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I. Problem Statement

- Write a program which does thinning on a down-sampled image (lena.bmp).

II. Programming Tools

- Programming language: Python 3.8.5
- Library: Numpy 1.19.1, OpenCV 4.0.1

III. Problem-Solving Process

使用 cv2.imread('lena.bmp',0)讀取灰階影像，之後對影像作 binarize 再做 down sampling 得到(64,64)的 img，之後對影像作以下動作：

step1. 對 img 作 Yokoi Operator [4 connectivity]

step2. 由 step1 結果作 Pair Relationship Operator

Step3. 由 step2 結果與原先 img 作 Connected Shrink Operator

Step4. 比較與原先 img 是否有差異，有的話回到 step1，沒有的話輸出影像

```
img = cv2.imread('lena.bmp',0)
img = np.where(img>127, 255, 0).astype(np.uint8) # binarilize
img = img[::8,::8] # down sampling

out = cv2.VideoWriter('./output/video.avi',cv2.VideoWriter_fourcc('M','J','P','G'), 2, img.shape)

change = True
while change:
    change = False
    v = cv2.merge([img,img,img])
    out.write(v)
    img_Yokoi =  Yokoi_connectivity_number(img)
    img_pair = pair_relationship(img_Yokoi)
    img, change = connected_shrink(img, img_pair)

cv2.imwrite('./output/thinning.png', img)
out.release()
```

以下為 Pair Relationship Operator 與 Connected Shrink Operator 程式碼。

```
def H(a, m): # do after the yokoi
    return 1 if a == m else 0

def Y(x0, x1, x2, x3, x4, m = 1): # do after the yokoi
    sum_ = H(x1,m) + H(x2,m) + H(x3,m) + H(x4,m)
    return 'p' if sum_ > 0 and x0 == m else 'q'

def pair_relationship(img_Yokoi):
    img_padding = np.pad(img_Yokoi, ((1,1),(1,1)), 'constant',constant_values = (0,0))
    ret = np.full_like(img_Yokoi, ' ', dtype='<U1')
    for r in range(img_Yokoi.shape[0]):
        for c in range(img_Yokoi.shape[1]):
            ret[r,c] = Y(img_padding[r+1,c+1], img_padding[r+1,c+2], img_padding[r,c+1], img_padding[r+1,c], img_padding[r+2,c+1])
    return ret

def G(b,c,d,e):
    return 1 if b == c and (b != d or b != e) else 0

def connected_shrink(img, img_pair):

    img_padding = np.pad(img, ((2,2),(2,2)), 'constant',constant_values = (0,0))
    change = False
    for r in range(img_pair.shape[0]):
        for c in range(img_pair.shape[1]):
            if img_pair[r,c] != 'p':
                continue
            a1 = G(img_padding[r+2,c+2], img_padding[r+2,c+3], img_padding[r+1,c+3], img_padding[r+1,c+2])
            a2 = G(img_padding[r+2,c+2], img_padding[r+1,c+2], img_padding[r+1,c+1], img_padding[r+2,c+1])
            a3 = G(img_padding[r+2,c+2], img_padding[r+2,c+1], img_padding[r+3,c+1], img_padding[r+3,c+2])
            a4 = G(img_padding[r+2,c+2], img_padding[r+3,c+2], img_padding[r+3,c+3], img_padding[r+2,c+3])
            if a1 + a2 + a3 + a4 == 1:
                img_padding[r+2,c+2] = 0
                change = True

    return img_padding[2:-2,2:-2], change
```

IV. Results

zip 檔裡面有完整的動圖。