Image Processing I

학습목표

학습목표

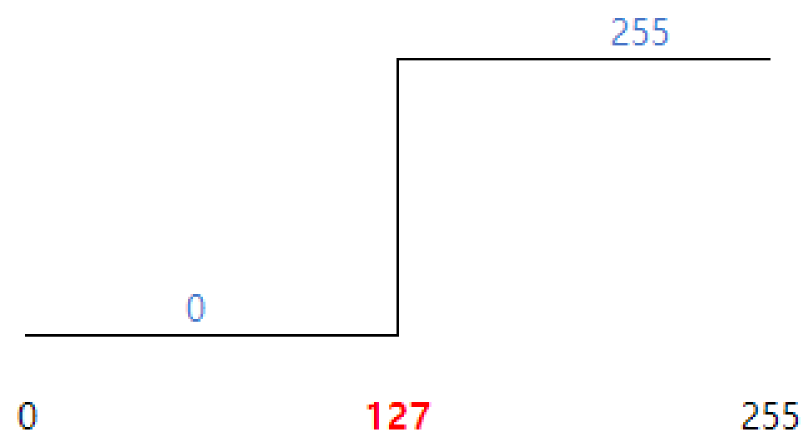
1. Image Thresholding
2. Image Blending

Image Thresholding

Image Thresholding

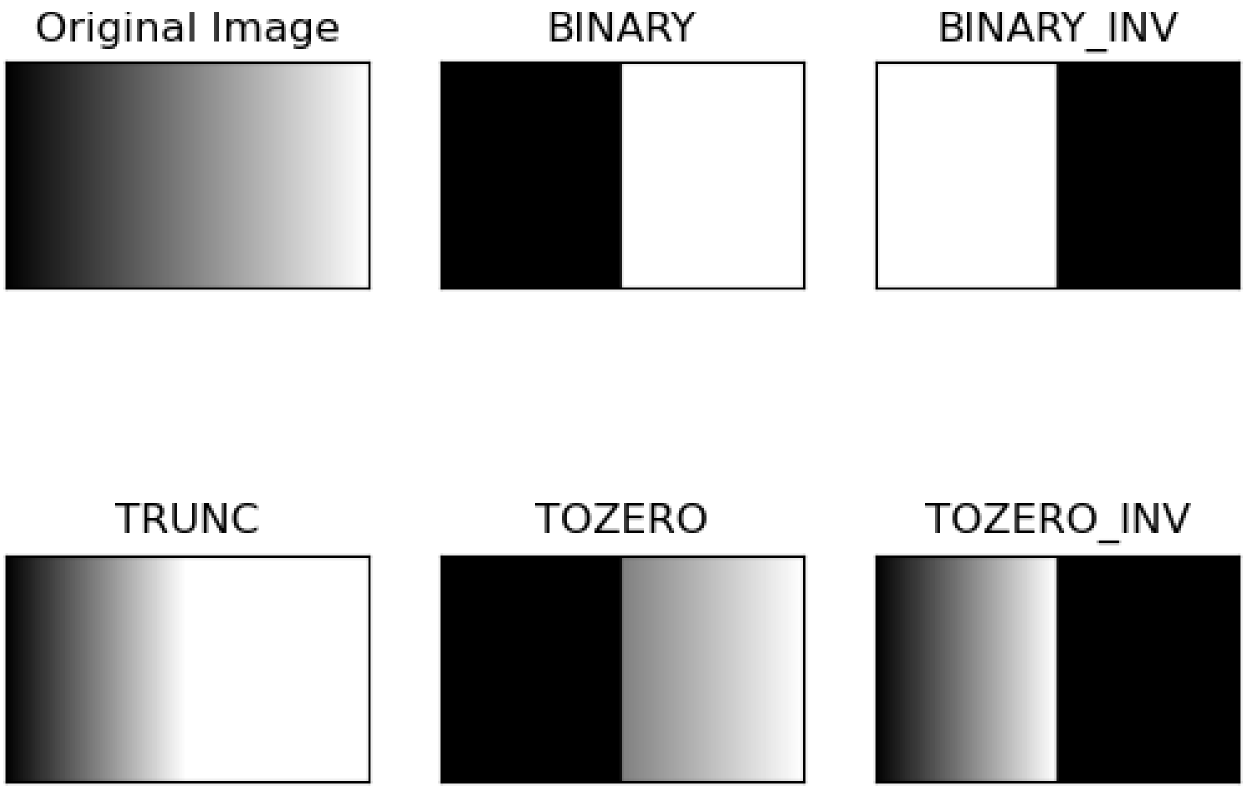
- Grayscale 이미지를 binary 이미지로 이진화 (binarization)
- 임계값(threshold)을 기준으로 흰색과 검은색 영역으로 분리

```
ret, result = cv2.threshold(img, 127, 255, cv2.THRESH_BINARY)
```



https://webnautes.tistory.com/1254

Image Thresholding: Example



https://opencv-python-tutroals.readthedocs.io/en/latest/py_tutorials/py_imgproc/py_thresholding/py_thresholding.html

Image Thresholding: Code

```python
import cv2
import numpy as np
from matplotlib import pyplot as plt

# Load a grayscale image
img = cv2.imread('gradient.png', 0)

# Image thresholding
thld = 127
max_v = 255
ret, img1 = cv2.threshold(img, thld, max_v, cv2.THRESH_BINARY)
ret, img2 = cv2.threshold(img, thld, max_v, cv2.THRESH_BINARY_INV)
ret, img3 = cv2.threshold(img, thld, max_v, cv2.THRESH_TRUNC)
ret, img4 = cv2.threshold(img, thld, max_v, cv2.THRESH_TOZERO)
ret, img5 = cv2.threshold(img, thld, max_v, cv2.THRESH_TOZERO_INV)

# Draw results
titles = ['Original
```

https://opencv-python-tutroals.readthedocs.io/en/latest/py_tutorials/py_imgproc/py_thresholding/py_thresholding.html

`cv.threshold()`[1]

```
retval, dst = cv.threshold(src, thresh, maxval, type[, dst])
```

- 고정된 임계점을 기준으로 각 픽셀을 이진화한다.
  - `src`: input array (multiple-channel, 8-bit or 32-bit floating point)
  - `dst`: output array of the same same and type and the same number of channels
  - `thresh`: threshold value
  - `maxval`: maximum value to use with the `THRESH_BINARY` and `THRESH_BINARY_INV` types
  - `type`: thresholding type

type[2]	
`cv.THRESH_BINARY`	`cv.THRESH_BINARY_INV`
`cv.THRESH_TRUNC`	
`cv.THRESH_TOZERO`	`cv.THRESH_TOZERO_INV`

1. https://docs.opencv.org/4.4.0/d7/d1b/group__imgproc__misc.html#gae8a4a146d1ca78c626a53577199e9c57
2. https://docs.opencv.org/4.4.0/d7/d1b/group__imgproc__misc.html#gaa9e58d2860d4afa658ef70a9b1115576

Threshold Types

- `cv.THRESH_BINARY`

$$\mathrm{dst}(x,y) = \begin{cases} \mathrm{maxval}, & \text{if } \mathrm{src}(x,y) > \mathrm{thresh} \\ 0, & \text{otherwise} \end{cases}$$

- `cv.THRESH_BINARY_INV`

$$\mathrm{dst}(x,y) = \begin{cases} 0, & \text{if } \mathrm{src}(x,y) > \mathrm{thresh} \\ \mathrm{maxval}, & \text{otherwise} \end{cases}$$

- `cv.THRESH_TRUNC`

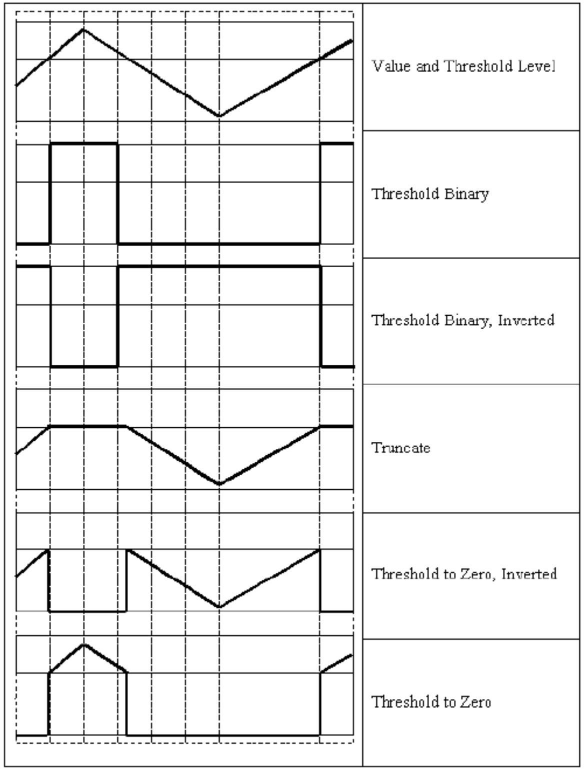
$$\mathrm{dst}(x,y) = \begin{cases} \mathrm{threshold}, & \text{if } \mathrm{src}(x,y) > \mathrm{thresh} \\ \mathrm{src}(x,y), & \text{otherwise} \end{cases}$$

- `cv.THRESH_TOZERO`

$$\mathrm{dst}(x,y) = \begin{cases} \mathrm{src}(x,y), & \text{if } \mathrm{src}(x,y) > \mathrm{thresh} \\ 0, & \text{otherwise} \end{cases}$$

- `cv.THRESH_TOZERO_INV`

$$\mathrm{dst}(x,y) = \begin{cases} 0, & \text{if } \mathrm{src}(x,y) > \mathrm{thresh} \\ \mathrm{src}(x,y), & \text{otherwise} \end{cases}$$

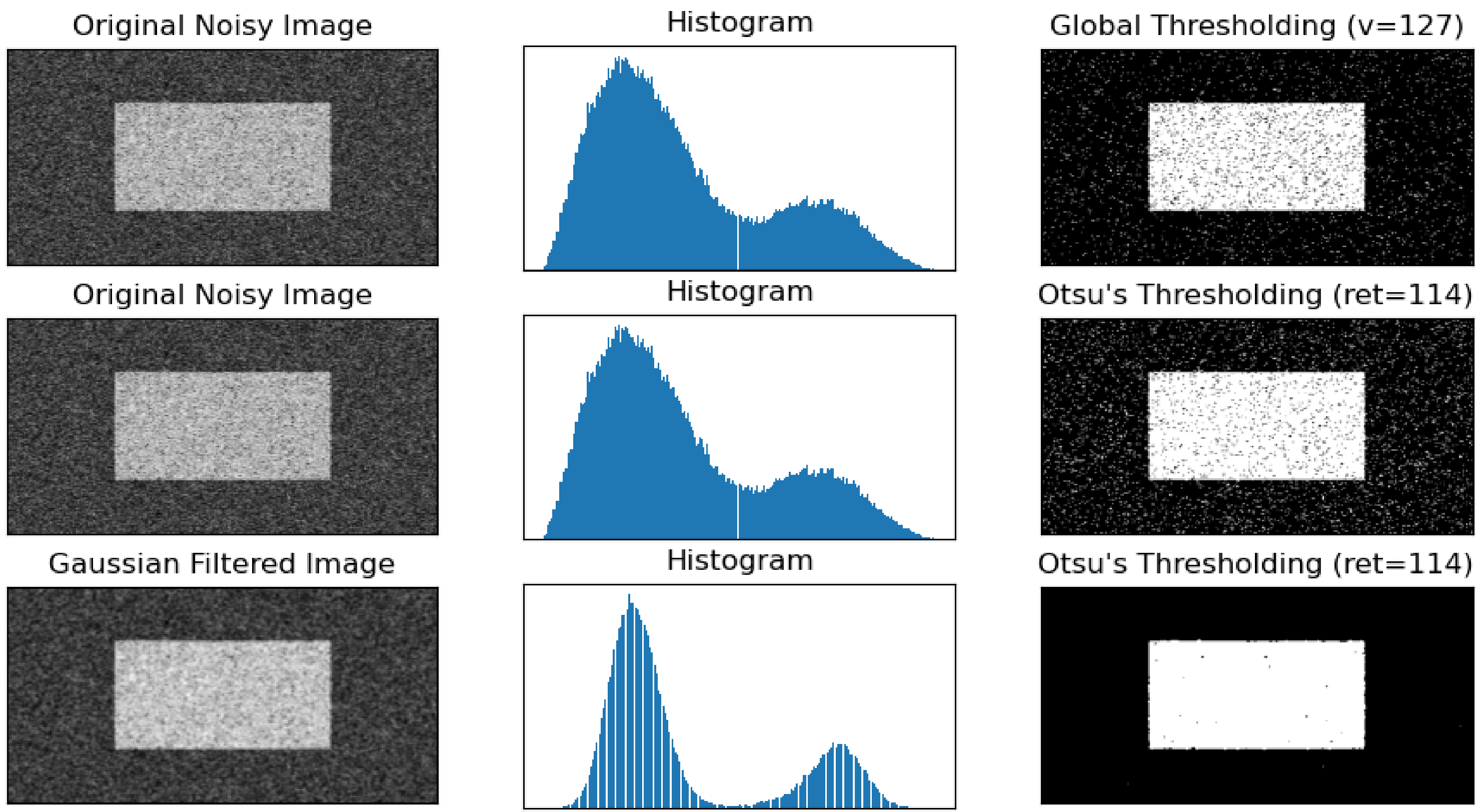


https://docs.opencv.org/4.4.0/d7/d1b/group__imgproc__misc.html#gaa9e58d2860d4afa658ef70a9b1115576

Otsu's Binarization

- Thresholding
  - Threshold value: manual selection
  - Threshold 값을 알고 있을 때 사용
- Otsu's Binarization: automatic selection
  - Otsu's Image Segmentation
  - Histogram의 peak가 두 개인 bimodal image일 때 사용
  - 자동으로 두 peak 사이의 중간값을 찾아서 사용
  - `retval`: optimal threshold

Otsu's Binarization: Example and Result



Otsu's Binarization: Code

```python
import cv2
import numpy as np
from matplotlib import pyplot as plt

# Load a grayscale image
img = cv2.imread('noisy2.png', 0)

# global thresholding
ret1, th1 = cv2.threshold(img, 127, 255, cv2.THRESH_BINARY)

# Otsu's thresholding
ret2,th2=cv2.threshold(img,0,255,cv2.THRESH_BINARY+cv2.THRESH_OTSU)

# Otsu's thresholding after Gaussian filtering
blur = cv2.GaussianBlur(img, (5,5), 0)
ret3,th3=cv2.threshold(blur,0,255,cv2.THRESH_BINARY+cv2.THRESH_OTSU

# plot all the images and their histograms
images = [img, 0, th1,
```

https://opencv-python-tutroals.readthedocs.io/en/latest/py_tutorials/py_imgproc/py_thresholding/py_thresholding.html#otsus-binarization

Otsu's Binarization: Under the Hood

- Optimal threshold value t
  - Minimizing the weighted within-class variance

$$\sigma_w^2 = q_1(t)\sigma_1^2(t) + q_2(t)\sigma_2^2(t)$$

where

- Cumulative probabilities for two classes

$$q_1(t) = \sum_{i=1}^{t} P(i), \quad q_2(t) = \sum_{i=t+1}^{I} P(i)$$

- Means

$$\mu_1 = \sum_{i=1}^{t} \frac{iP(i)}{q_1(t)}, \quad \mu_2 = \sum_{i=t+1}^{I} \frac{iP(i)}{q_2(t)}$$

- Variances

$$\sigma_1^2 = \sum_{i=1}^{t} [i - \mu_1(t)]^2 \frac{P(i)}{q_1(t)}, \quad \sigma_2^2 = \sum_{i=t+1}^{I} [i - \mu_2(t)]^2 \frac{P(i)}{q_2(t)}$$

Otsu's Binarization: Under the Hood

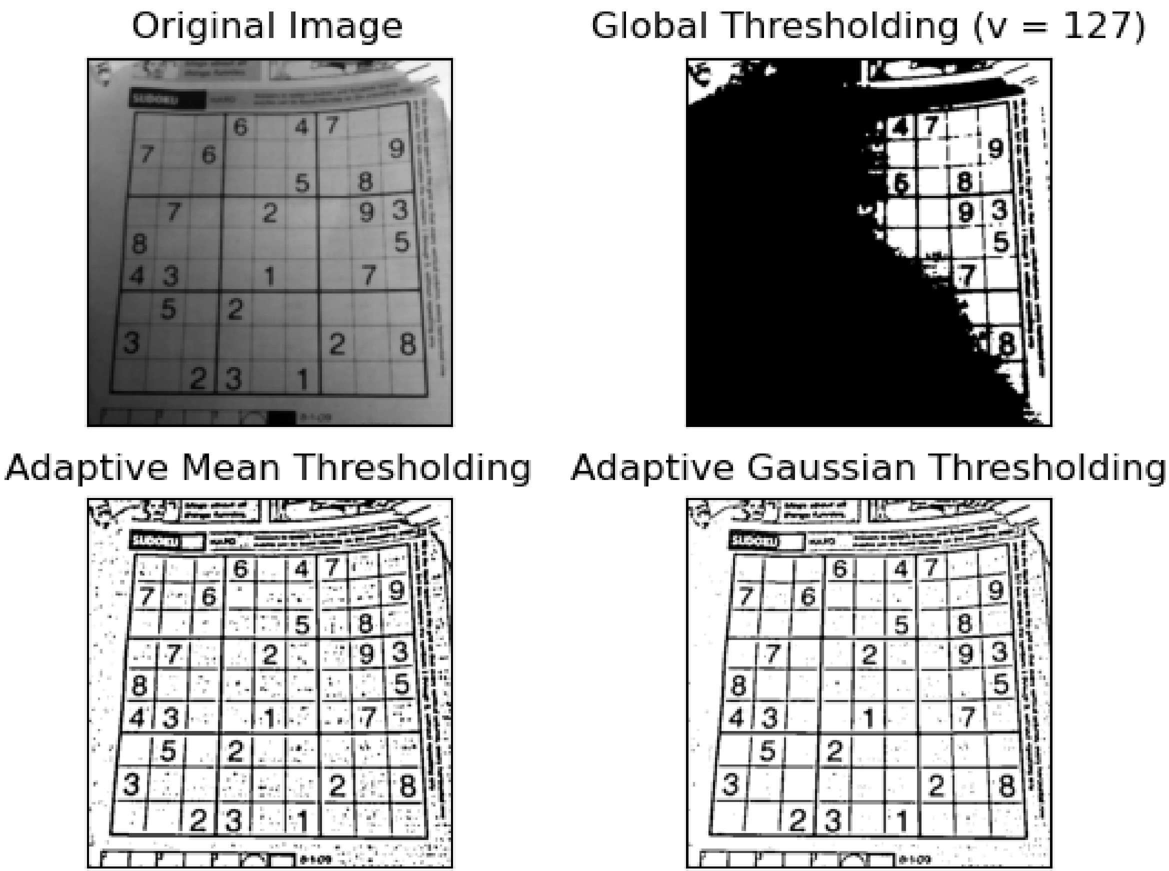
```
import cv2
import numpy as np
from matplotlib import pyplot as plt

# Load a grayscale image
img = cv2.imread('noisy2.png', 0)

# Blur the image
blur = cv2.GaussianBlur(img, (5,5), 0)

# Find normalized_histogram, and its cumulative distribution
hist = cv2.calcHist([blur], [0], None, [256], [0,256])
hist_norm = hist.ravel()/hist.max()
Q = hist_norm.cumsum()

# Find probabilities
bins = np.arange(256)

fn_min = np.inf
```

https://opencv-python-tutroals.readthedocs.io/en/latest/py_tutorials/py_imgproc/py_thresholding/py_thresholding.html#otsus-binarization

Adaptive Thresholding

- Thresholding
  - Threshold value: global
  - Image 모든 영역에서 lighting condition이 동일할 때 사용
- Adaptive Thresholding
  - Threshold value: local
  - Image 각 영역의 lighting condition이 다를 때 사용

Adaptive Thresholding: Example 1



Adaptive Thresholding: Code 1

```
import cv2
import numpy as np
from matplotlib import pyplot as plt

# Load a grayscale image
img_gray = cv2.imread('sudoku.png', 0)

# Blur the image
img_blurred = cv2.medianBlur(img_gray, 5)
cv2.imshow('Original vs Blurred', cv2.hconcat([img_gray,
img_blurred]))
cv2.waitKey(0)
cv2.destroyAllWindows()

# Threshold the image
ret, img1 = cv2.threshold(img_blurred, 127, 255,
cv2.THRESH_BINARY)
img2 = cv2.adaptiveThreshold(img_blurred, 255,
cv2.ADAPTIVE_THRESH_MEAN_C, cv2.THRESH_BINARY, 11, 2)
img3 = cv2.adaptiveThreshold(img_blurred, 255,
```

https://opencv-python-tutroals.readthedocs.io/en/latest/py_tutorials/py_imgproc/py_thresholding/py_thresholding.html

`cv.adaptiveThreshold()`[1]

```
dst = cv.adaptiveThreshold(src, maxValue, adaptiveMethod,
thresholdType, blockSize, C[, dst])
```

- Array에 adaptive threshold를 적용한다.
  - `src`: input 8-bit single-channel image
  - `dst`: output image of the same size and the same type as input
  - `maxval`: non-zero value assigned to the pixels for which the condition is satisfied
  - `adaptiveMethod`: adaptive thresholding algorithm to use
  - `thresholdType`: thresholding type that must be either `THRESH_BINARY` or `THRESH_BINARY_INV`
  - `blockSize`: Size of a pixel neighborhood that is used to calculate a threshold value for the pixel: 3, 5, 7, and so on.
  - `C`: constant subtracted from the mean or weighted mean. Normally, it is positive but may be zero or negative as well.

1. https://docs.opencv.org/4.4.0/d7/d1b/group__imgproc__misc.html#ga72b913f352e4a1b1b397736707afcde3

Threshold Types

- `cv.THRESH_BINARY`

$$\mathrm{dst}(x, y) = \begin{cases} \mathrm{maxval}, & \text{if}\ \mathrm{src}(x, y) > T(x, y) \\ 0, & \text{otherwise} \end{cases}$$

- `cv.THRESH_BINARY_INV`

$$\mathrm{dst}(x, y) = \begin{cases} 0, & \text{if}\ \mathrm{src}(x, y) > T(x, y) \\ \mathrm{maxval}, & \text{otherwise} \end{cases}$$

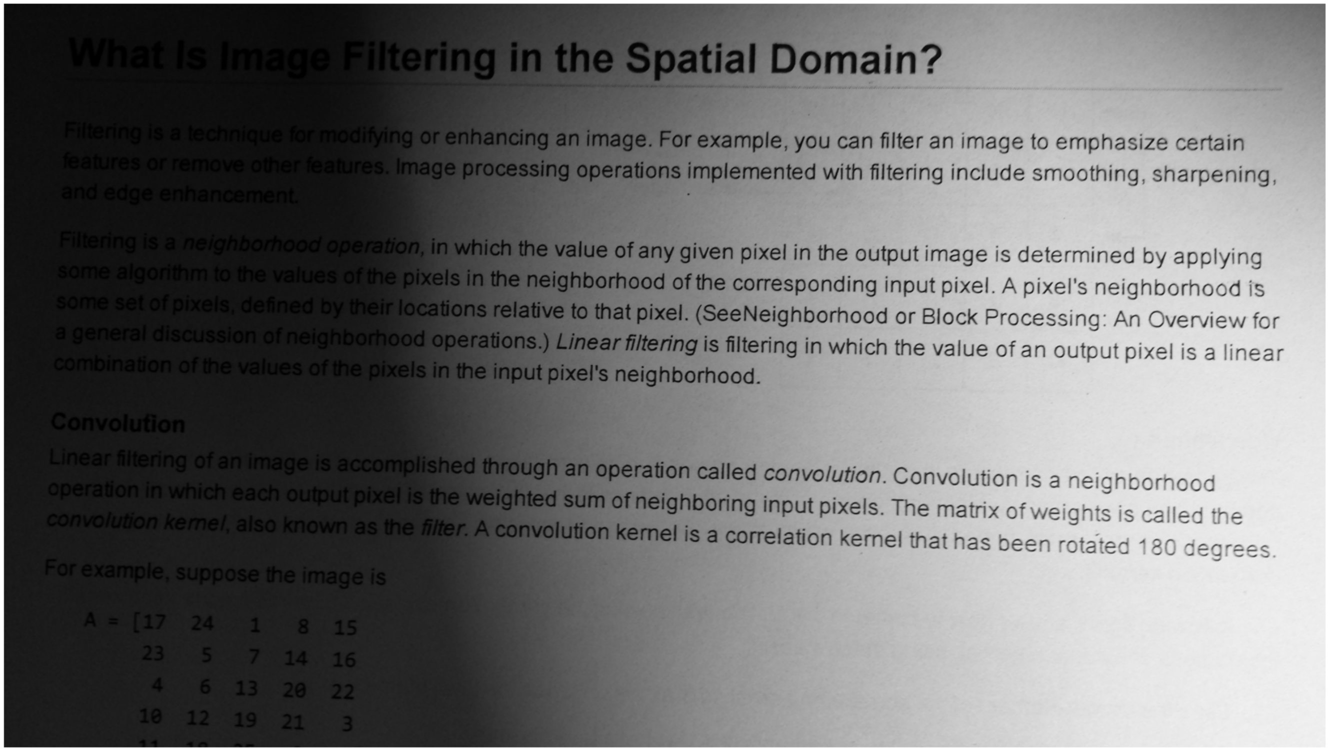
https://docs.opencv.org/4.4.0/d7/d1b/group__imgproc__misc.html#ga72b913f352e4a1b1b397736707afcde3

`AdaptiveThresholdTypes`[1]

`AdaptiveThresholdTypes`[2]	
`cv.ADAPTIVE_THRESH_MEAN_C`	The threshold value T(x,y) is a mean of the `blockSize`×`blockSize` neighborhood of (x,y) minus `C`
`cv.ADAPTIVE_THRESH_GAUSSIAN_C`	The threshold value T(x,y) is a weighted sum (cross-correlation with a Gaussian window) of the `blockSize`×`blockSize` neighborhood of (x,y) minus `C` . The default sigma (standard deviation) is used for the specified blockSize

1. https://docs.opencv.org/4.4.0/d7/d1b/group__imgproc__misc.html#gaa42a3e6ef26247da787bf34030ed772c

Adaptive Thresholding: Example 2



What Is Image Filtering in the Spatial Domain?

Filtering is a technique for modifying or enhancing an image. For example, you can filter an image to emphasize certain features or remove other features. Image processing operations implemented with filtering include smoothing, sharpening, and edge enhancement.

Filtering is a *neighborhood operation*, in which the value of any given pixel in the output image is determined by applying some algorithm to the values of the pixels in the neighborhood of the corresponding input pixel. A pixel's neighborhood is some set of pixels, defined by their locations relative to that pixel. (SeeNeighborhood or Block Processing: An Overview for a general discussion of neighborhood operations.) *Linear filtering* is filtering in which the value of an output pixel is a linear combination of the values of the pixels in the input pixel's neighborhood.

Convolution

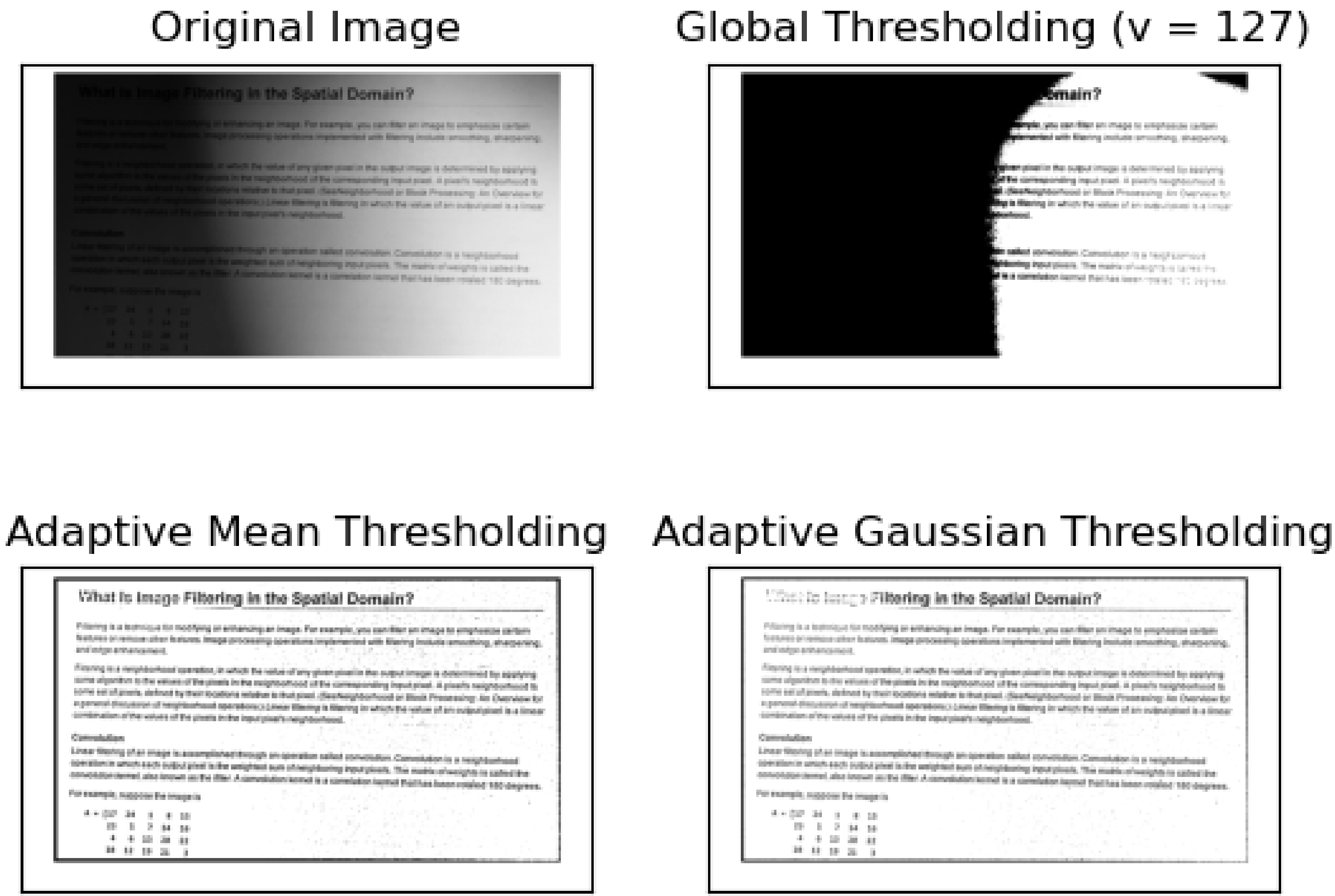
Linear filtering of an image is accomplished through an operation called *convolution*. Convolution is a neighborhood operation in which each output pixel is the weighted sum of neighboring input pixels. The matrix of weights is called the *convolution kernel*, also known as the *filter*. A convolution kernel is a correlation kernel that has been rotated 180 degrees.

For example, suppose the image is

```
A = [17  24   1   8  15
     23   5   7  14  16
      4   6  13  20  22
     10  12  19  21   3
```

https://blogs.mathworks.com/steve/2016/07/25/adaptive-thresholding-for-binarization/

Adaptive Thresholding: Result 2



Adaptive Thresholding: Code 2

```
import cv2
import numpy as np
from matplotlib import pyplot as plt

# Load a grayscale image
img = cv2.imread('book-scan.png', 0)

# Thresholding
ret, img1 = cv2.threshold(img, 127, 255, cv2.THRESH_BINARY)
img2 = cv2.adaptiveThreshold(img, 255,
cv2.ADAPTIVE_THRESH_MEAN_C, cv2.THRESH_BINARY, 21, 5)
img3 = cv2.adaptiveThreshold(img, 255,
cv2.ADAPTIVE_THRESH_GAUSSIAN_C, cv2.THRESH_BINARY, 21, 5)

# Draw results
titles = ['Original Image', 'Global Thresholding (v = 127)',
'Adaptive Mean Thresholding', 'Adaptive Gaussian Thresholding']
images = [img, img1, img2, img3]
```

1. https://opencv-python-tutroals.readthedocs.io/en/latest/py_tutorials/py_imgproc/py_thresholding/py_thresholding.html
2. https://webnautes.tistory.com/1254

Image Blending

Image Addition

- Numpy
  - `res = img1 + img2`
  - Modulo operation
- OpenCV:
  - `res = cv2.add(img1, img2)`
  - Saturated operation

```
>>> x = np.uint8([250])
>>> y = np.uint8([10])

>>> print cv2.add(x,y) # 250+10 = 260 => 255
[[255]]

>>> print x+y          # 250+10 = 260 % 256 = 4
[4]
```

Use OpenCV for Image Addition!

https://opencv-python-tutroals.readthedocs.io/en/latest/py_tutorials/py_core/py_image_arithmetics/py_image_arithmetics.html

Image Blending

http://theviewers.co.kr/View.aspx?No=302972

Image Blending

- Weighted sum

$$z = (1 - \alpha)x + \alpha y$$

- `cv.addWeighted()`

$$\mathrm{dst}(I) = \mathrm{saturate}(\alpha \cdot \mathrm{src1}(I) + \beta \cdot \mathrm{src2}(I) + \gamma)$$

Image Blending

```
import numpy as np
import cv2

# Load two images
img_park = cv2.imread('park.png')
img_tom = cv2.imread('tom.png')

# Blend those two images
cv2.imshow('Image Blening', cv2.hconcat([img_park, img_park, 
img_tom]))
cv2.waitKey(0)
for i in np.linspace(0, 1, 100):
    dst = cv2.addWeighted(img_park, 1-i, img_tom, i, 0)
    cv2.imshow('Image Blening', cv2.hconcat([img_park, dst, 
img_tom]))
    cv2.waitKey(30)
cv2.waitKey(0)
cv2.destroyAllWindows()
```

https://opencv-python-tutroals.readthedocs.io/en/latest/py_tutorials/py_core/py_image_arithmetics/py_image_arithmetics.html#image-blending

`cv.addWeighted()`[1]

```
dst = cv.addWeighted(src1, alpha, src2, beta, gamma[, dst[,
dtype]])
```

- 두 array의 weighted sum을 계산한다.
    - `src1`: first input array
    - `alpha`: weight of the first array elements
    - `src2`: second input array
    - `beta`: weight of the second array elements
    - `gamma`: scalar added to each sum
    - `dst`: output array that has the same size and number of channels as the input arrays
    - `dtype`: optional depth of the output array

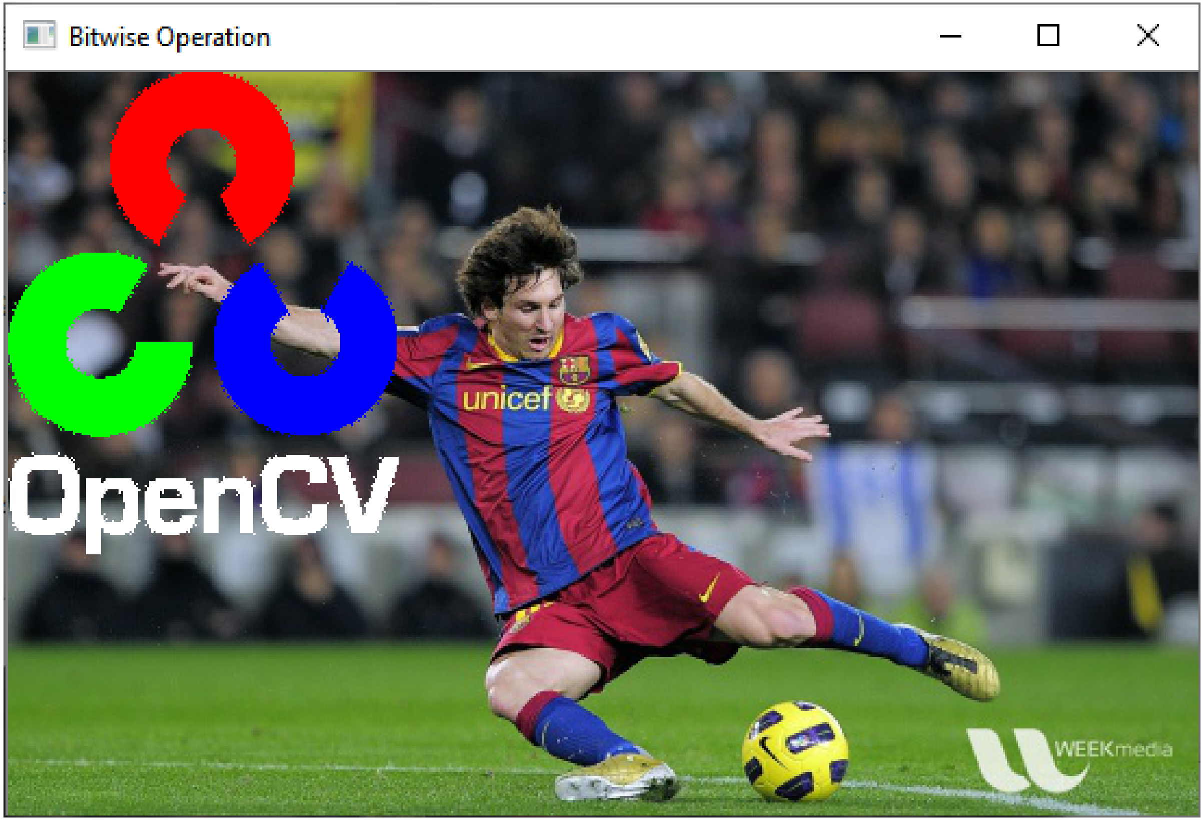
$$\mathrm{dst}(I) = \mathrm{saturate}(\alpha \cdot \mathrm{src1}(I) + \beta \cdot \mathrm{src2}(I) + \gamma)$$

1. https://docs.opencv.org/4.4.0/d2/de8/group__core__array.html#gafafb2513349db3bcff51f54ee5592a19

Bitwise Operations

- AND, OR, NOT, XOR
- Image에서 특정 영역을 추출할 때 사용
- 사각형 이외의 특이한 ROI가 필요할 때 사용

Bitwise Operations: Example

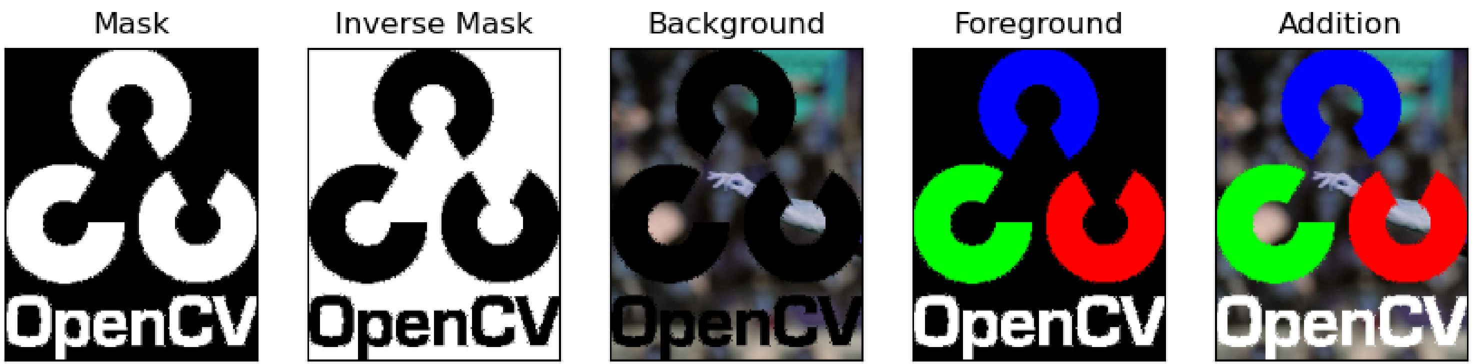


Bitwise Operations: Code

```python
import numpy as np
import cv2
from matplotlib import pyplot as plt

# Load two images
img_messi = cv2.imread('messi5.jpg')
img_logo = cv2.imread('opencv-logo-white.png')
cv2.imshow('Lionel Messi', img_messi)
cv2.imshow('OpenCV Logo', img_logo)
cv2.waitKey(0)

# I want to put logo on top-left corner, So I create a ROI
rows, cols, channels = img_logo.shape
roi = img_messi[0:rows, 0:cols]

# Now create a mask of logo and create its inverse mask also
img_logo_gray = cv2.cvtColor(img_logo, cv2.COLOR_BGR2GRAY)
ret, mask = cv2.threshold(img_logo_gray, 10, 255,
cv2.THRESH_BINARY)
```

https://opencv-python-tutroals.readthedocs.io/en/latest/py_tutorials/py_core/py_image_arithmetics/py_image_arithmetics.html#bitwise-operations

Bitwise Operations: Result



`cv.bitwise_and()`[1]

```
dst = cv.bitwise_and(src1, src2[, dst[, mask]])
```

- Bit-wise AND 연산
  - `src1`: first input array or a scalar
  - `src2`: second input array or a scalar
  - `dst`: output array that has the same size and type as the input arrays
  - `mask`: optional operation mask, 8-bit single channel array, that specifies elements of the output array to be changed

$$\mathrm{dst}(I) = \mathrm{src1}(I) \ \wedge \ \mathrm{src2}(I), \quad \mathrm{if} \ \mathrm{mask}(I) \neq 0$$

$$\mathrm{dst}(I) = \mathrm{src1}(I) \ \wedge \ \mathrm{src2}, \quad \mathrm{if} \ \mathrm{mask}(I) \neq 0$$

$$\mathrm{dst}(I) = \mathrm{src1} \ \wedge \ \mathrm{src2}(I), \quad \mathrm{if} \ \mathrm{mask}(I) \neq 0$$

1. https://docs.opencv.org/4.4.0/d2/de8/group__core__array.html#ga60b4d04b251ba5eb1392c34425497e14

`cv.bitwise_or()`[1]

```
dst = cv.bitwise_or(src1, src2[, dst[, mask]])
```

- Bit-wise OR 연산
  - `src1`: first input array or a scalar
  - `src2`: second input array or a scalar
  - `dst`: output array that has the same size and type as the input arrays
  - `mask`: optional operation mask, 8-bit single channel array, that specifies elements of the output array to be changed

$$\mathrm{dst}(I) = \mathrm{src1}(I) \ \vee \ \mathrm{src2}(I), \quad \text{if } \mathrm{mask}(I) \neq 0$$

$$\mathrm{dst}(I) = \mathrm{src1}(I) \ \vee \ \mathrm{src2}, \quad \text{if } \mathrm{mask}(I) \neq 0$$

$$\mathrm{dst}(I) = \mathrm{src1} \ \vee \ \mathrm{src2}(I), \quad \text{if } \mathrm{mask}(I) \neq 0$$

1. https://docs.opencv.org/4.4.0/d2/de8/group__core__array.html#gab85523db362a4e26ff0c703793a719b4

`cv.bitwise_not()`[1]

```
dst = cv.bitwise_not(src[, dst[, mask]])
```

- Bit-wise NOT 연산
  - `src`: input array or a scalar
  - `dst`: output array that has the same size and type as the input arrays
  - `mask`: optional operation mask, 8-bit single channel array, that specifies elements of the output array to be changed

$$\mathrm{dst}(I) = \neg\mathrm{src}(I) \quad \text{if } \mathrm{mask}(I) \neq 0$$

1. https://docs.opencv.org/4.4.0/d2/de8/group__core__array.html#ga0002cf8b418479f4cb49a75442baee2f

`cv.bitwise_xor()`[1]

```
dst = cv.bitwise_xor(src1, src2[, dst[, mask]])
```

- Bit-wise XOR 연산
  - `src1`: first input array or a scalar
  - `src2`: second input array or a scalar
  - `dst`: output array that has the same size and type as the input arrays
  - `mask`: optional operation mask, 8-bit single channel array, that specifies elements of the output array to be changed

$$\mathrm{dst}(I) = \mathrm{src1}(I) \ \oplus \ \mathrm{src2}(I), \quad \text{if } \mathrm{mask}(I) \neq 0$$

$$\mathrm{dst}(I) = \mathrm{src1}(I) \ \oplus \ \mathrm{src2}, \quad \text{if } \mathrm{mask}(I) \neq 0$$

$$\mathrm{dst}(I) = \mathrm{src1} \ \oplus \ \mathrm{src2}(I), \quad \text{if } \mathrm{mask}(I) \neq 0$$

1. https://docs.opencv.org/4.4.0/d2/de8/group__core__array.html#ga84b2d8188ce506593dcc3f8cd00e8e2c

Push Code to GitHub

References

References

- OpenCV Python Tutorials
  - Core Operations
    - Basic Operations on Images
    - Arithmetic Operations on Images

  https://github.com/opencv/opencv/tree/225566da7bab2147d71

  https://opencv-
  python.readthedocs.io/en/latest/doc/11.imageSmoothing/image