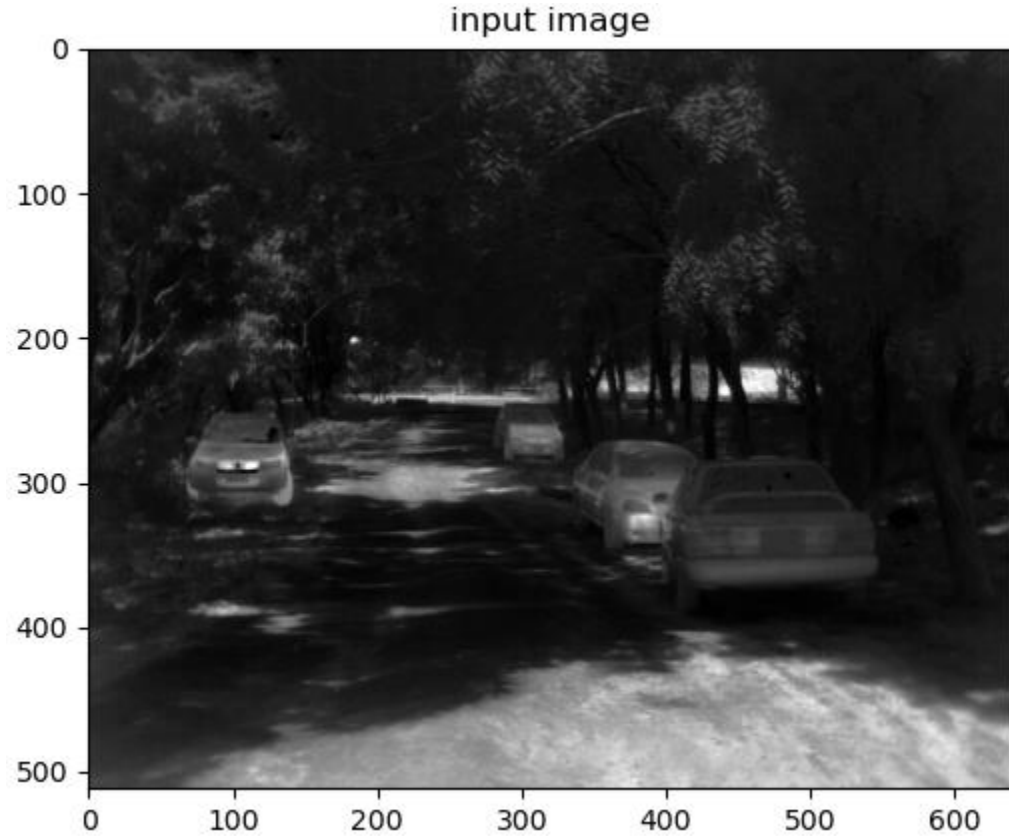

- Image was divided into 16 blocks.

1. Contrast limited adaptive histogram equalization (CLAHE)

1. Contrast limited adaptive histogram equalization (CLAHE)

2. Image pyramid

- An image pyramid is a set of images with different resolutions and different sizes of the same image.
- The image pyramid is made by smoothing the image with an appropriate smoothing filter and then subsampling the filtered image.
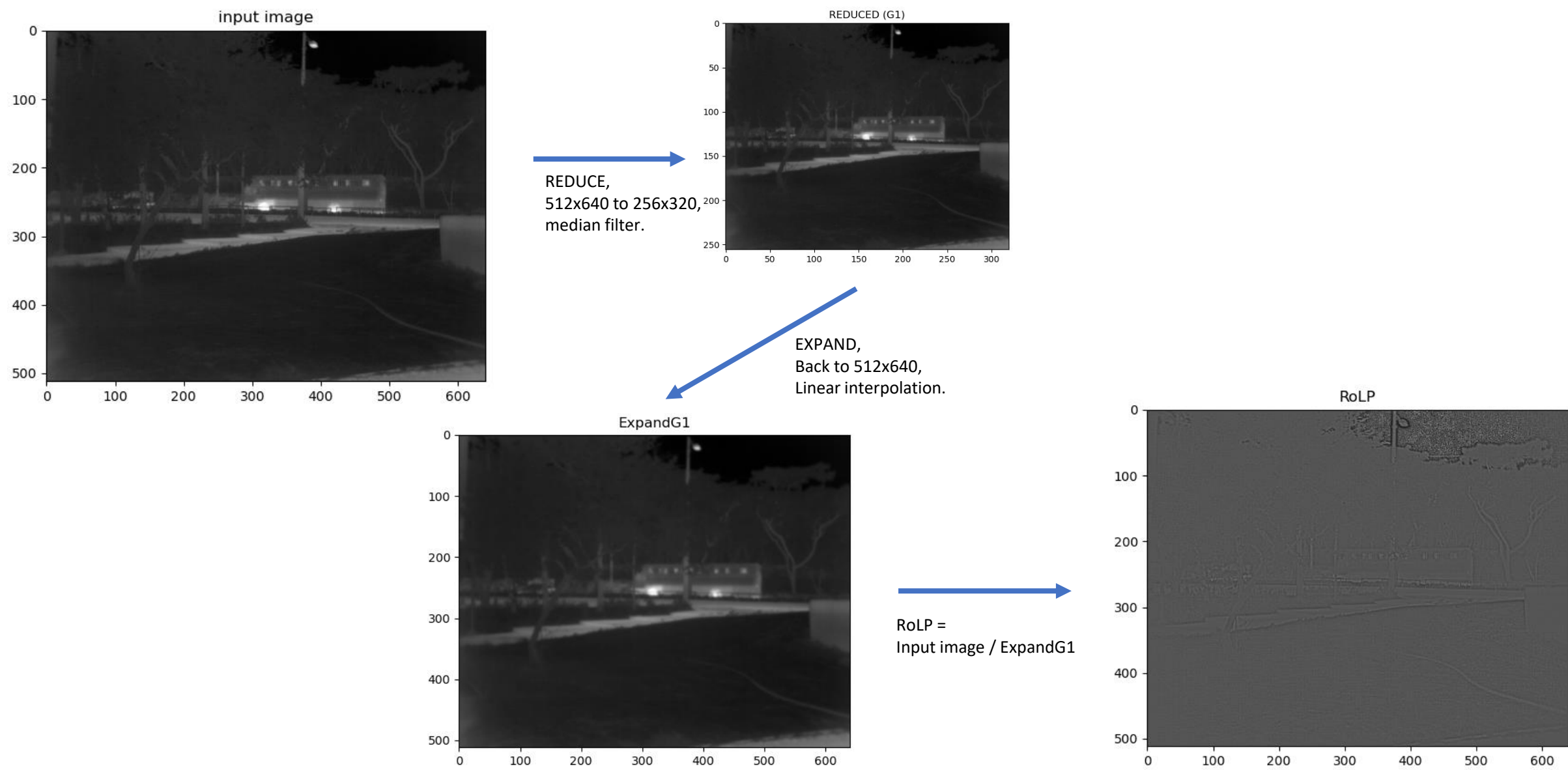
Summary of the algorithm

1. Find RoLP (ratio of low-pass) pyramid.
2. REDUCE operator reduces resolution and dimension by two.
3. EXPAND operator is the inverse of the REDUCE operator.
4. It uses interpolation to bring the size of the image to its original size.

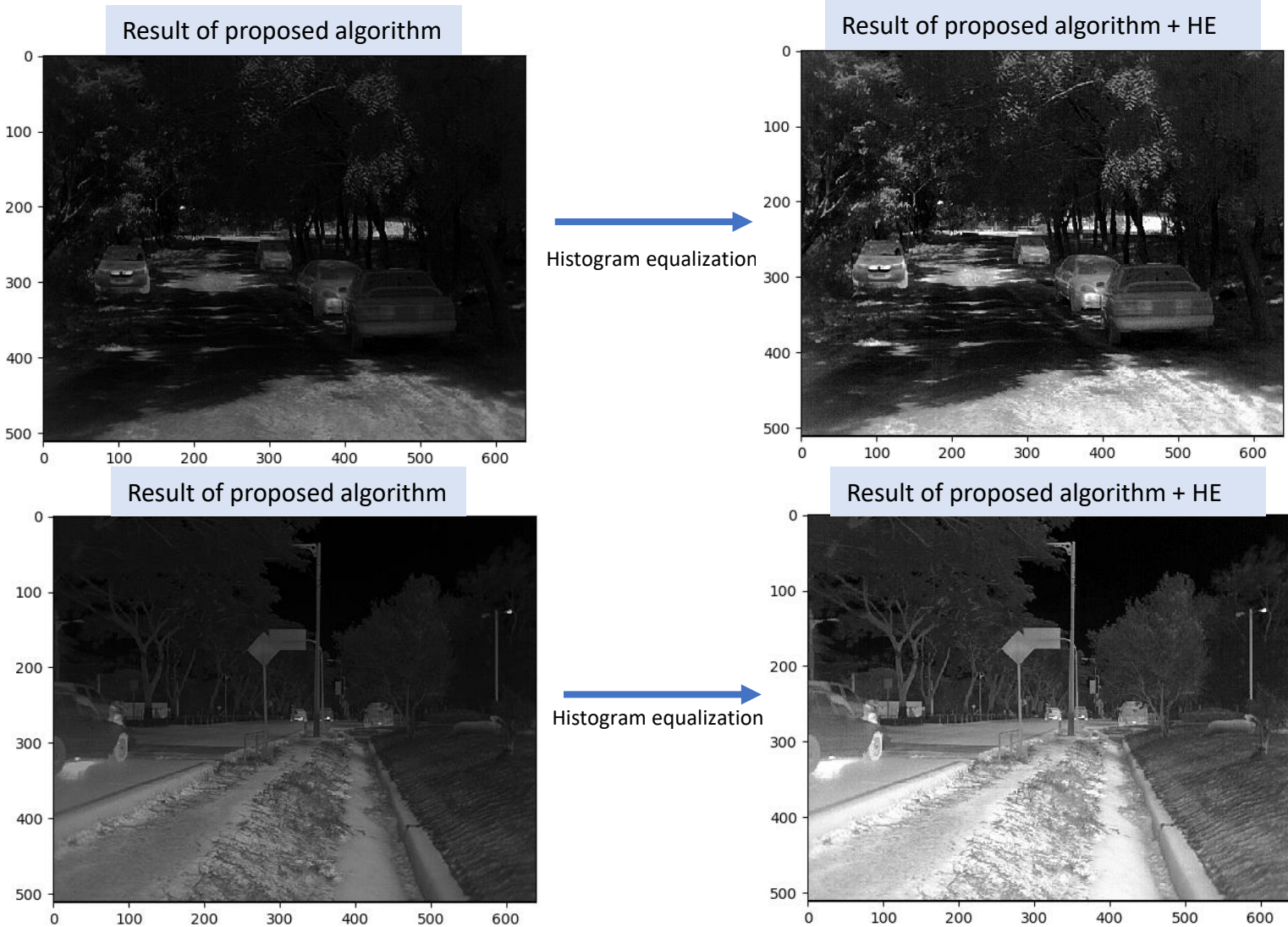$$RoLP_{(i,j)} = \frac{G_{(i,j)}}{EXPAND\ (REDUCE(G_{(i,j)}))}$$

$$If\ RoLP_{(i,j)} < 1:\ (i,j) = \min\ (i-1:i+1\ ,j-1:j+1)$$
$$RoLP_{(i,j)}\ > 1:\ (i,j) = \max\ (i-1:i+1\ ,j-1:j+1)$$

2. Image pyramid

input image

REDUCE,
512x640 to 256x320,
median filter.

REDUCED (G1)

EXPAND,
Back to 512x640,
Linear interpolation.

ExpandG1

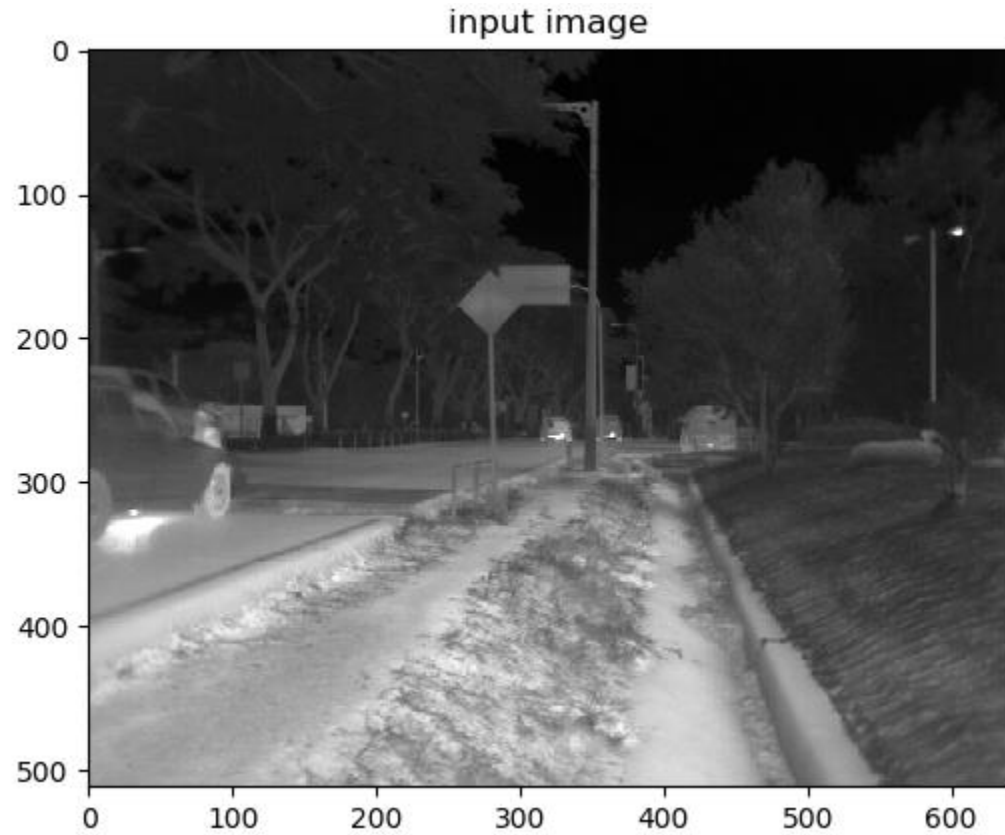RoLP =
Input image / ExpandG1

RoLP

2. Image pyramid + HE

Because the proposed algorithm produced dark image, the histogram equalization (HE) was applied.

Result of proposed algorithm
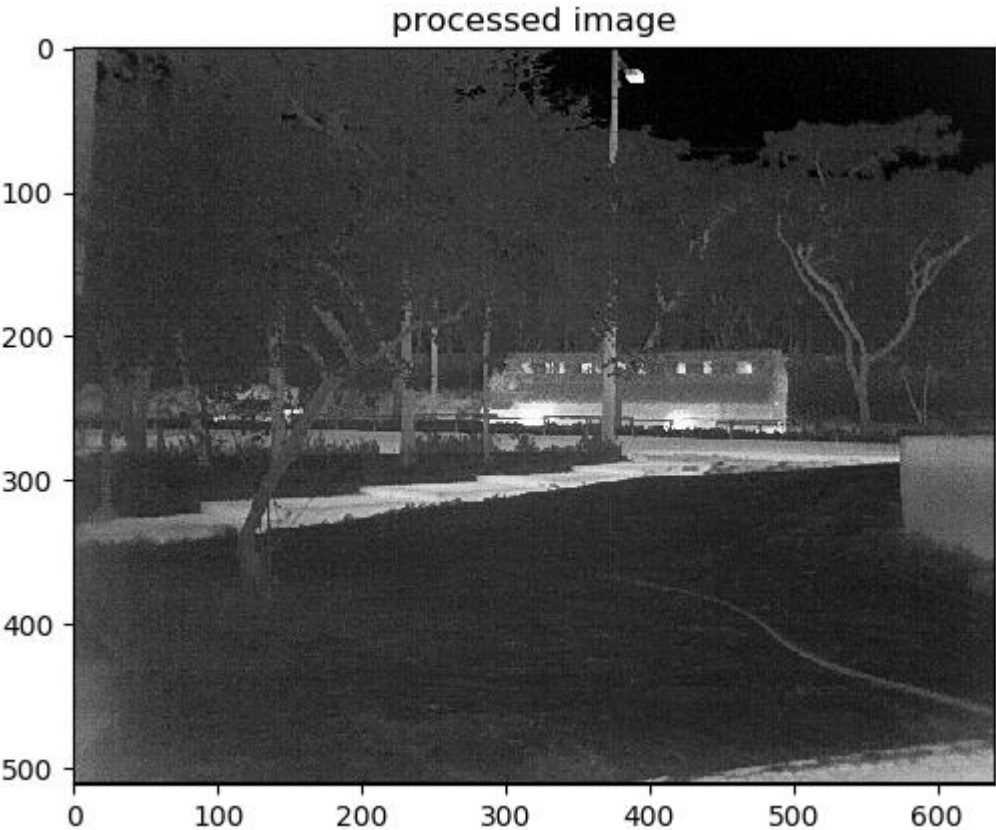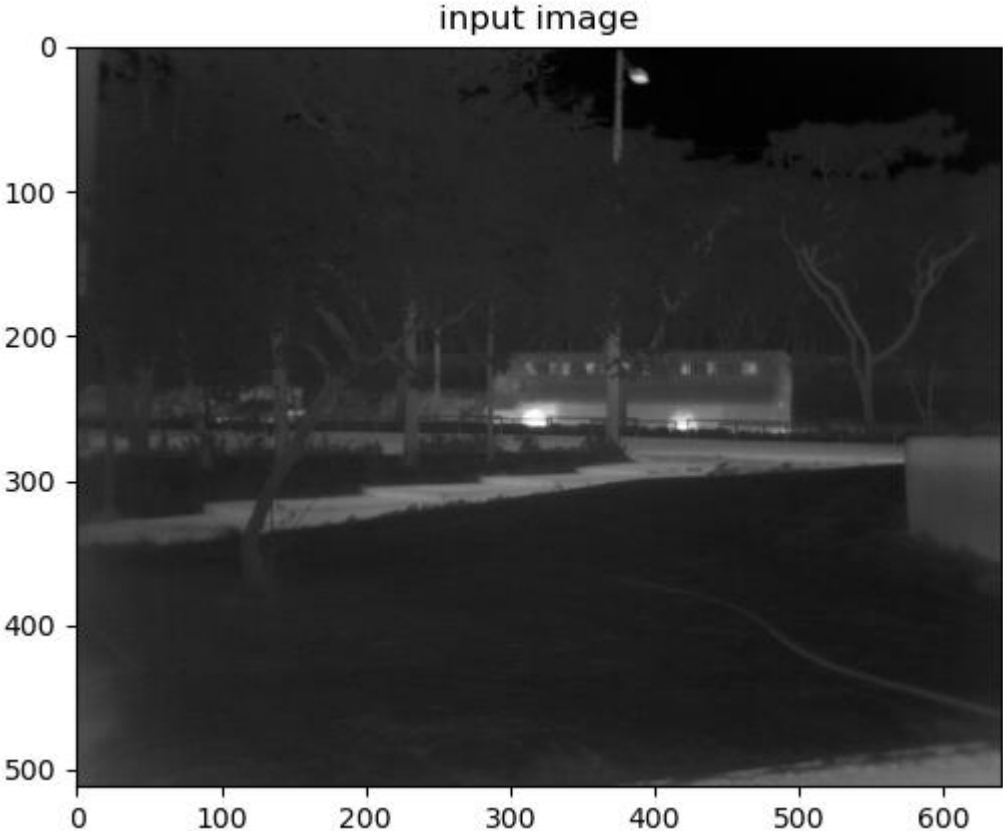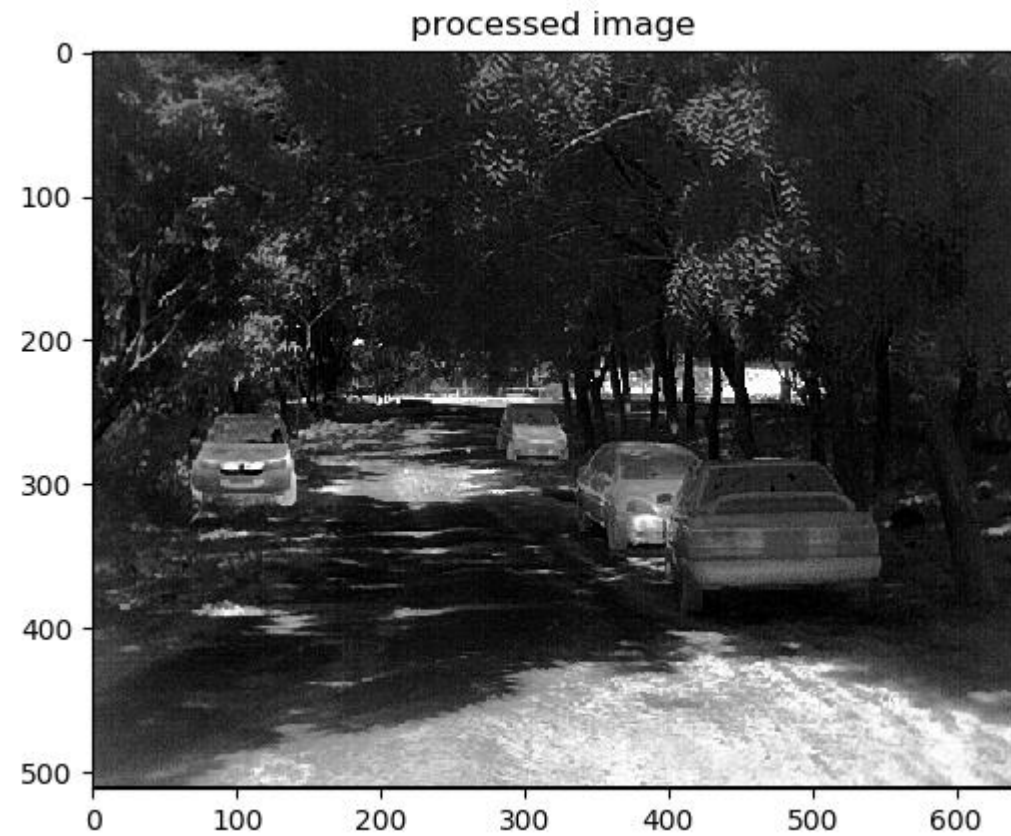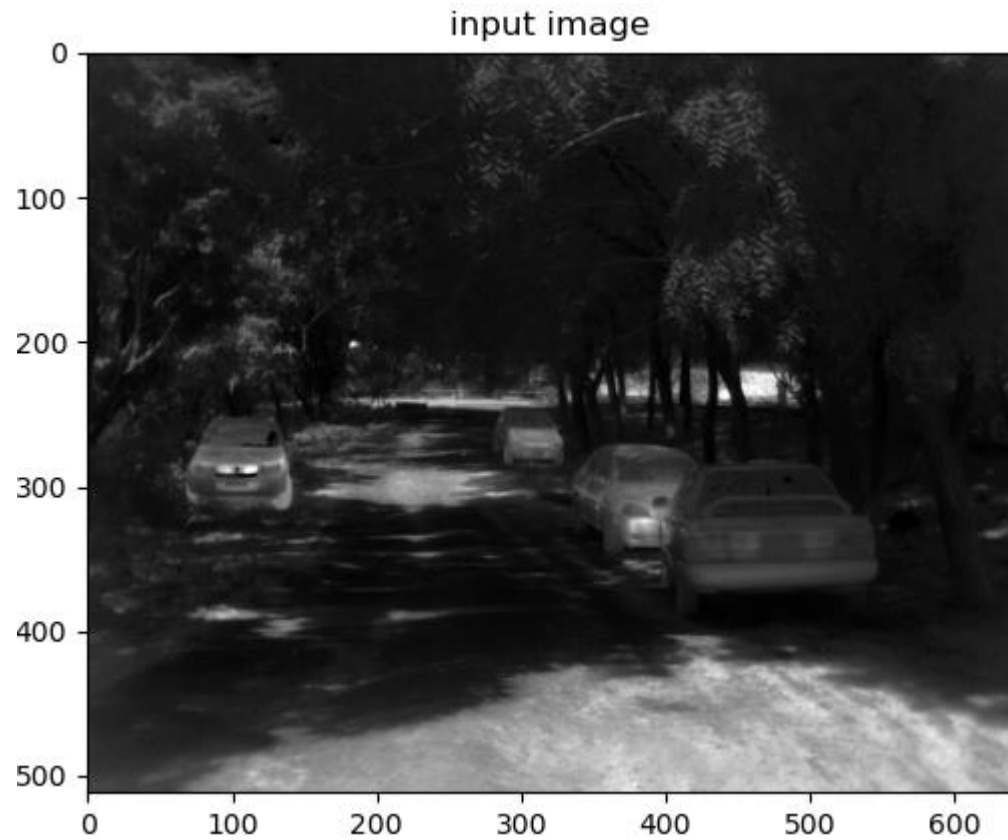
Result of proposed algorithm + HE

Histogram equalization

Result of proposed algorithm

Result of proposed algorithm + HE

Histogram equalization

2. Image pyramid + HE

input image

processed image

2. Image pyramid + HE

2. Image pyramid + HE

3. A multiscale morphology

- A multiscale morphology stretches the contrast based on the presence of spatial features.

- It extracts features from the image using different sized kernels.
- To extract the features, *tophat* and *blackhat* operations are employed.
  - Tophat: The tophat operator (*) is an excellent tool for extracting bright features smaller than the kernel size.
  - Blackhat: Blackhat operator (**) is the opposite to the tophat operator. It extracts darker features smaller than the kernel size.

- Five different size of kernels 2x2, 3x3, 4x4, 5x5, 6x6, and 7x7.
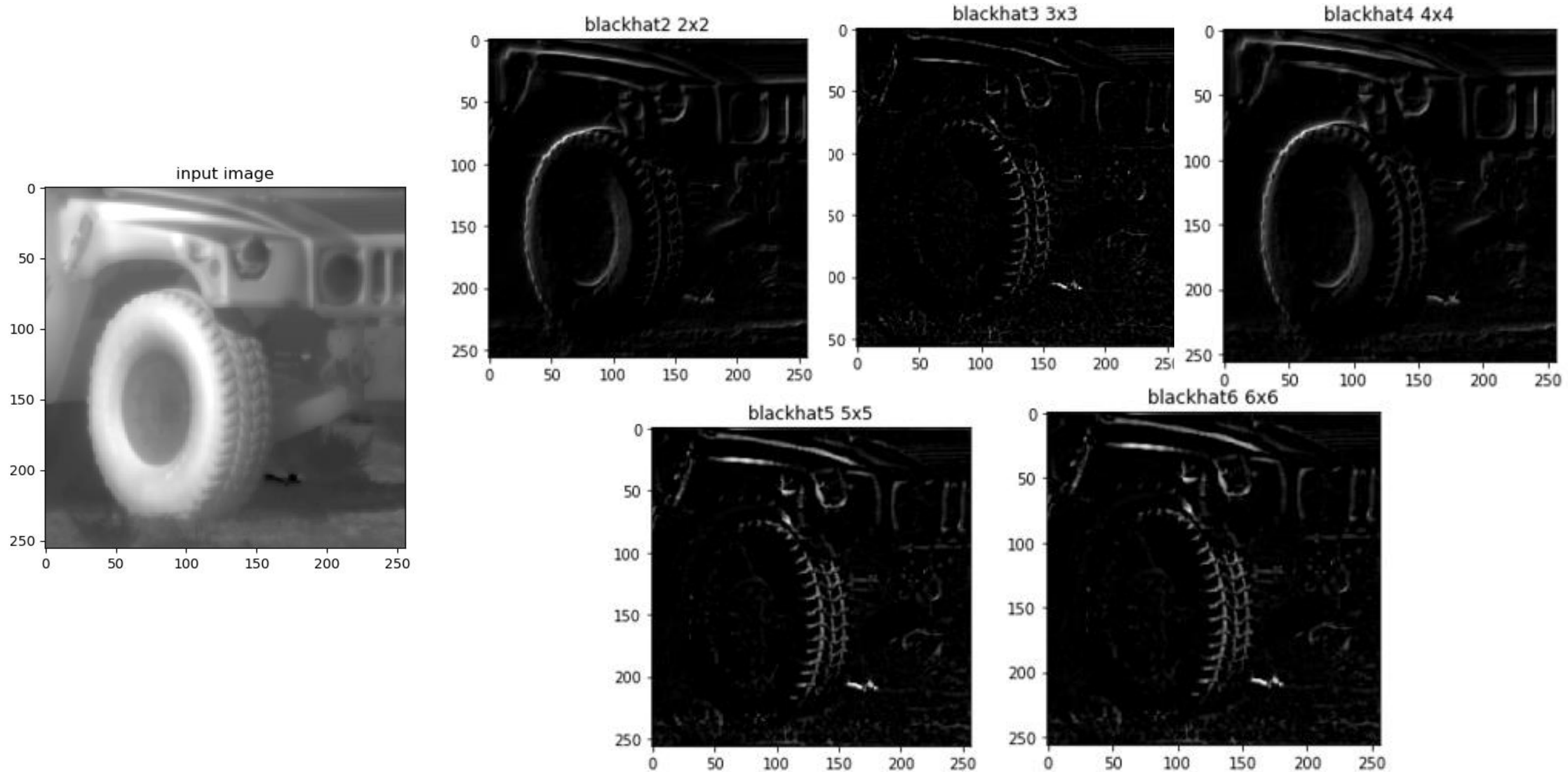
Final image is expressed as

$$Final = image + \omega\,(tophat2 + tophat3 + tophat4 + tophat5 + tophat6 + tophat7)$$
$$- \omega\,(blackhat2 + blackhat3 + blackhat4 + blackhat5 + blackhat6 + blackhat7)$$
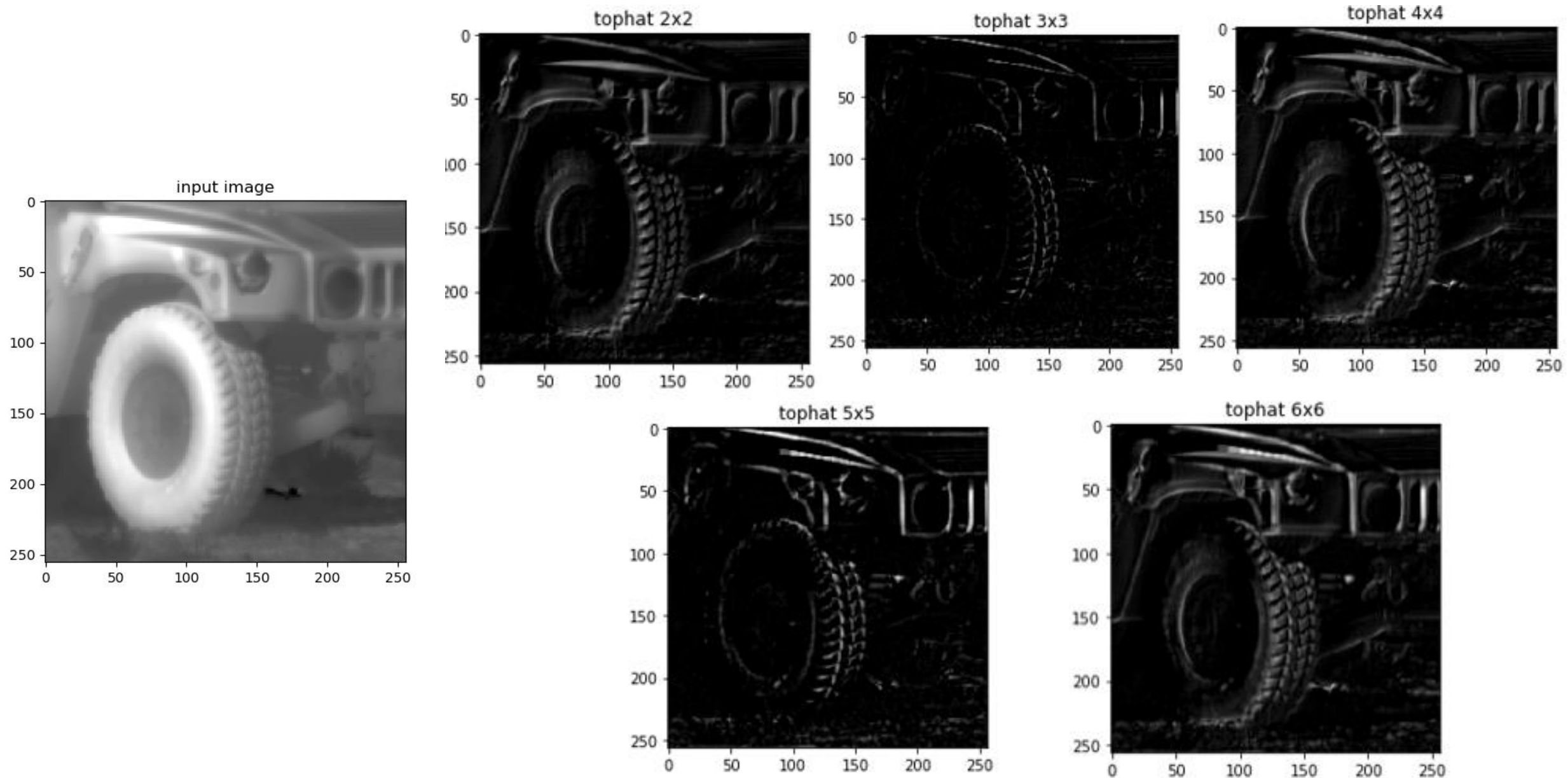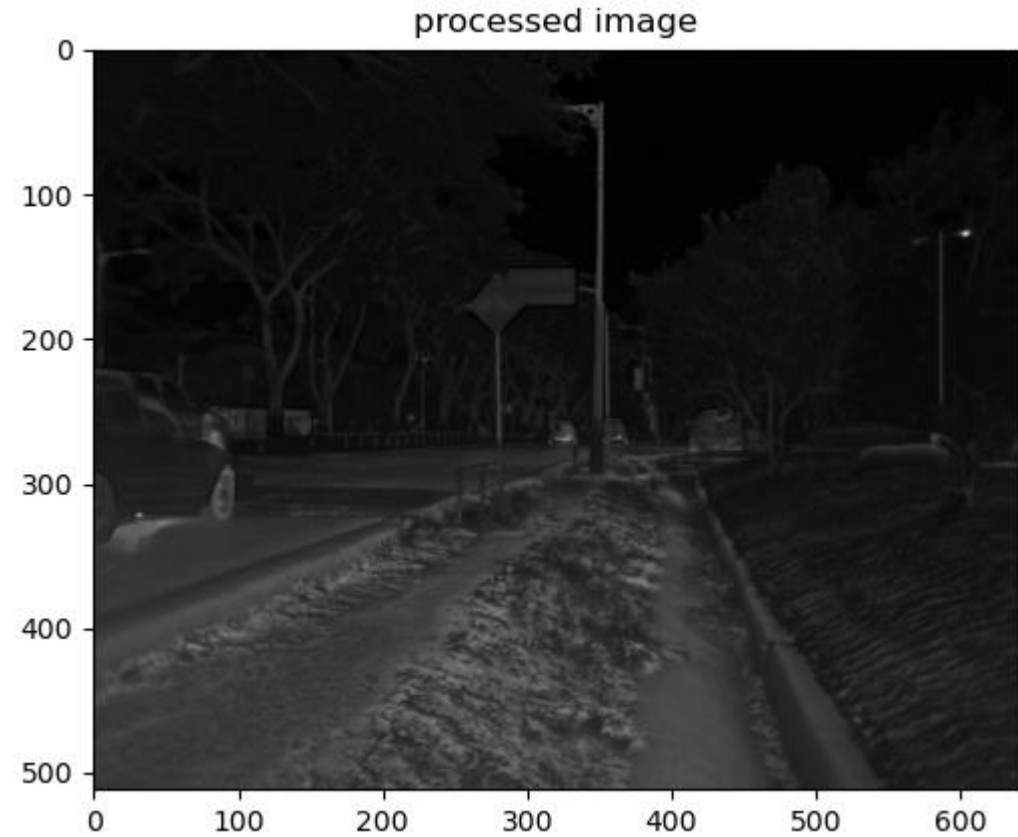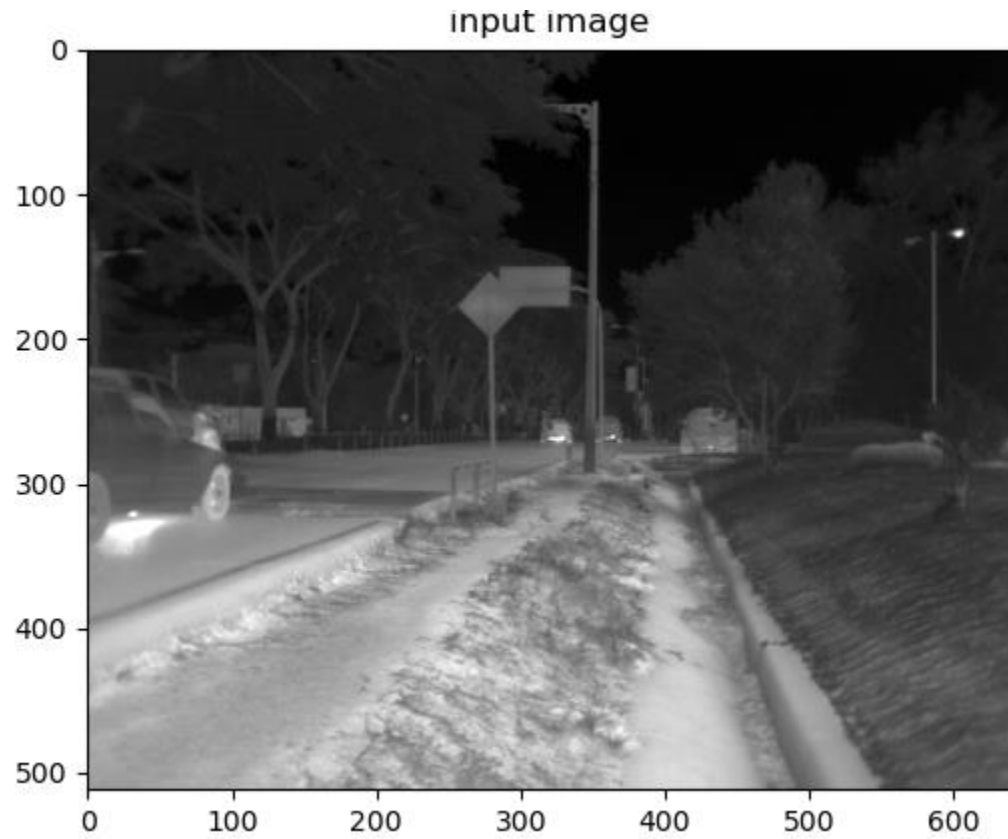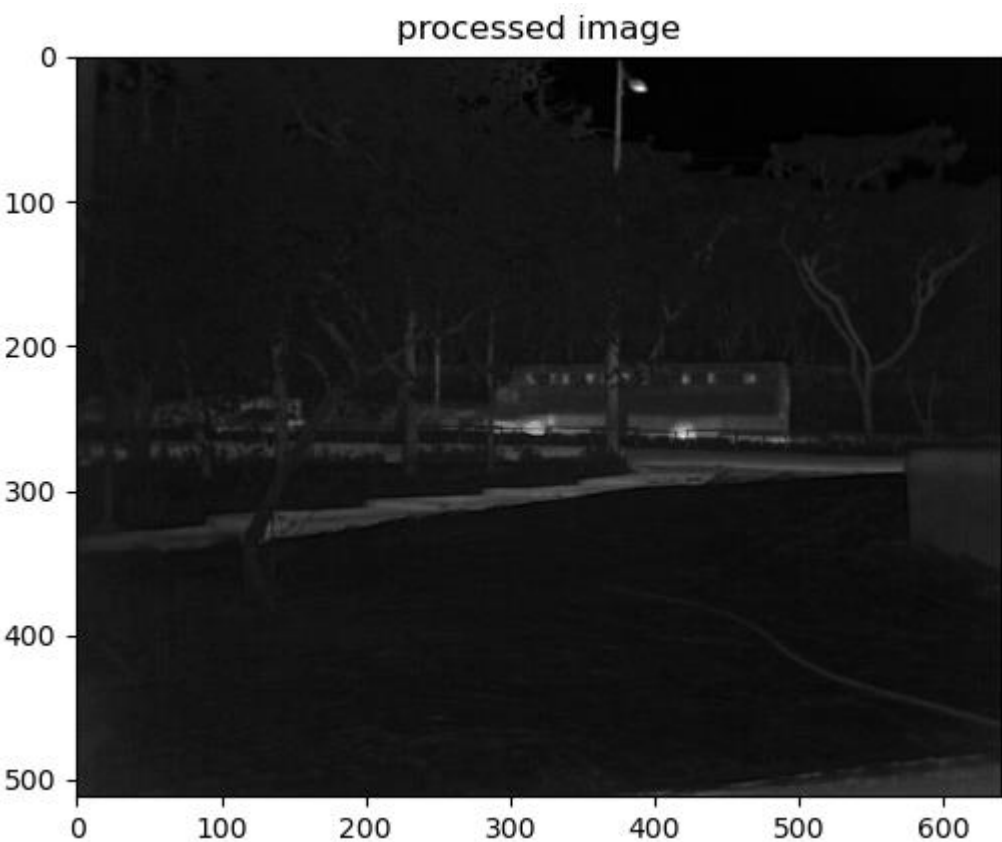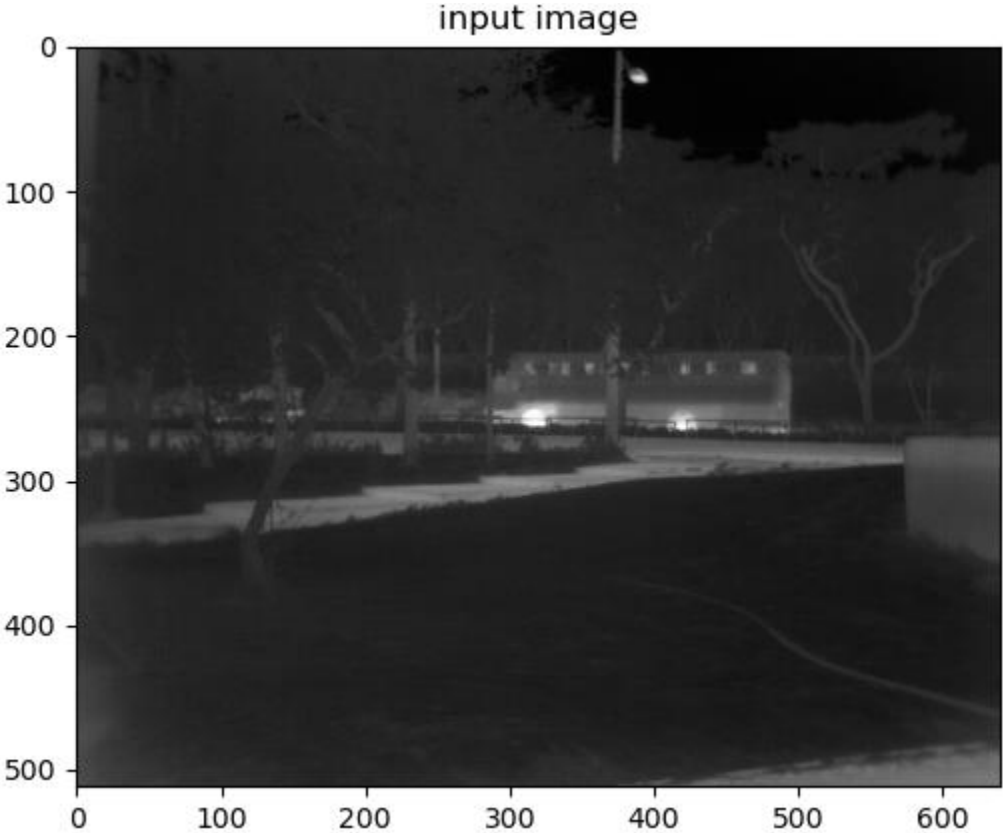
3. A multiscale morphology

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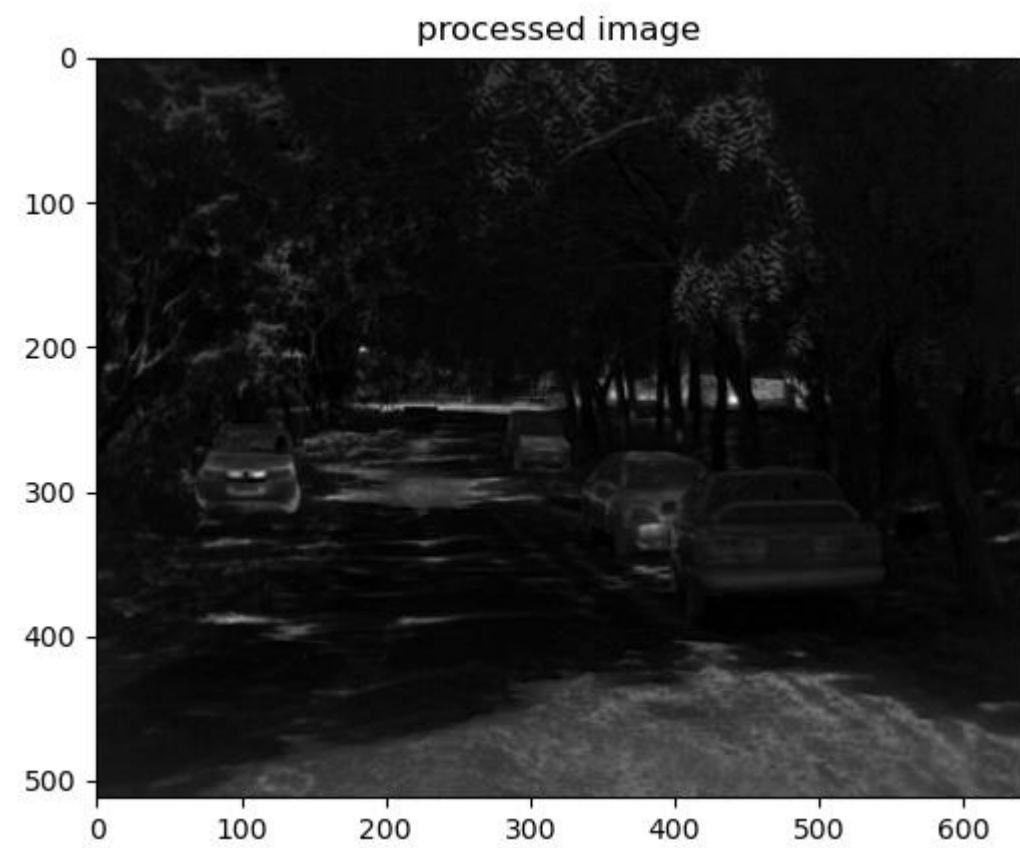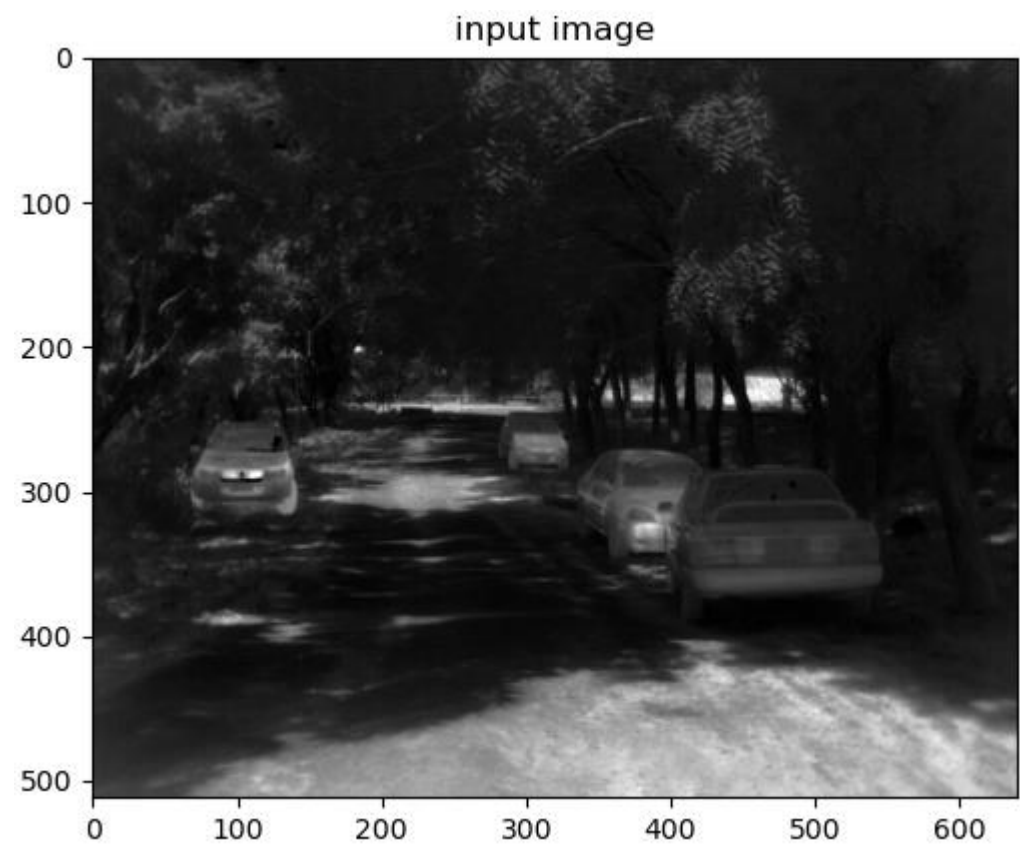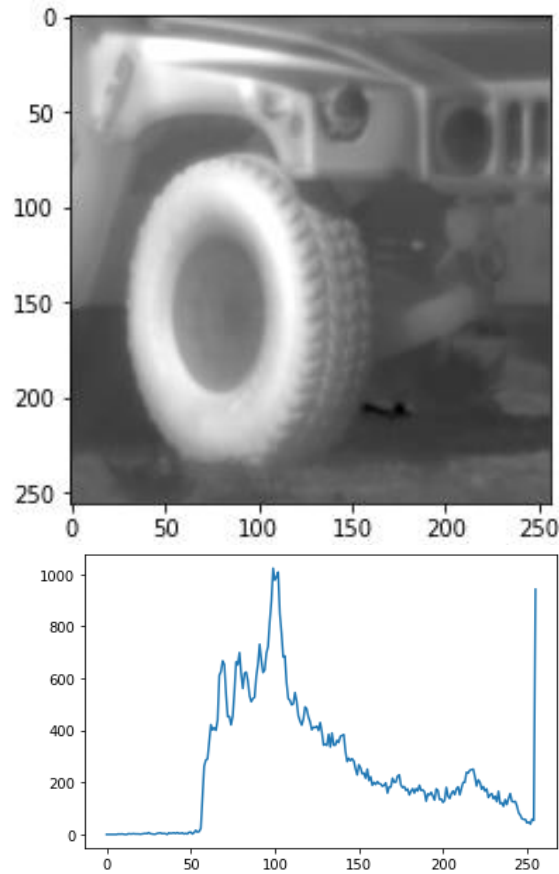
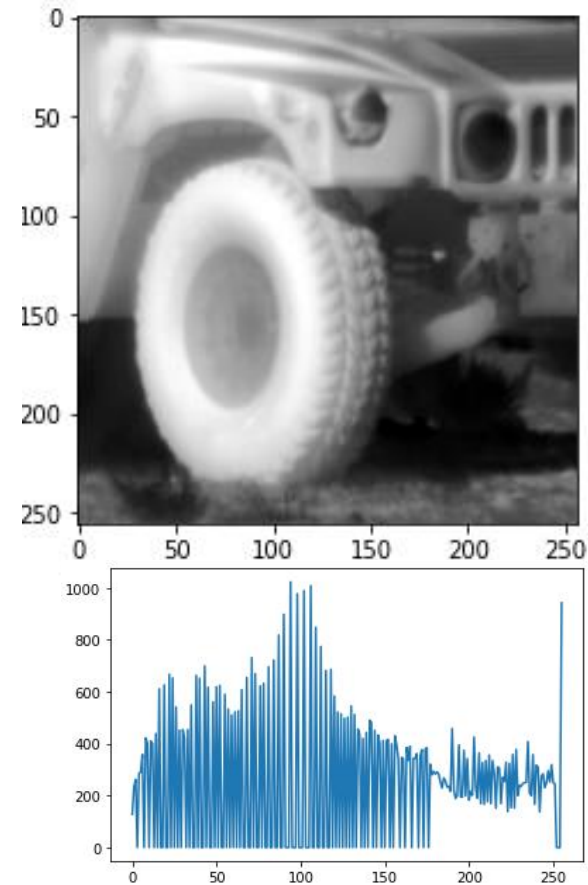# 3. A multiscale morphology

3. A multiscale morphology

4. Adaptive contrast enhancement using histogram equalization

- Sometimes, a regular histogram equalization makes the bright area too bright and the dark area too dark.
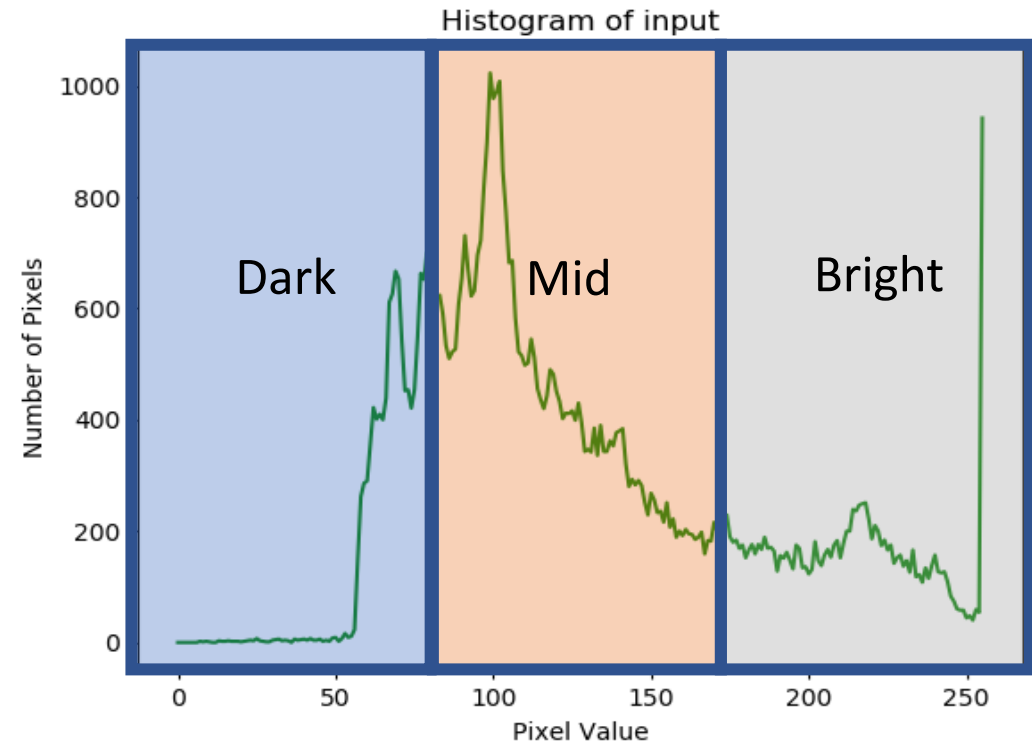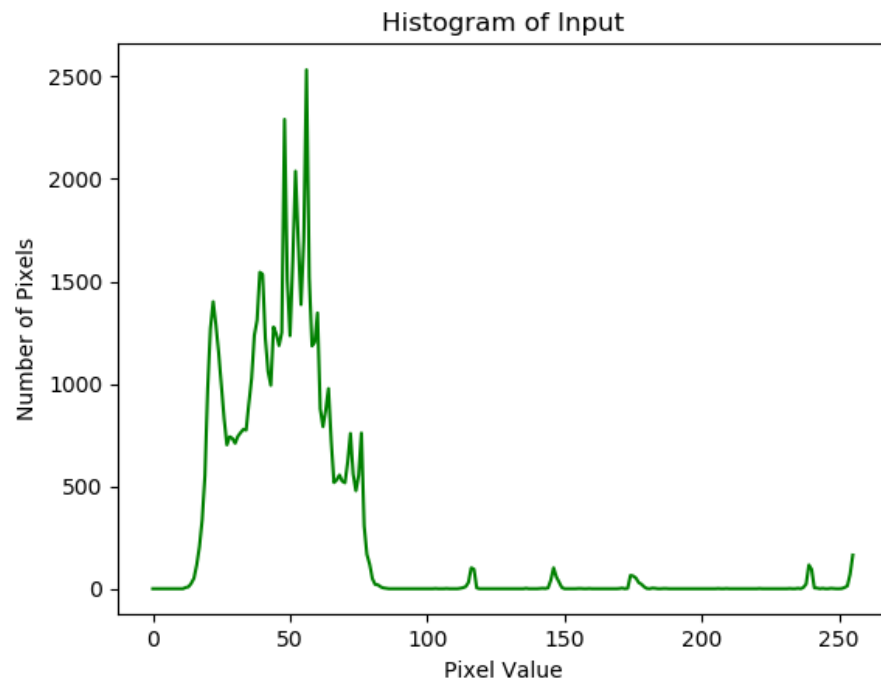
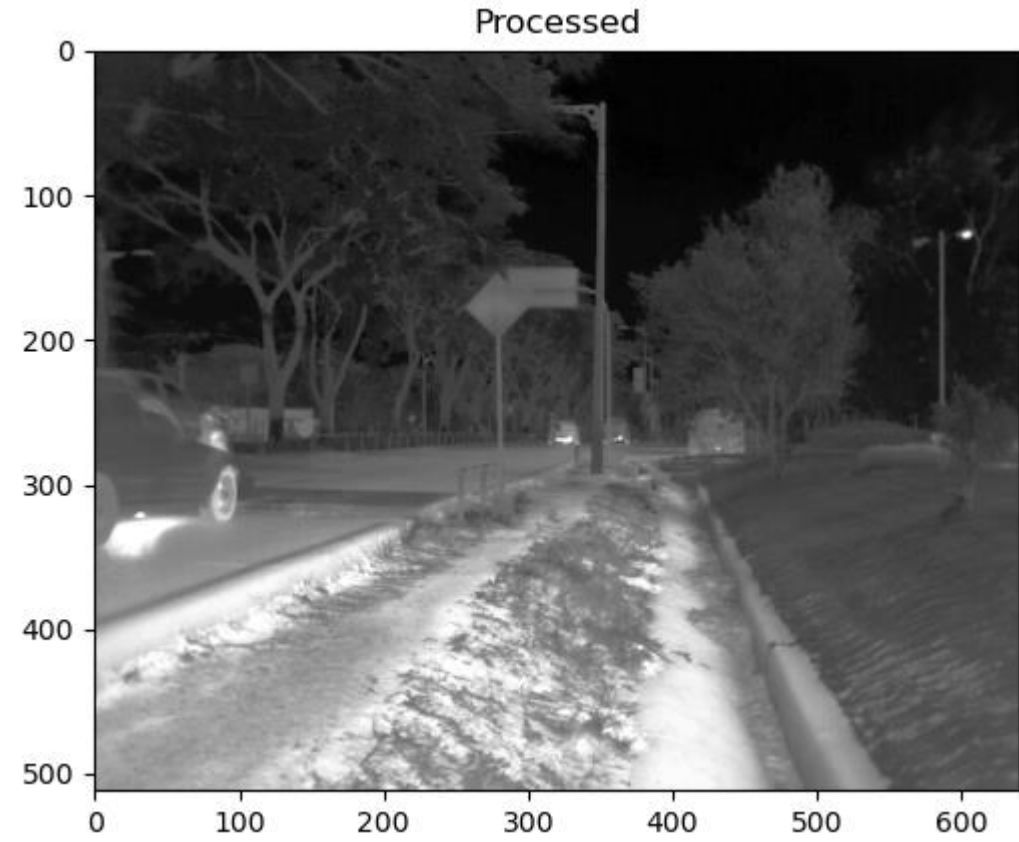

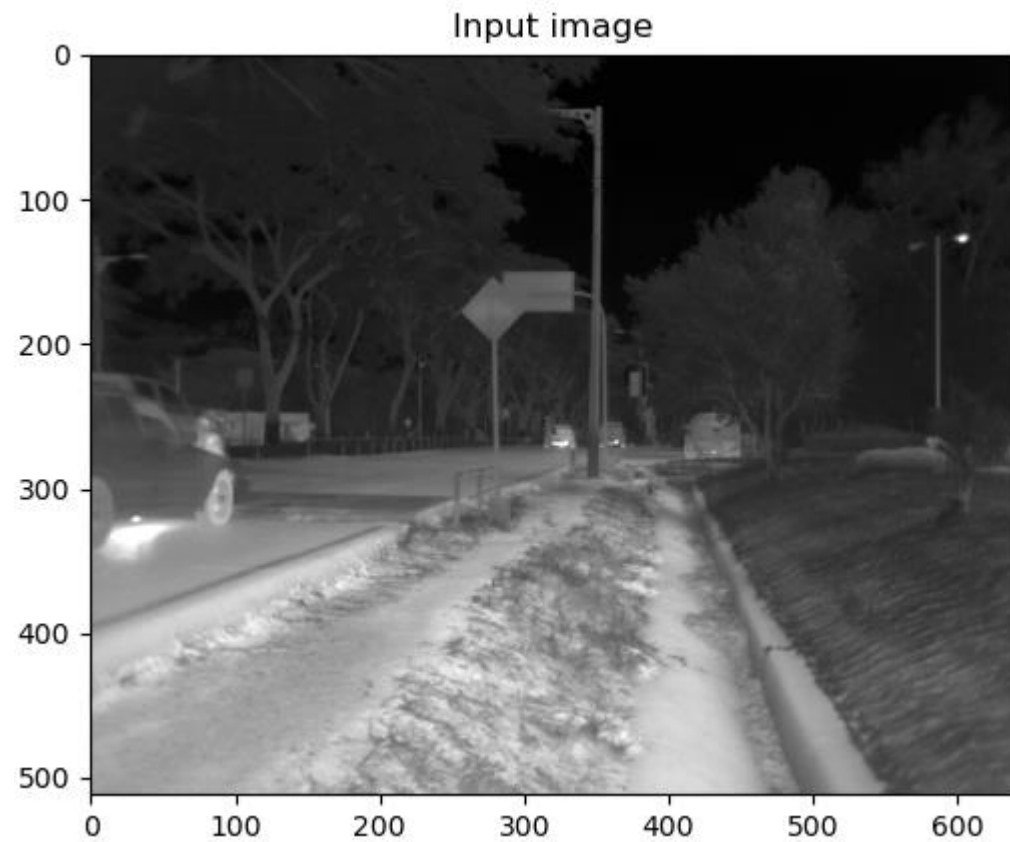< Before histogram equalization>

< After histogram equalization>

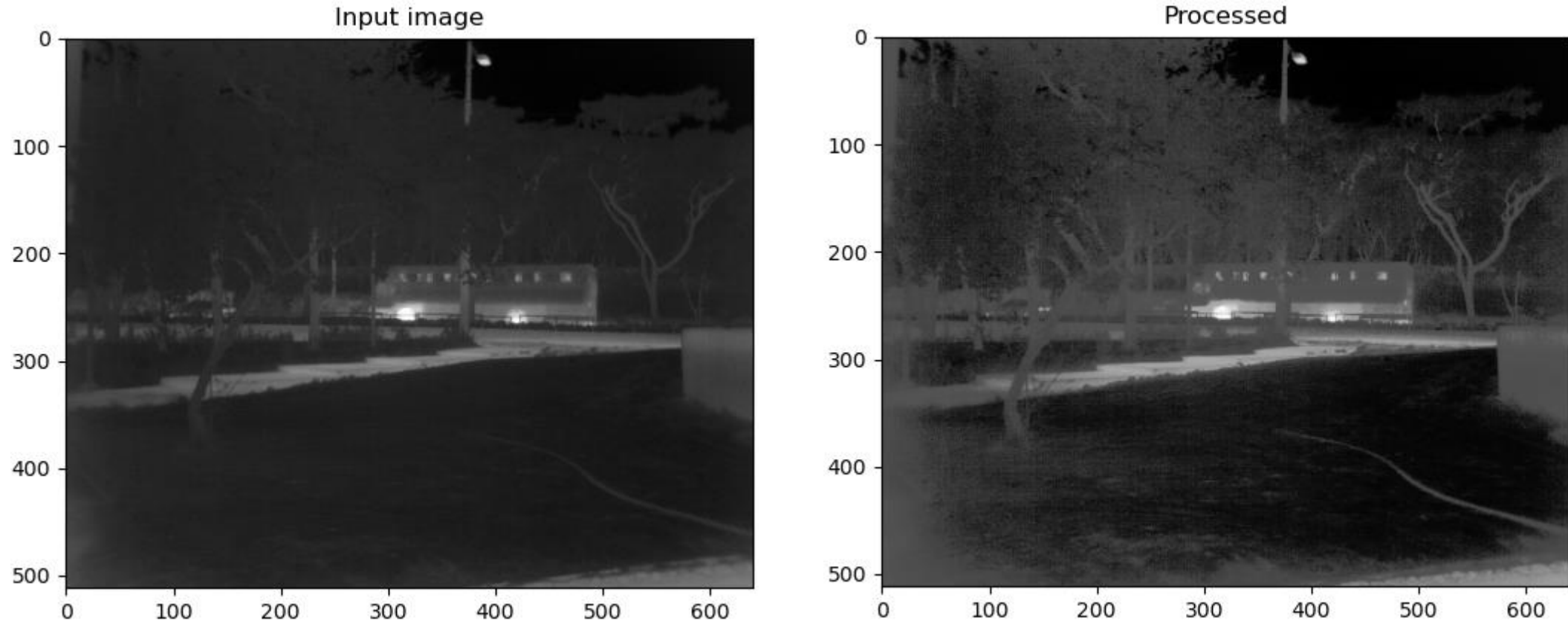# 4. Adaptive contrast enhancement using histogram equalization

- It divides the histogram into three regions – dark, mid, and bright.
- Apply histogram equalization individually.

4. Adaptive contrast enhancement using histogram equalization

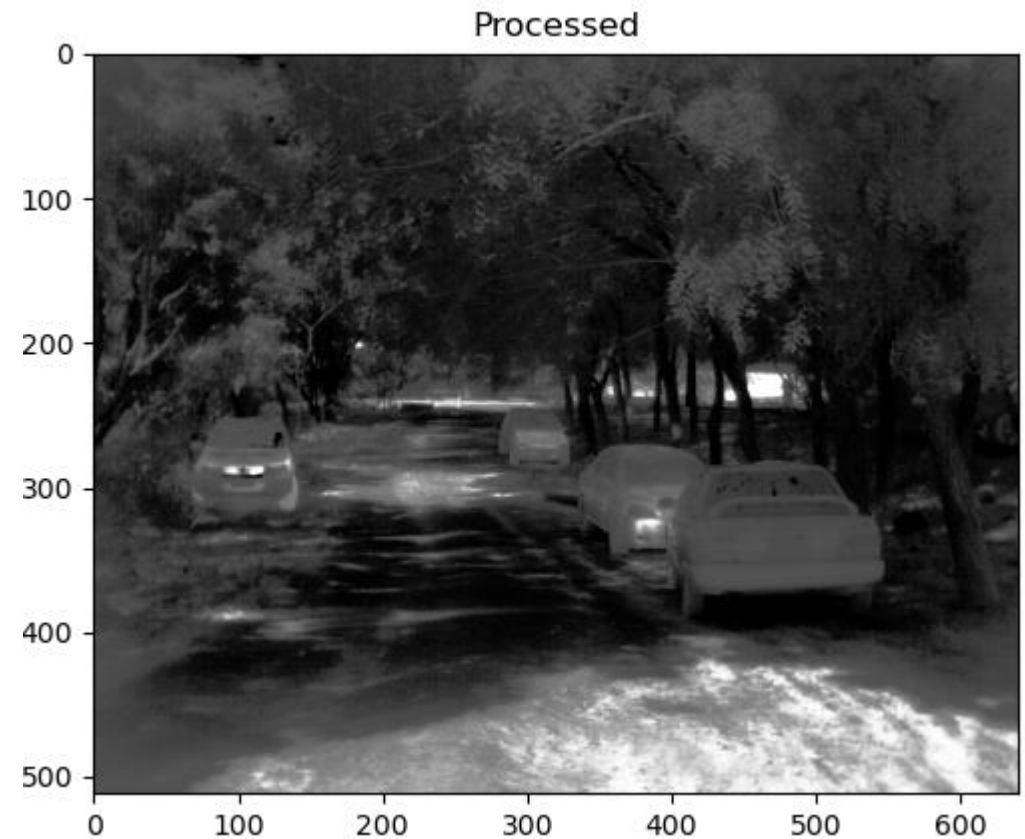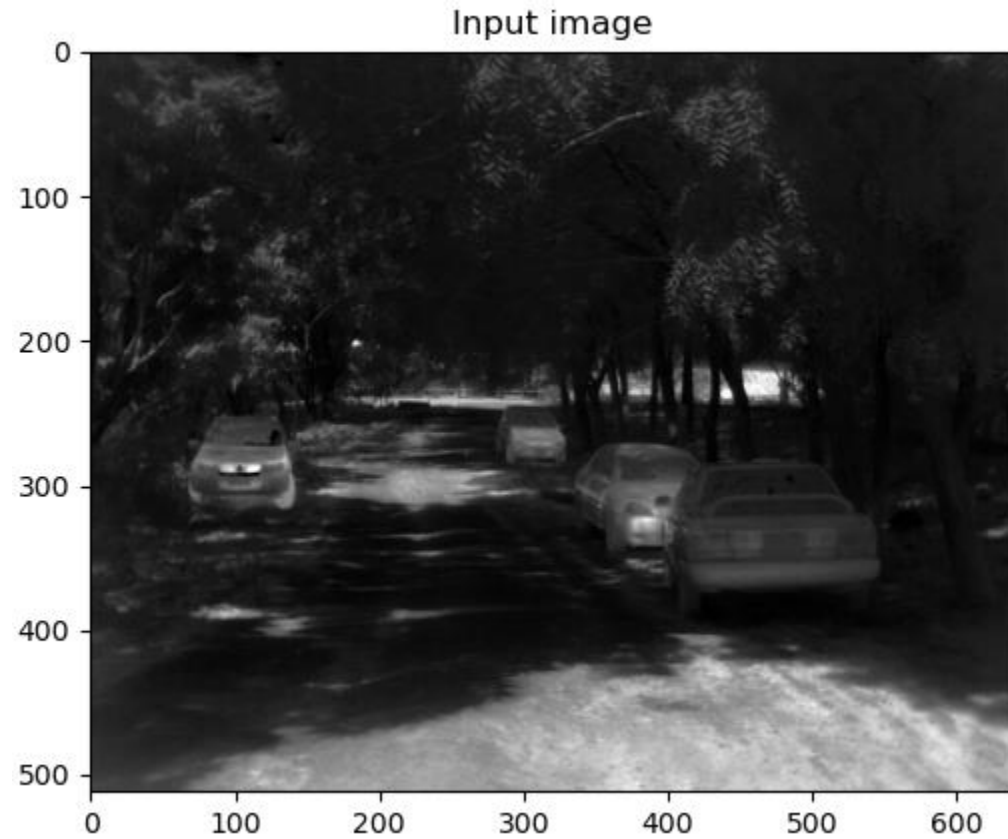# 4. Adaptive contrast enhancement using histogram equalization

Cons: When the light is limited and the image is dark, it produces an unnatural scene.

# 4. Adaptive contrast enhancement using histogram equalization
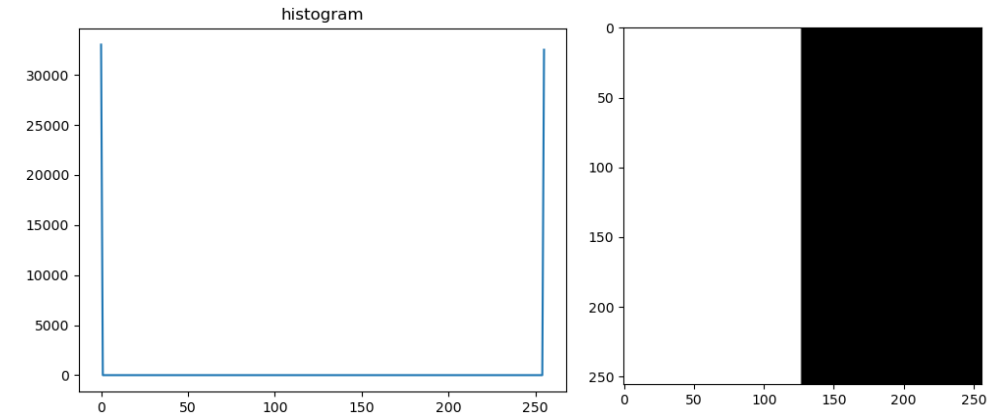
Shannon's entropy

- Entropy is used to measure the content of an image, where a higher value indicates an image with richer details.
- Higher entropy means that pixel values are distributed evenly.

$$E(I) = -\sum_{k=0}^{L-1} p(k) log_2(p(k)),$$

K is the number of gray level (256 for 8-bit images),
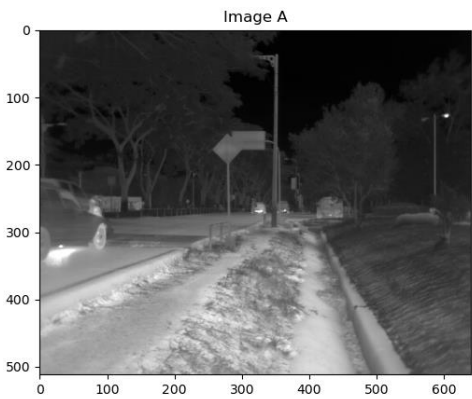*P(k)* is the probability of a pixel having gray level k.
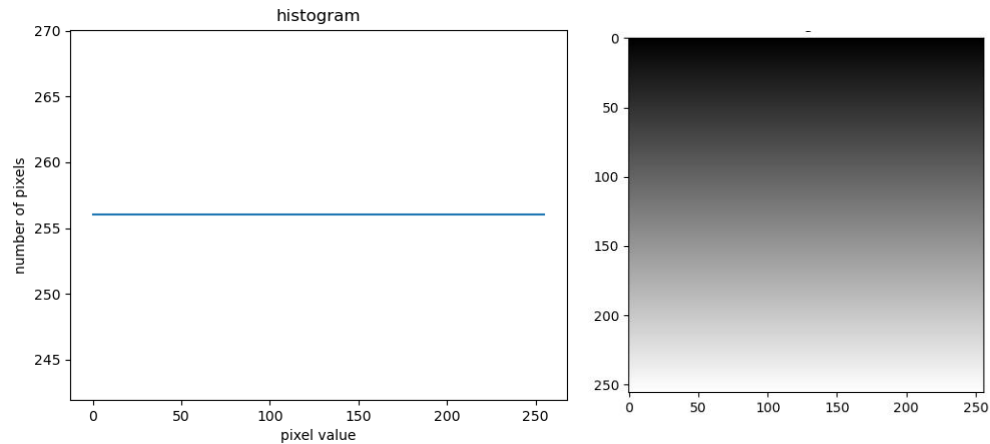
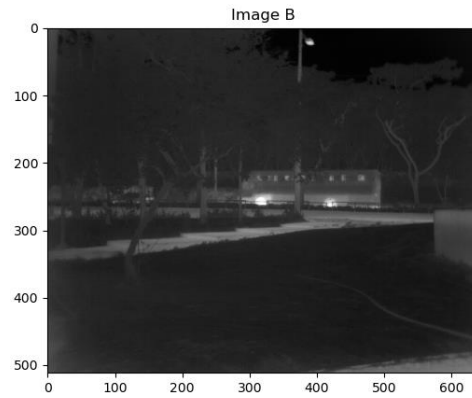When the pixels are distributed evenly, the entropy
has the maximum values, 8.

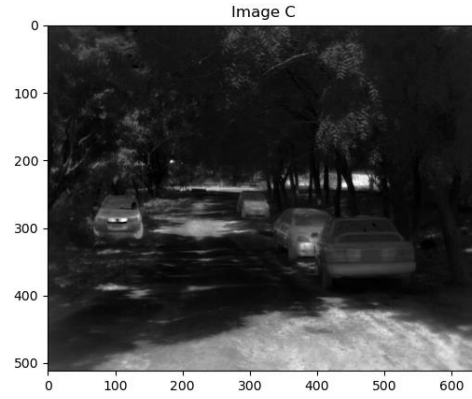When the pixels have only 0 and 255, the entropy is 1.

Shannon's entropy

Algorithm	Image	Entropy
Contrast limited adaptive histogram equalization (CLAHE)	A	**7.48**
	B	**6.5**
	C	**7.18**
Image pyramid and HE	A	6.67
	B	5.39
	C	5.91
A multiscale morphology	A	6.46
	B	5.28
	C	5.69
Adaptive histogram equalization	A	7.04
	B	5.36
	C	6.22

Image A — Entropy : 7.30

Image B — Entropy : 5.69

Image C — Entropy : 6.50

Pros and Cons

Algorithm	Pros	Cons
Contrast limited adaptive histogram equalization (CLAHE)	• High entropy • Highest contrast • Great result when the light is limited	• Doesn't have edge sharpening effect.
Image pyramid and HE	• Edge sharpening	• Slow process time (3 seconds)
A multiscale morphology	• Based on spatial features	• Size of object changed • Doesn't work well with IR image.
Adaptive contrast enhancement	• Local area processing	• Unnatural scene