Computer Vision

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About me

Lecturer

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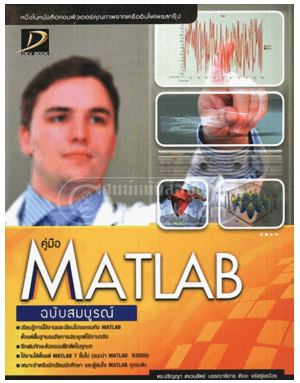
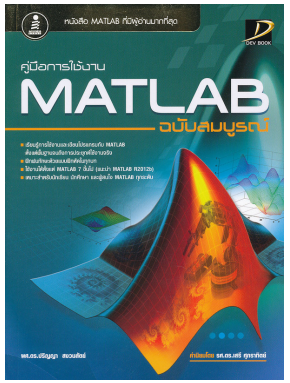
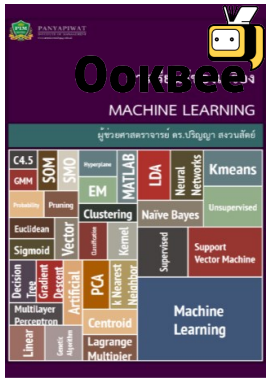
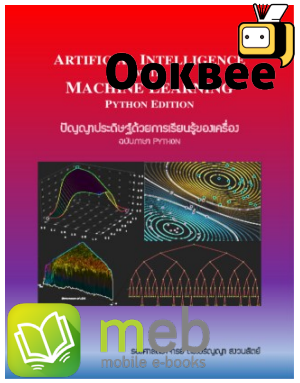
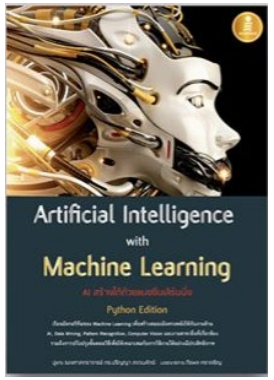
Writer



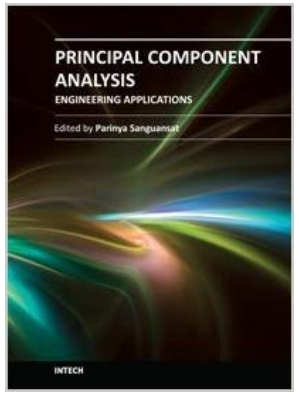


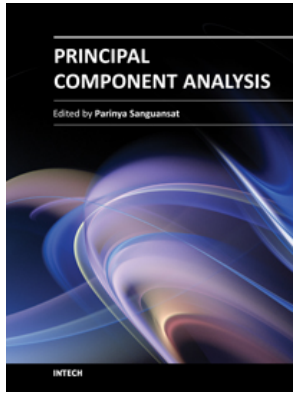






Editor





Youtuber

AI บ้าน บ้าน

Play around with image and video

- Create
- Visualize
- Import
- Export

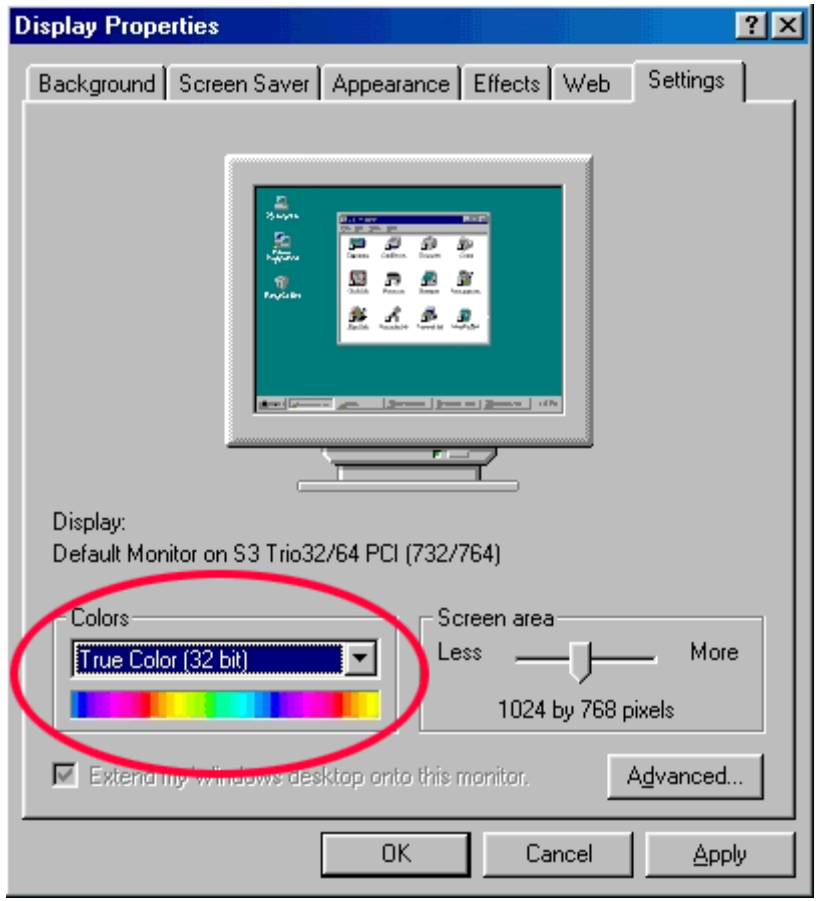
How to create an image

- Any data types can use but uint8, float32, and float64 are most frequently used

- For Python, numpy array is the medium

How to visualize an image

- You can create image in any data types but



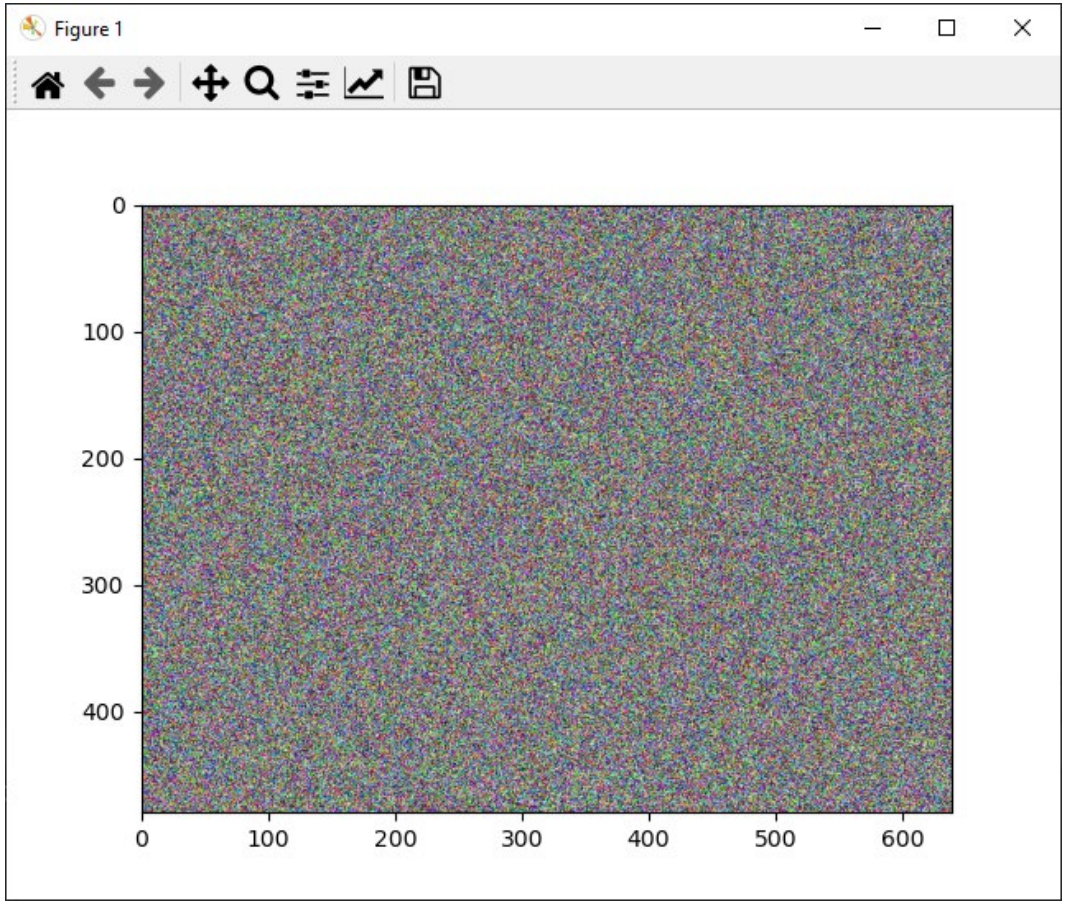
Ex: How to create an image

- Image of Noise in VGA resolution

```
import numpy as np
import matplotlib.pyplot as plt

im_shape = 480, 640, 3
im = np.random.rand(*im_shape)
plt.imshow(im)
plt.show()
```

Default data type is float64

What happens if we convert im to float32, float16, or uint8 and visualize with pyplot?

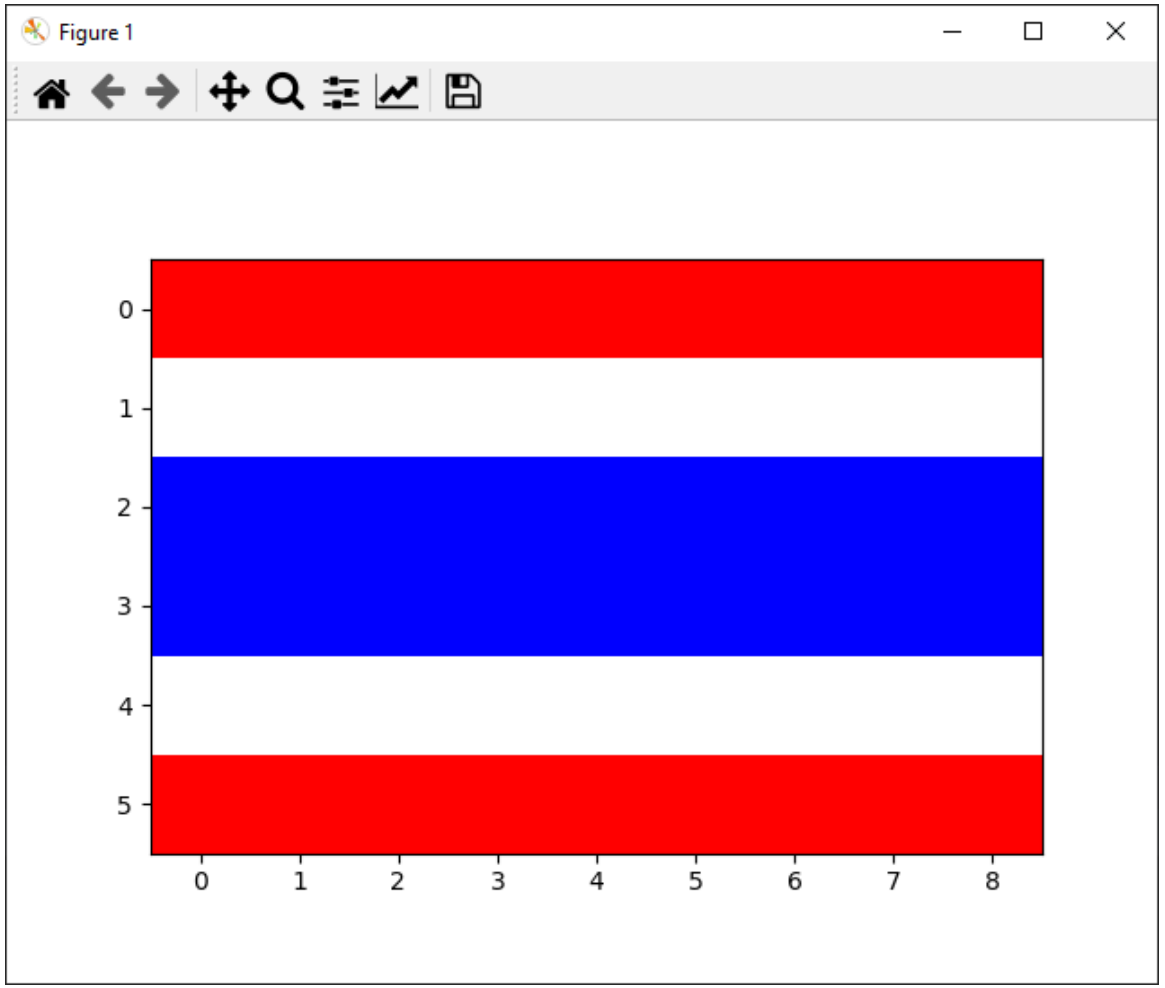


Ex: Flag of Thailand

```
Thai = np.ones((6, 9, 3))
Thai[[0, -1], :, 1:] = 0
Thai[2:4, :, :2] = 0
plt.imshow(Thai)
plt.show()
```

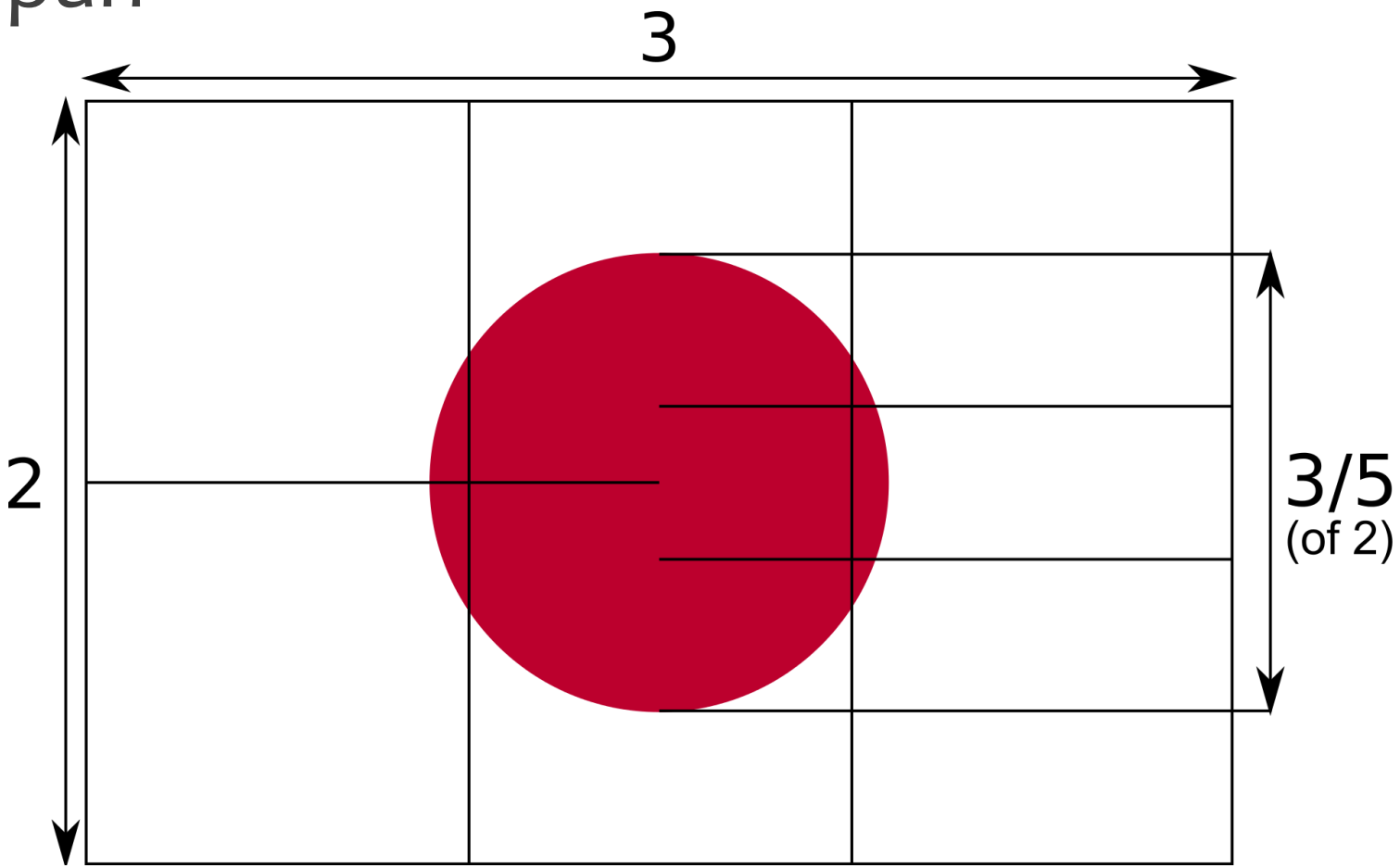
What happens if

- we initialize Thai with zeros
- we want to use unit8
- we use cv2.imshow() instead of plt.imshow()



5 min. challenge I

- Flag of Japan



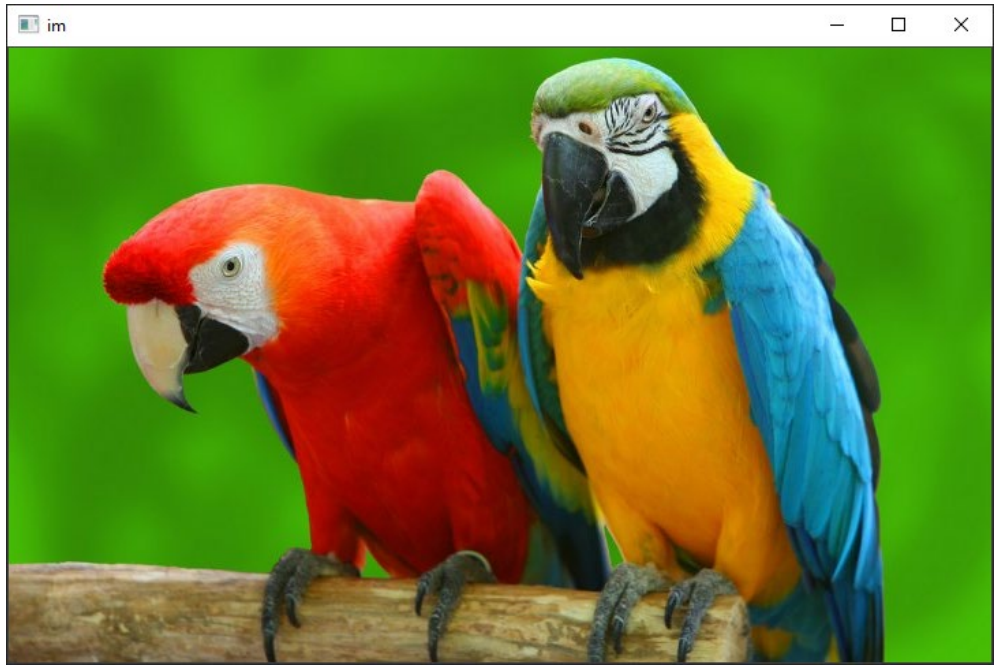
How to import an image

```
import matplotlib.pyplot as plt
im = plt.imread('parrot.jpg')
plt.imshow(im)
plt.show()
```

```
from PIL import Image
im = Image.open('parrot.jpg')
im = np.array(im)
plt.imshow(im)
plt.show()
```

```
import cv2
im = cv2.imread('parrot.jpg')
cv2.imshow('im', im)
cv2.waitKey()
```

Matplotlib can only read PNGs natively. Further image formats are supported via the optional dependency on Pillow



How to export an image

- Choose image file extension
  - Lossless: png, gif, tiff, bmp
  - Lossy: jpg
  - Multiple images: gif, tiff
  - Light weight: gif
  - High quality: tiff

```
cv2.imwrite('Thai.png', np.uint8(Thai[:, :, ::-1]*255))
```

```
im = Image.fromarray(np.uint8(Thai*255))
im.save('Thai.jpg')
```

```
im2 = Image.fromarray(np.uint8(255-Thai*255))
im.save('Thai.gif', save_all=True, append_images=[im2, im]*20)
```

1st frame

2nd frame

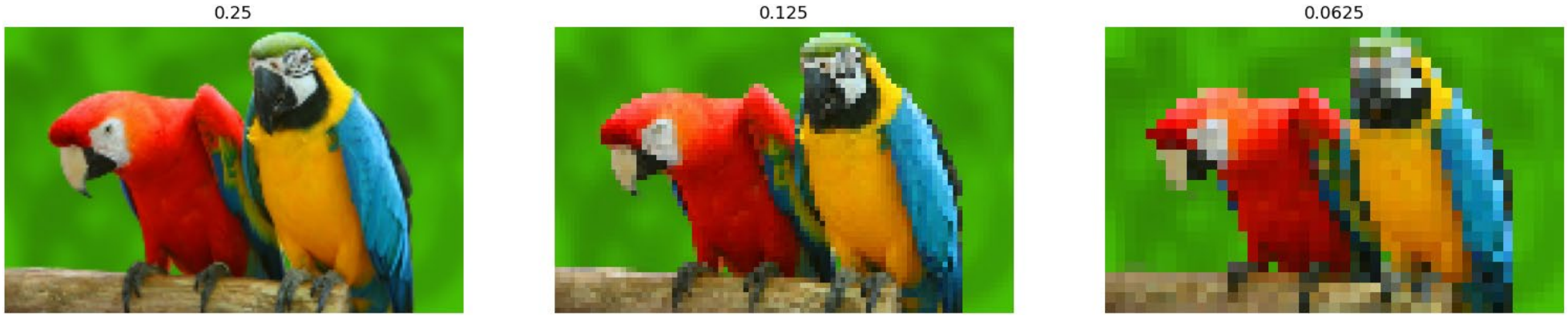
Remarks

- Can images have more than 8 bit per channel?
- Can images have more than 3 channel values?

Resolutions

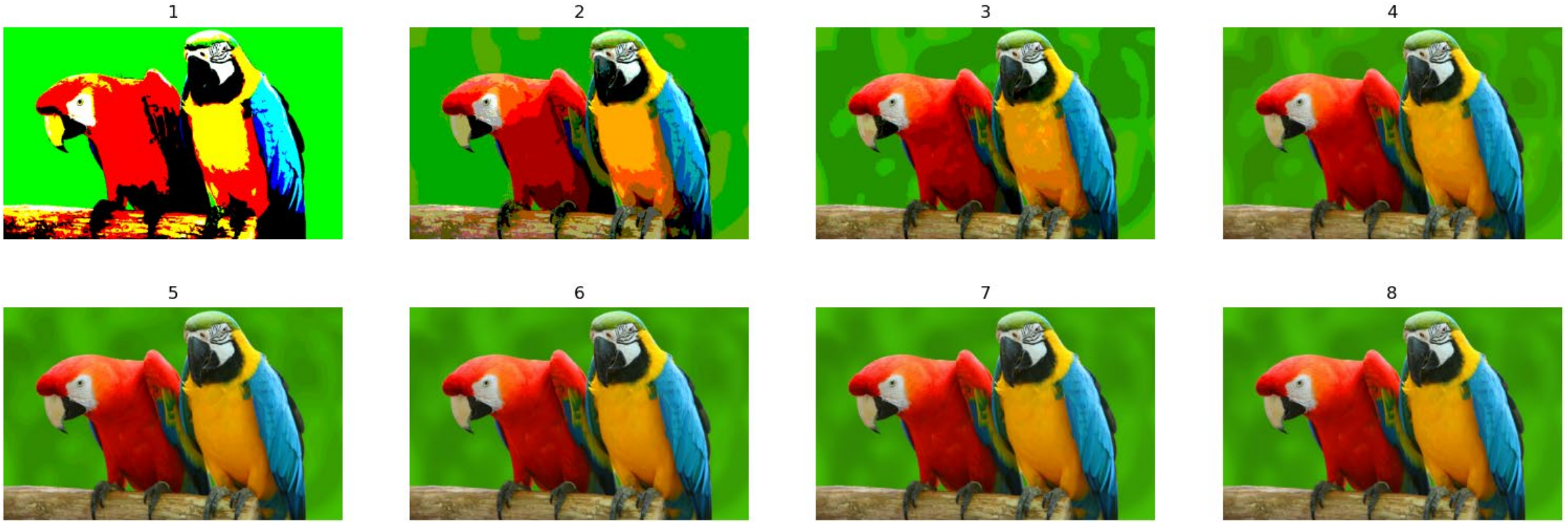
- Spatial resolution

```
n = 3
for i in range(1, n+1):
    plt.subplot(1, n, i)
    s = 1/2**(i+1)
    plt.imshow(cv2.resize(im, None, fx=s, fy=s))
    plt.axis('off'); plt.title(str(s))
plt.show()
```



Resolutions

- Intensity (gray) level resolution: bit per channel



- Need to fix the scale for visualization (8 bpc)

Bit planes

- Convert pixel value into bit
  - 8 bit planes per channel
  - 24 bit planes per colored image

```
def image2bitplane(img):
    bp = []
    for c in range(img.shape[2]):
        for i in range(8):
            bp.append(img[:, :, c] // 2 ** i % 2)
    return np.array(bp)

def bitplane2image(bp):
    img = np.zeros((bp[0].shape[0], bp[0].shape[1], 3))
    for b in range(len(bp)):
        img[:, :, b//8] = img[:, :, b//8] + (bp[b] * 2**(b % 8))
    return np.uint8(img)
```

```
for bpc in range(1, 9):
    bp = image2bitplane(im)
    bp[0:8-bpc, :, :] = 0  # R
    bp[8:8+8-bpc, :, :] = 0  # G
    bp[16:16+8-bpc, :, :] = 0  # B
    im_ = bitplane2image(bp)
    max_vl = sum([2**i for i in range(8-bpc, 8)])
    im_ = np.uint8(im_ / max_vl * 255)
    plt.subplot(2, 4, bpc)
    plt.imshow(im_)
    plt.axis('off')
    plt.title(str(bpc))
plt.show()
```

5 min. challenge II

- Find another image in this image
  - Hint:
    - Use cv2.imread
    - Secret sequence = [19, 18, 17, 16, 11, 10, 9, 8, 3, 2, 1, 0]

challenge_2.png

How to create an video

- Select supported video format: DIVX, XVID, MJPG, X264, WMV1, WMV2, MP4V,

```
import cv2
import numpy as np

fourcc = cv2.VideoWriter_fourcc(*'mp4v')
frame_size = (480, 640, 3)
vdo_writer = cv2.VideoWriter('out.mp4', fourcc, 30, (frame_size[1], frame_size[0]))

for i in range(640):
    frame = np.zeros(frame_size, np.uint8)
    cv2.circle(frame, (i, 200), 20, (255,255,255), -1)
    vdo_writer.write(frame)
vdo_writer.release()
```

How to import a video

- Read frame-by-frame

```
import cv2

cap = cv2.VideoCapture('out.mp4')
while cap.isOpened():
    ret, frame = cap.read()
    if ret:
        cv2.imshow('frame', frame)
    if cv2.waitKey(1) == ord('q') or not ret:
        break
cap.release()
cv2.destroyAllWindows()
```

Filename: out.mp4, …

Webcam: 0, 1, 2, …
Use cv2.CAP_DSHOW if it slowly opened

IPcam, NVS: rtsp://u:p@192.168.1.47:554/

Basic Computer vision techniques

- Color Detection
- Frame Difference
- Thresholding
- Morphological Transformations
- Image Segmentation
- Geometric transformations
- Blob analysis

Color Detection

- RGB color space
  - But in OpenCV will be BGR

A

A[:,:,2]

A[:,:,1]

A[:,:,0]

Detect a defined color

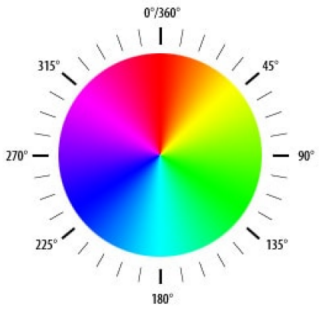
```
import cv2
import numpy as np

A = cv2.imread('parrot.jpg')

tol = 30
color = np.array([64, 116, 138])

mask = cv2.inRange(A, color-tol, color+tol)
Amask = cv2.bitwise_and(A, A, mask=mask)
cv2.imshow('mask', mask)
cv2.imshow('Amask', Amask)
cv2.waitKey()
```

mask

Amask

5 min. challenge III

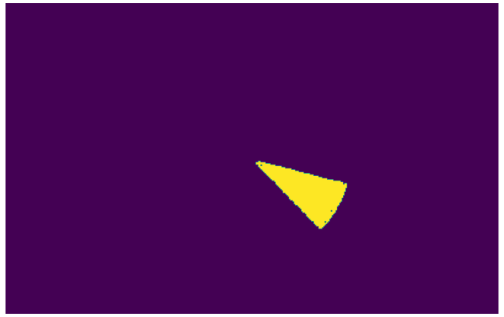
RGB



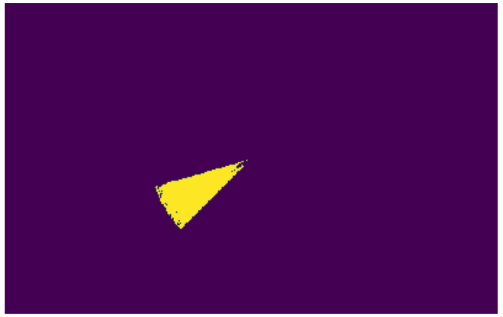
challenge_3.jpg

red

green

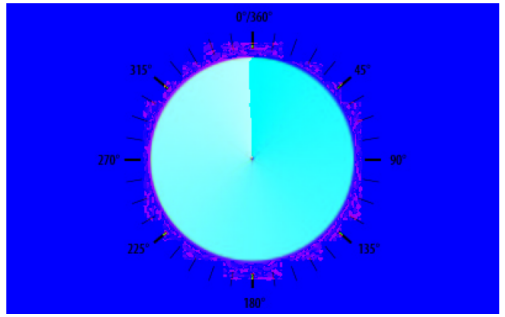


blue

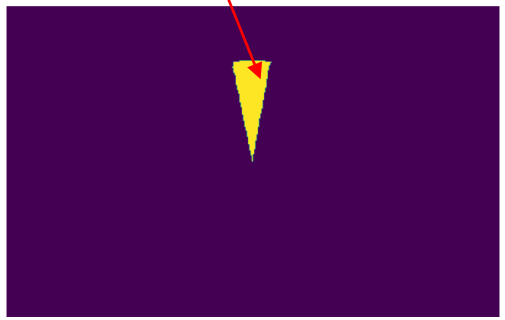


How?

HSV

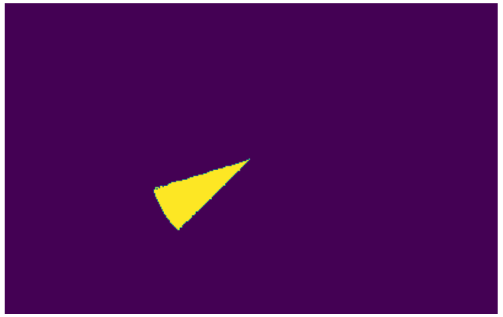


red



green

blue



Background Subtraction

If we have background

Absolute difference

- Beware the data type (uint8)
- Positive or negative value of difference is considered equally

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

im1 = plt.imread('im1.jpg')
im2 = plt.imread('im2.jpg')

diff = cv2.absdiff(im1, im2)
diff = np.uint8(np.abs(im1/255 - im2/255)*255)
```

- HSV for Hue [0, 360]:
  - Opencv [0, 180]
  - Return [0, 1]

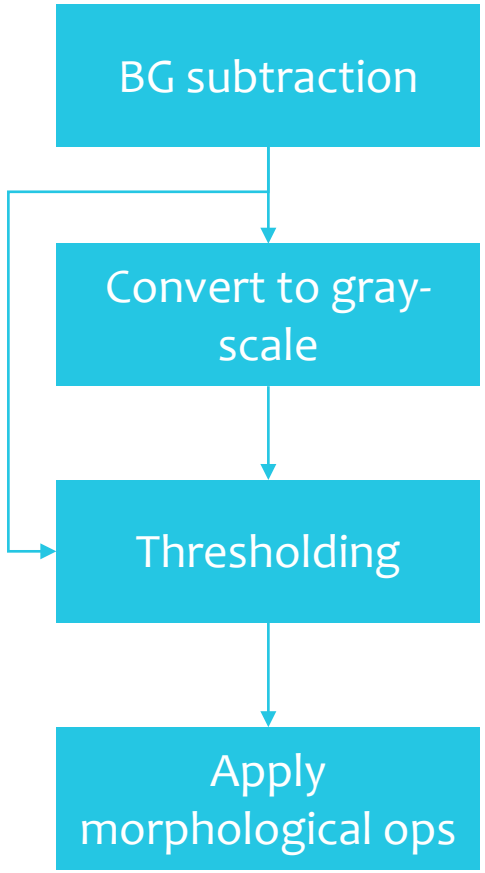
```
def angle_diff(a1, a2):
    return (180 - abs(abs(a1 - a2) - 180)) / 360
```

Absolute difference

diff_RGB

diff_H

Basic image segmentation




```
A = cv2.absdiff(im1,im2)
```

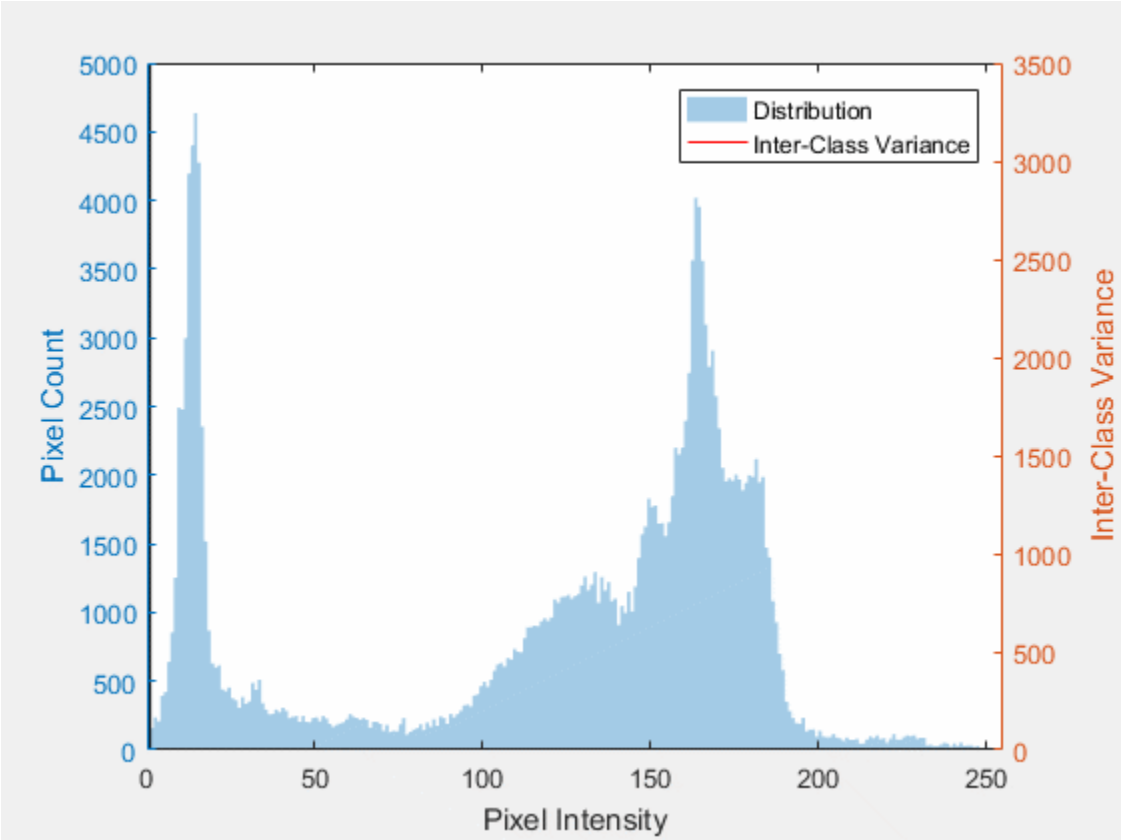
```
G = cv2.cvtColor(A,cv2.COLOR_BGR2GRAY)
```

```
bw = cv2.threshold(G,125,255,cv2.THRESH_BINARY)[1]
bw = cv2.threshold(G,0,255,cv2.THRESH_BINARY|cv2.THRESH_OTSU)[1]
```

```
kernel = np.ones((5,5),np.uint8)
erosion = cv2.erode(bw,kernel,iterations=1)
dilation = cv2.dilate(bw,kernel,iterations=1)
```

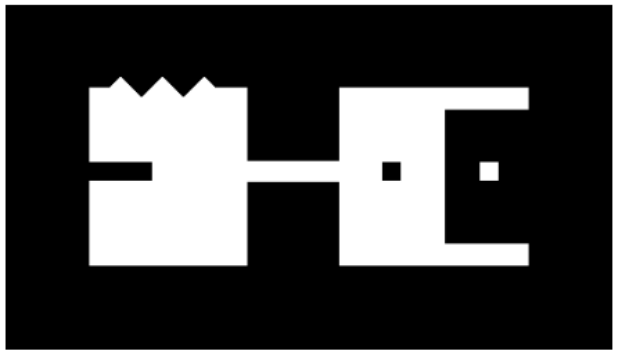
OTSU's method

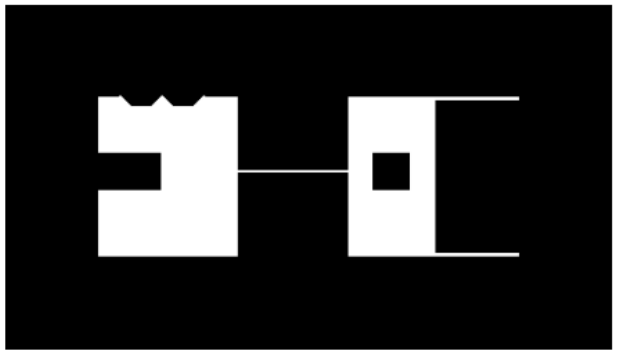
- Assume: The histogram have bimodal distribution
  - Minimize intra-class variance or
  - Maximize inter-class variance



https://en.wikipedia.org/wiki/Otsu%27s_method#/media/File:Otsu's_Method_Visualization.gif

Morphological operations

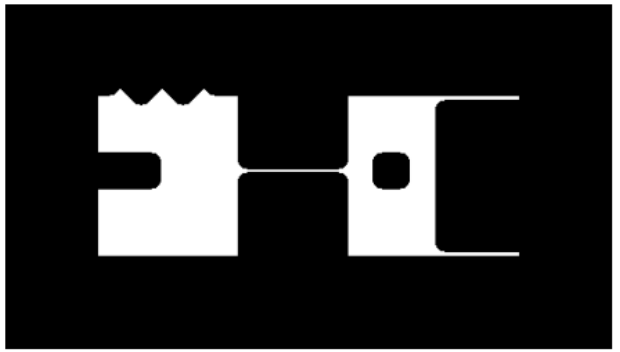




```
kernel = np.ones((17, 17))
```

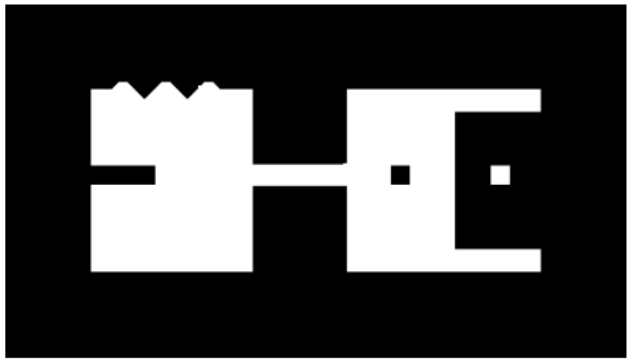
```
cv2.dilate(im, kernel)
```

```
cv2.erode(im, kernel)
```

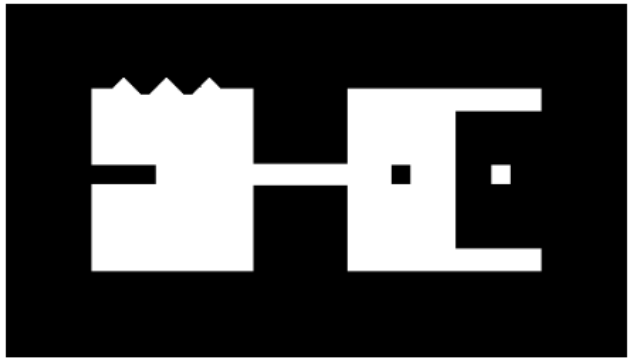


```
kernel = cv2.getStructuringElement(cv2.MORPH_ELLIPSE, (17, 17))
```

Morphological operations



Opening = erosion followed by dilation (removing noise)
Closing = dilation followed by erosion (closing small holes)



Remarks

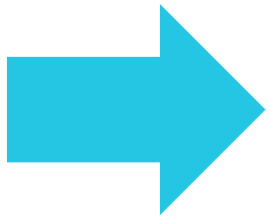
- How to add noise in image
  - Uniform noise: np.random.rand()
  - Gaussian noise: np.random.randn()
  - Salt-and-Pepper: use uniform noise with thresholding
  - Beware the data type
  - EX: add uniform noise (with size)

```
noise = (np.random.rand(*im.shape) > 0.999) + 0.  # float -> bool -> float
noise = cv2.dilate(noise, np.ones((5, 5)))  # bigger size
im1 = im / 255 + noise # float
im1[im1 > 1] = 1  # remove out of range values
im1 = np.uint8(im1*255)  # optional convert to uint8
```

5 min. challenge IV

im1.jpg

im2.jpg



object

Background Subtraction

- If we don't have background
- Non-recursive method
  - |f(t)-f(t-1)| > t
  - |f(t)-mean(f(t-n)… f(t-1))| > t
  - |f(t)-median(f(t-n)… f(t-1))| > t
- Recursive method
  - MOG
  - KNN
  - etc.

BG subtraction: |f(t)-f(t-1)| > t

```
import cv2
import numpy as np

cap = cv2.VideoCapture('cctv.mp4')
buffer = None
while True:
    ret, frame = cap.read()
    if not ret:
        break
    if buffer is not None:
        diff = np.mean(cv2.absdiff(frame, buffer), axis=2)
        fg = np.uint8((diff > 0.5*np.max(diff)) * 255)
        cv2.imshow('diff', np.uint8(diff / np.max(diff) * 255))
        cv2.imshow('fg', fg)
    buffer = frame
    cv2.imshow('frame', frame)
    cv2.waitKey(1)
```

Can use any color space

- Gray, RGB, HSV, etc.

BG subtraction: |f(t)-mean(f(t-n)…f(t-1))| > t

```
import cv2
import numpy as np

cap = cv2.VideoCapture('cctv.mp4')
n_buffer = 10
buffer = None
iframe = 0
while True:
    ret, frame = cap.read()
    if not ret:
        break
    gray = cv2.cvtColor(frame, cv2.COLOR_BGR2GRAY)
    if buffer is None:
        buffer = np.zeros((n_buffer, *gray.shape))
    buffer[iframe % n_buffer] = gray
    if iframe >= n_buffer:
        M = np.mean(buffer, axis=0)
        diff = cv2.absdiff(gray, np.uint8(M))
        fg = np.uint8((diff > .4 * np.max(diff)) * 255)
        cv2.imshow('fg', fg)
    cv2.imshow('frame', frame)
    cv2.waitKey(1)
    iframe += 1
```

Can use any color space

- Gray, RGB, HSV, etc.

BG subtraction: |f(t)-med(f(t-n)…f(t-1))| > t

```python
import cv2
import numpy as np

cap = cv2.VideoCapture('cctv.mp4')
n_buffer = 10
buffer = None
iframe = 0
while True:
    ret, frame = cap.read()
    if not ret:
        break
    gray = cv2.cvtColor(frame, cv2.COLOR_BGR2GRAY)
    if buffer is None:
        buffer = np.zeros((n_buffer, *gray.shape))
    buffer[iframe % n_buffer] = gray
    if iframe >= n_buffer:
        M = np.median(buffer, axis=0)
        diff = cv2.absdiff(gray, np.uint8(M))
        fg = np.uint8((diff > .4 * np.max(diff)) * 255)
        cv2.imshow('fg', fg)
    cv2.imshow('frame', frame)
    cv2.waitKey(1)
    iframe += 1
```

Need sorted data, slow processing

Can use any color space

- Gray, RGB, HSV, etc.

BG subtraction: Recursive method

MOG

- Parametric based algorithm
- Use mixture of Gaussian for modeling each pixel

$$\hat{p}(\vec{x}|\mathcal{X}_T, \text{BG} + \text{FG}) = \sum_{m=1}^{M} \hat{\pi}_m \mathcal{N}(\vec{x}; \hat{\vec{\mu}}_m, \hat{\sigma}_m^2 I)$$

- Approximate the background model by the first B largest clusters

$$\hat{p}(\vec{x}|\mathcal{X}_T, \text{BG}) \sim \sum_{m=1}^{B} \hat{\pi}_m \mathcal{N}(\vec{x}; \hat{\vec{\mu}}_m, \sigma_m^2 I)$$

$$B = \arg\min_b \left(\sum_{m=1}^{b} \hat{\pi}_m > (1 - c_f) \right)$$

KNN

- Non-parametric based algorithm
- Use kernel function for modeling each pixel

$$\hat{p}(\vec{x}|\mathcal{X}_T, \text{BG} + \text{FG}) = \frac{1}{TV} \sum_{m=t-T}^{t} \mathcal{K}\left(\frac{\|\vec{x}^{(m)} - \vec{x}\|}{D} \right) = \frac{k}{TV}$$

- Approximate the background model by the first B largest clusters

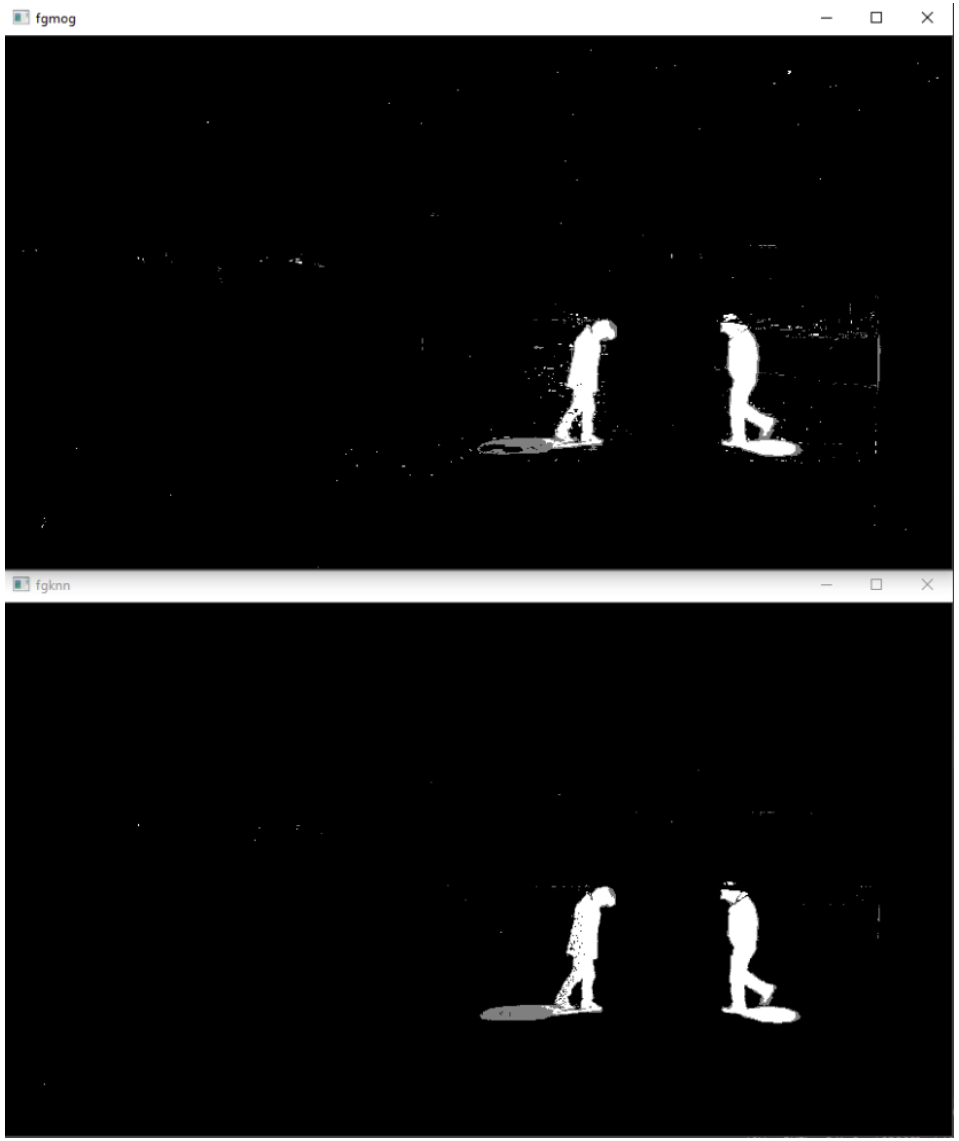
$$\hat{p}(\vec{x}|\mathcal{X}_T, \text{BG}) \approx \frac{1}{TV} \sum_{m=t-T}^{t} b^{(m)} \mathcal{K}\left(\frac{\|\vec{x}^{(m)} - \vec{x}\|}{D} \right)$$

$b^{(m)}$ = 1 if it belongs to background else 0

BG subtraction: Recursive method

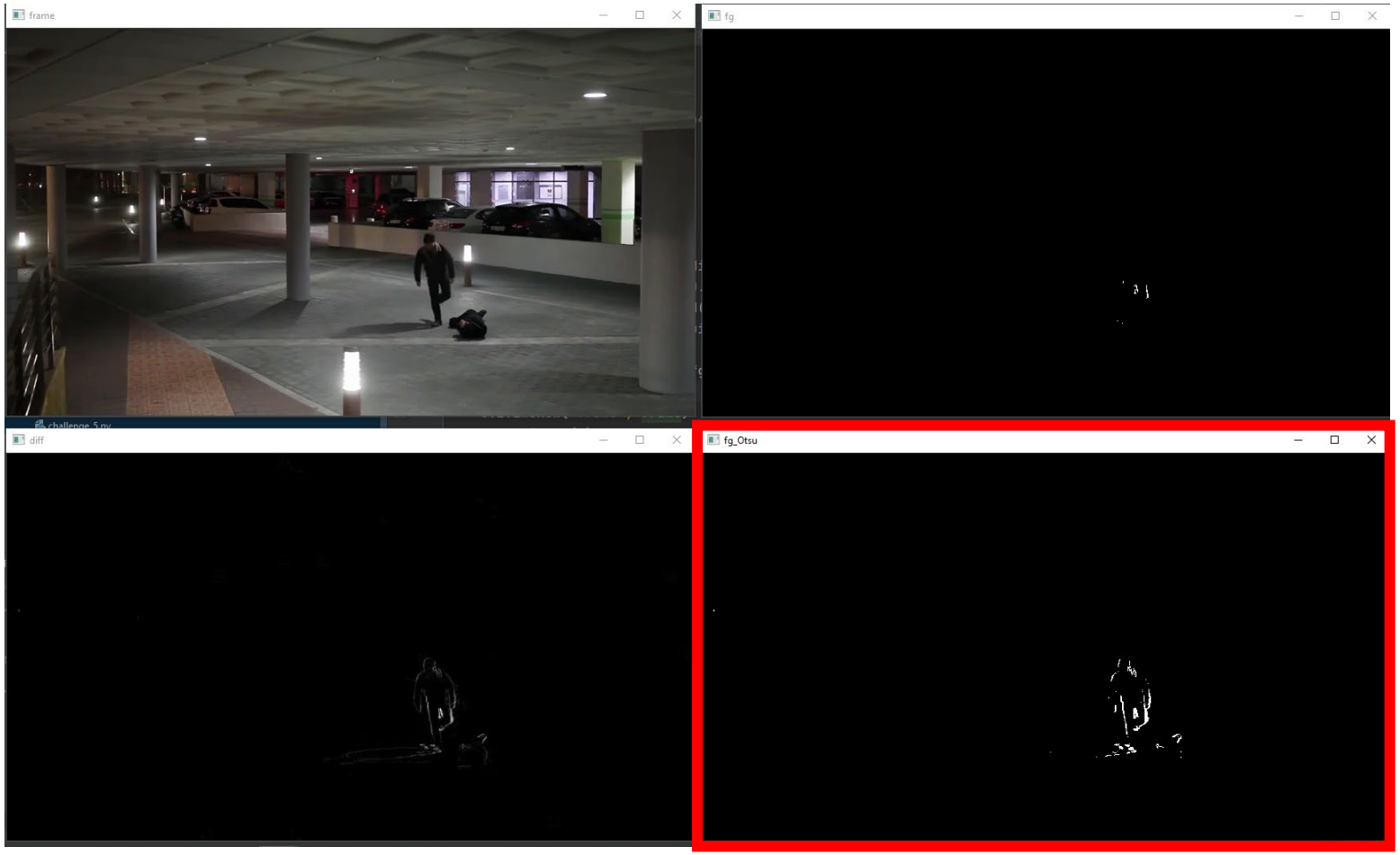
```
import cv2

cap = cv2.VideoCapture('cctv.mp4')
bgsubknn = cv2.createBackgroundSubtractorKNN()
bgsubmog = cv2.createBackgroundSubtractorMOG2()
while True:
    ret, frame = cap.read()
    if not ret:
        break
    fgknn = bgsubknn.apply(frame)
    fgmog = bgsubmog.apply(frame)
    cv2.imshow('frame', frame)
    cv2.imshow('fgknn', fgknn)
    cv2.imshow('fgmog', fgmog)
    cv2.waitKey(1)
```

Normally, KNN perform better than MOG



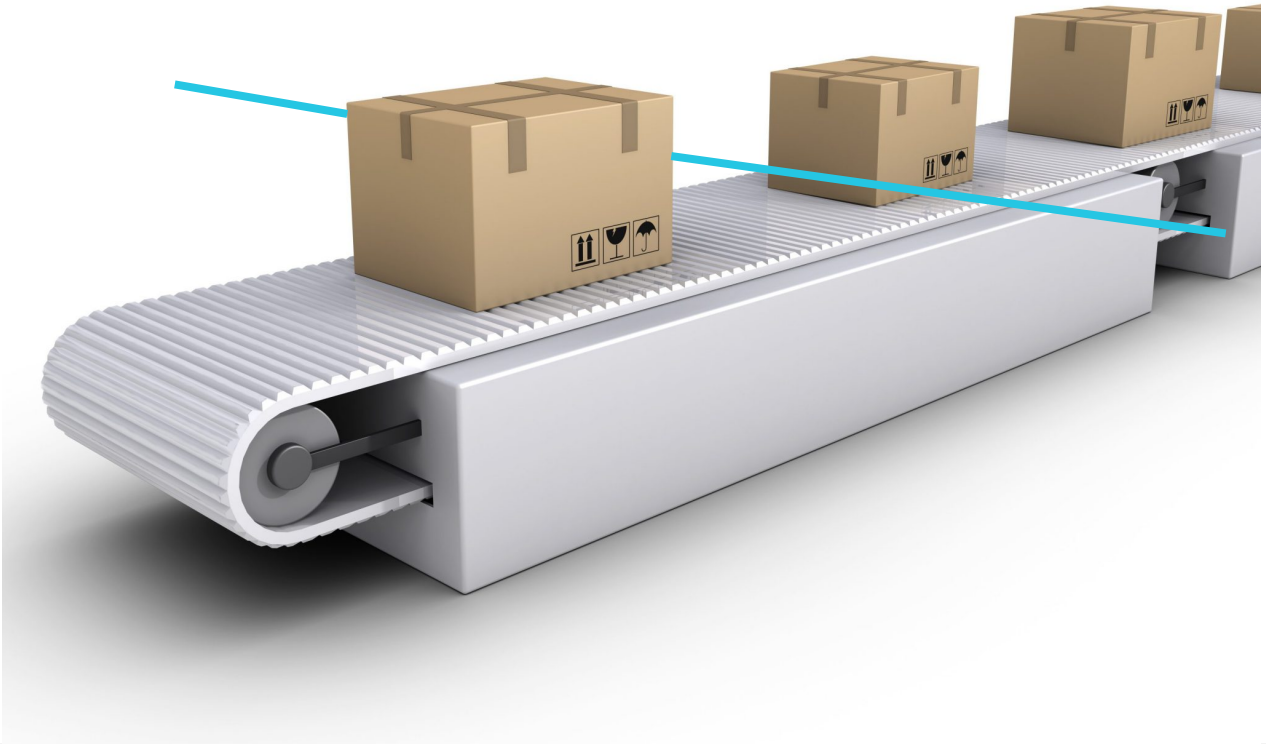
5 min. challenge V

- Use Otsu's method for thresholding in |f(t)-f(t-1)| > t



Line sensor

- Belt conveyor



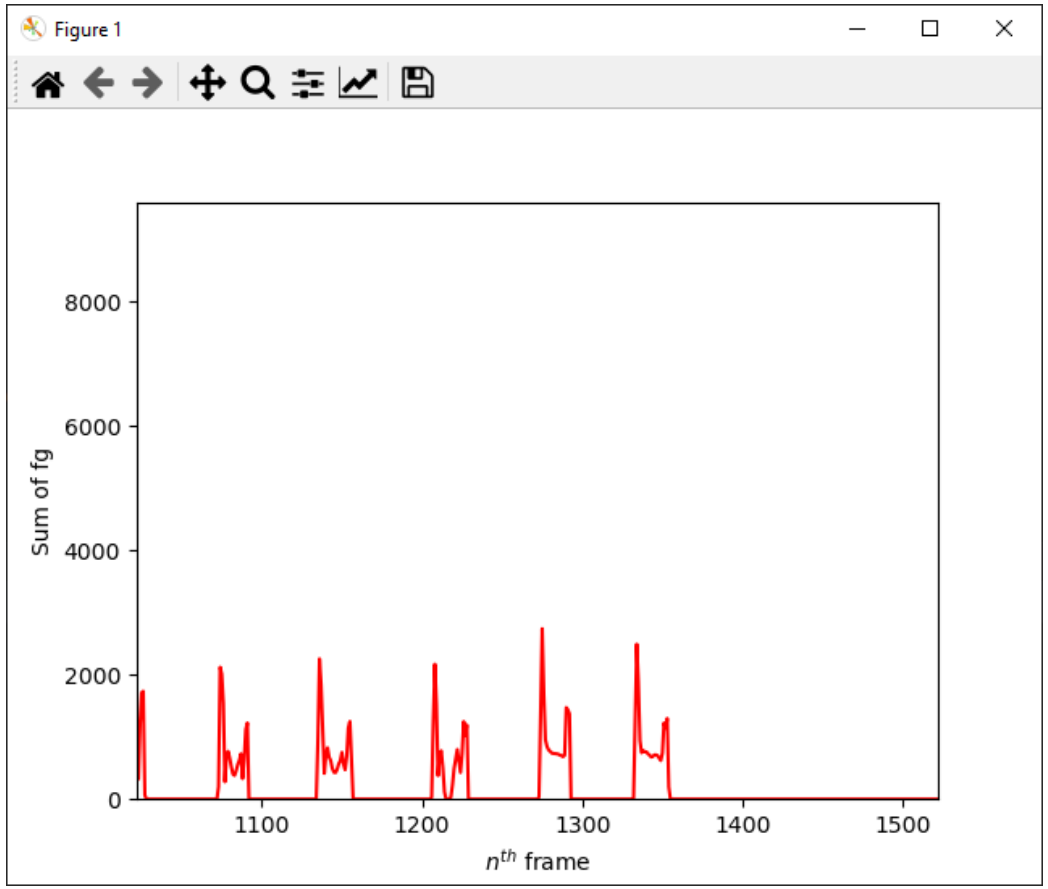
Line sensor

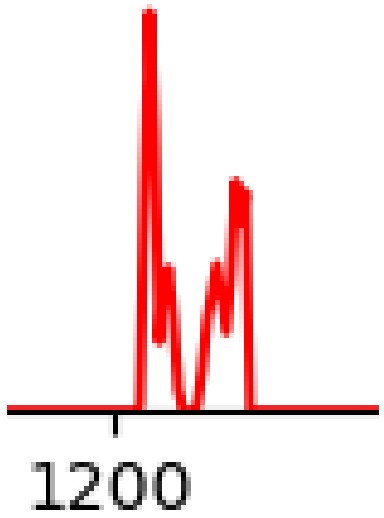
- Use background subtraction in sensor area

```
import cv2
import numpy as np

cap = cv2.VideoCapture(0)
L1 = np.r_[100:120]
bgsub = cv2.createBackgroundSubtractorKNN()
while True:
    ret, frame = cap.read()
    if not ret:
        break
    gray = cv2.cvtColor(frame[:, L1, :], cv2.COLOR_BGR2GRAY)
    fg = bgsub.apply(gray)
    if np.sum(fg) > 100:
        frame[:, L1, :2] = 0
    else:
        frame[:, L1, 1:] = 0
    cv2.imshow('fg', fg)
    cv2.imshow('frame', frame)
    cv2.waitKey(1)
```

Counting: Line sensor

- Consider the sensor data





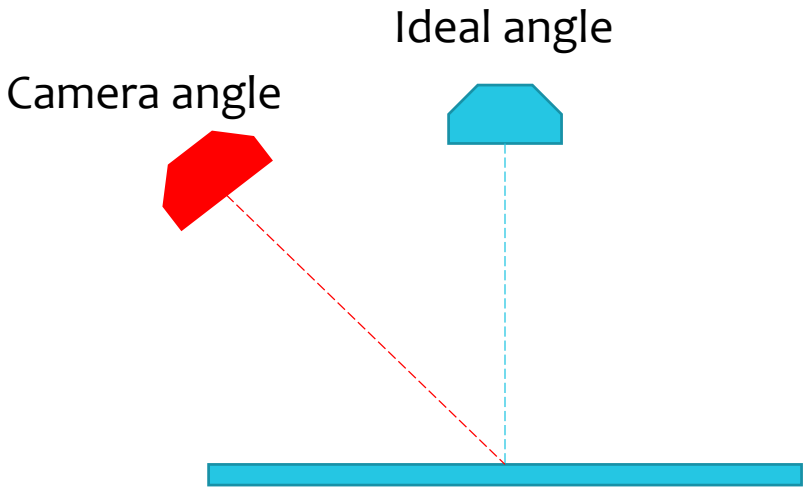
Counting: Line sensor

- Add multiple lines
  - Sensor lines
  - Reset lines

```
import cv2
import numpy as np
cap = cv2.VideoCapture(0)
L1, L2, L3, L4 = np.r_[100:120], np.r_[540:560], np.r_[0:20], np.r_[620:640]
line1, line2, line3, line4 = False, False, False, False
bgsub = cv2.createBackgroundSubtractorKNN(history=1)
count = 0
while True:
    ret, frame = cap.read()
    if not ret:
        break
    gray = cv2.cvtColor(frame, cv2.COLOR_BGR2GRAY)
    fg = bgsub.apply(gray)
    if np.sum(fg[:, L1]) > 100:
        frame[:, L1, :2] = 0
        line1 = True
    else:
        frame[:, L1, 1:] = 0
    if np.sum(fg[:, L2]) > 100:
        frame[:, L2, :2] = 0
        line2 = True
    else:
        frame[:, L2, 1:] = 0
    if np.sum(fg[:, L3]) > 100 or np.sum(fg[:, L4]) > 100 :
        line1, line2 = False, False
    if line2 and line1:
        line1, line2 = False, False
        count += 1
    cv2.putText(frame, str(count), (10, 30), cv2.FONT_HERSHEY_SIMPLEX, 1, (0, 255, 0), 2)
    cv2.imshow('fg', fg)
    cv2.imshow('frame', frame)
    cv2.waitKey(1)
```

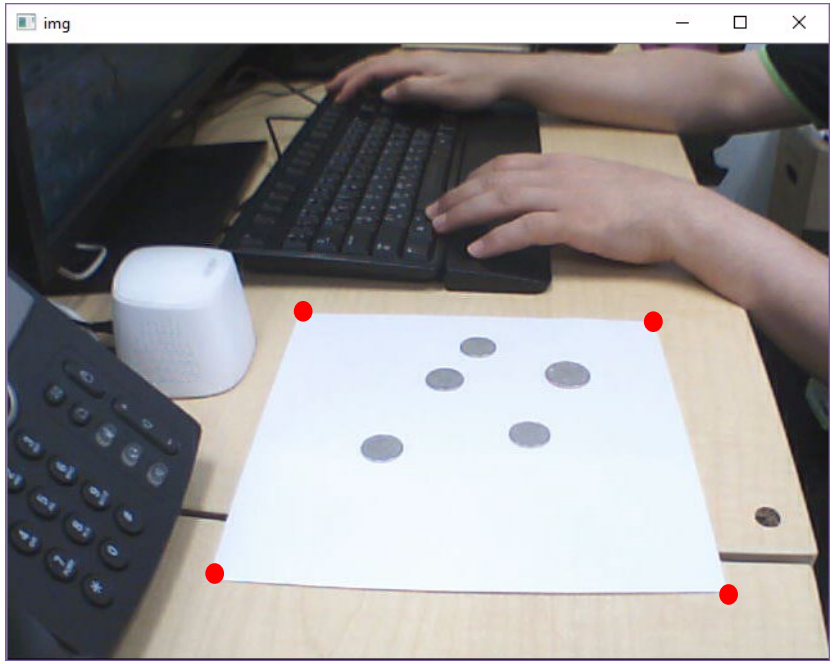
Perspective transformation

- The best viewing angle for this application is top view but sometimes we cannot set camera at this angle



Perspective Transform

- Object is smaller as its distance from camera increases
- Find 4 points to estimate the transformation (same sequence)




```
T = cv2.getPerspectiveTransform(np.float32(pts1),np.float32(pts2))
img = cv2.warpPerspective(img, T, template_size)
```

Point selecting with mouse click

- Define a callback that corresponding with display window

```
def onClick(event, x, y, flags, param):
    if event == cv2.EVENT_LBUTTONDOWN:
        ...


cv2.namedWindow('img')
cv2.setMouseCallback('img', onClick)
```

Blob analysis

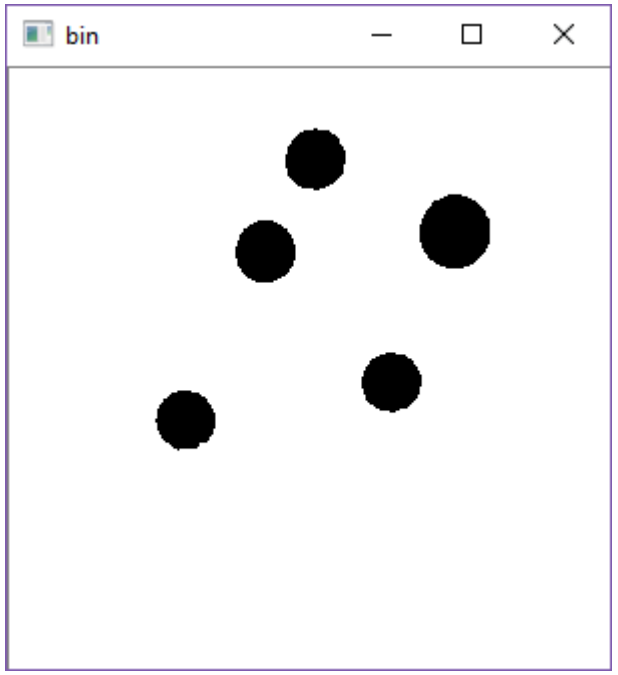
- cv2.findContours() for binary image
  - Connected points are grouped together as object
  - Find object with suitable properties, e.g. find the smallest circle that can cover this object

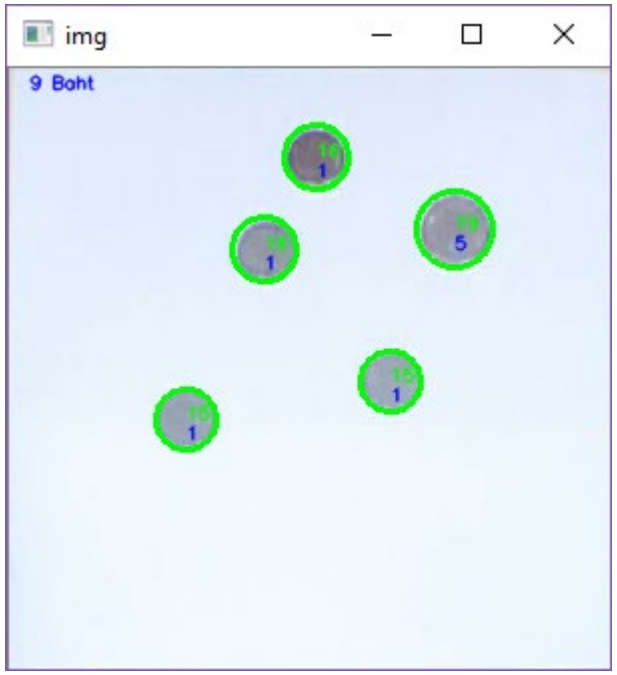
```
contours, hierarchy = cv2.findContours(bin, cv2.RETR_TREE, cv2.CHAIN_APPROX_SIMPLE)
for cnt in contours:
    (x, y), radius = cv2.minEnclosingCircle(cnt)
    center = (int(x), int(y))
    radius = int(radius)
    img = cv2.circle(img, center, radius, (0, 255, 0), 2)
```

- The number of contours is huge because of noise
  - Add preprocessing with **erode** for denoising and **dilate** to maintain the object size

```
kernel = np.ones((11,11))
bw = cv2.erode(bw, kernel)
bw = cv2.dilate(bw, kernel)
```

Coin Counting






```
if 14 <= radius <= 17:
    img = cv2.putText(img, '1', (int(x), int(y) + 10), font, .3, (255, 0, 0), 1, cv2.LINE_AA)
    count += 1
if 18 <= radius <= 20:
    img = cv2.putText(img, '5', (int(x), int(y) + 10), font, .3, (255, 0, 0), 1, cv2.LINE_AA)
    count += 5
```

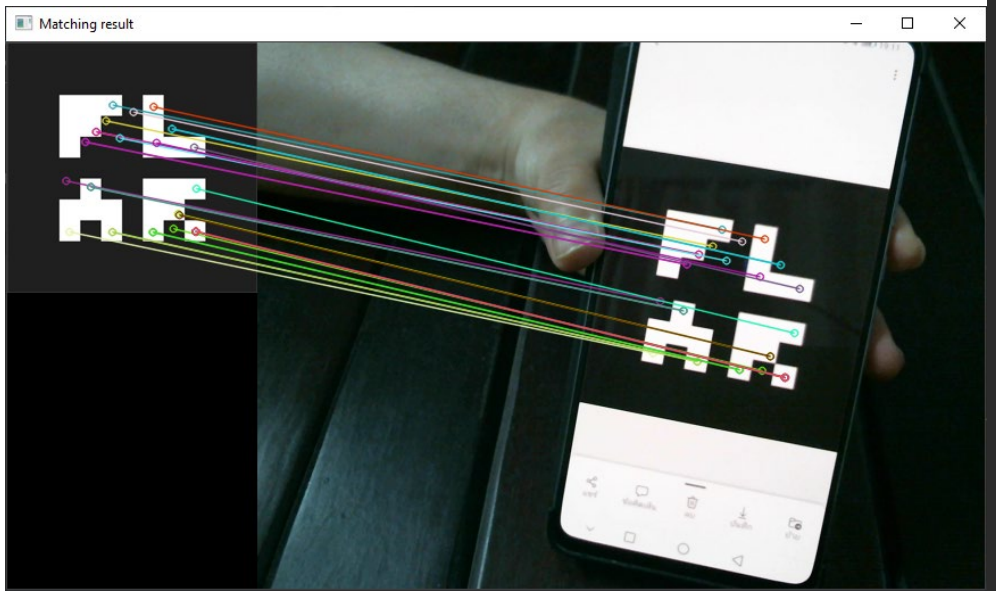
Feature Detection

- Scale-invariant feature transform: SIFT
  - Output
    - Keypoint: location, angle, size, etc.
    - Descriptor: 128-D vector of each keypoint
      - Use for similarity measurement


```
import cv2

img1 = cv2.imread("ARmarker.png", cv2.IMREAD_GRAYSCALE)
ft = cv2.SIFT_create()
kp, des = ft.detectAndCompute(img1, None)
img = cv2.drawKeypoints(img1, kp, img1, flags=cv2.DRAW_MATCHES_FLAGS_DRAW_RICH_KEYPOINTS)
cv2.imshow('img', img)
cv2.waitKey()
```

Feature Matching

- Brute-Force
- FLANN (Fast Library for Approximate Nearest Neighbors)
  - Randomized kd-tree k-nn




```python
import cv2
import numpy as np

img1 = cv2.imread("ARmarker.png", cv2.IMREAD_GRAYSCALE)
ft = cv2.SIFT_create()
kp1, des1 = ft.detectAndCompute(img1, None)
cap = cv2.VideoCapture(0, cv2.CAP_DSHOW)

# FLANN parameters
index_params = dict(algorithm=1, trees=5)
search_params = dict(checks=50)
flann = cv2.FlannBasedMatcher(index_params, search_params)

while True:
    ret, img2 = cap.read()
    kp2, des2 = ft.detectAndCompute(img2, None)
    matches = flann.knnMatch(des1.astype(np.float32), des2.astype(np.float32), k=2)
    good = []
    for m, n in matches:
        if m.distance < 0.6*n.distance:
            good.append(m)
    matching_result = cv2.drawMatches(img1, kp1, img2, kp2, good[:50], None, flags=2)
    cv2.imshow("Matching result", matching_result)
    cv2.waitKey(1)
```

Ex: Augmented Reality

- Use SIFT for detect location and position of AR core
- Use FLANN for feature matching
- Use Perspective transformation for mapping an image onto the AR core

Object tracking

- Initial object location
- Find object in search space (lower than original space)

- Standard OpenCV 4.5.1:
  - MIL
  - GOTURN (CNN-based)
    - Pretrained: https://github.com/spmallick/goturn-files

Big challenge

- Create game recording for checker (Thai rule)
  - Create demonstration video and submit your video link