Programming for Engineers in Python

Recitation 10

Plan

- Image Processing:
  - Segmentation using Otsu threshold selection method
  - Morphological operators
    - Erosion
    - Dilation
  - Denoising

Image Processing in Python

- How to handle an image?
- The Python Imaging Library http://www.pythonware.com/products/pil/
- Example tutorial: http://www.geeks3d.com/20100930/tutorial-first-steps-with-pil-python-imaging-library
- The Image Module: http://www.pythonware.com/library/pil/handbook/image.htm
- Capacities:
  - Read / write images
  - Display image
  - Basic image processing

Binary Segmentation

- Goal – reduction of a gray level image to a binary image. Simple segmentation:

```
def segment(im, thrd = 128):
    width, height = im.size
    mat = im.load()
    out = Image.new('1',(width, height)) # '1' means black & white (no grays)
    out_pix = out.load()
    for x in range(width): # go over the image columns
        for y in range(height): # go over the image rows
            if mat[x, y] >= thrd: # compare to threshold
                out_pix[x, y] = 255
            else:
                out_pix[x, y] = 0
    return out
```

Binary Segmentation

Threshold = 50

Threshold = 128

Threshold = 200

Otsu Threshold

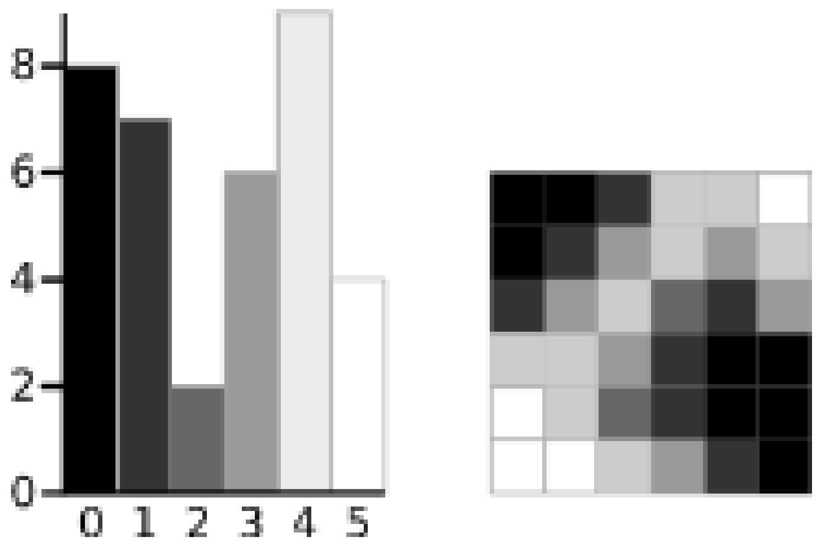
- The algorithm assumes that the image contains two classes of pixels - foreground and background.
- Finds an optimum threshold separating the classes by:
  - calculating the image histogram
  - separating these classes so that their intra-class variance is minimal.

Coming next: image histogram, intra-class variance

Image Histogram

Histogram of an image: a graphical representation of the colors distribution in an image.

- x-axis - represents the colors
- y-axis - the number of pixels with a particular color

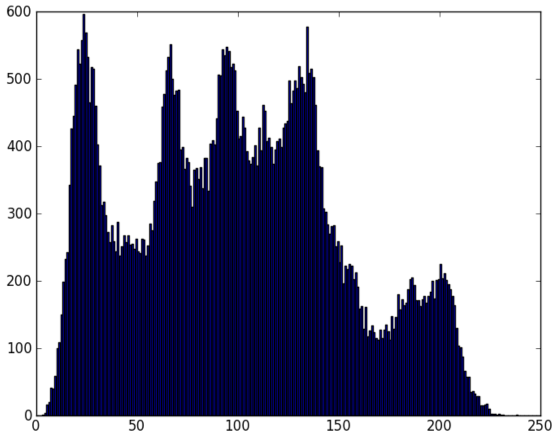


Gray-scale histogram

Image Histogram - Code

```
def histogram(im):
    pix =im.load()
    width, height = im.size
    hist = [0]*256

    for y in range(height):
        for x in range(width):
            gray_level= pix[x, y]
            hist[gray_level] = hist[gray_level]+1
    return hist
```

- Note: We use the gray level as the index of the histogram!

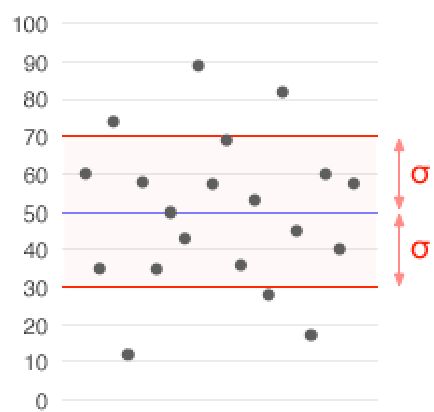


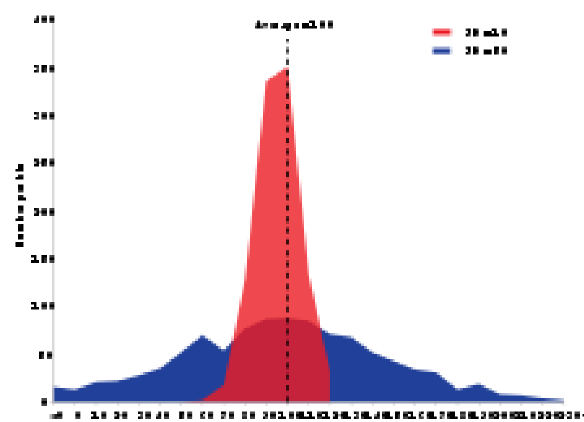
Class Variance

- Variance (σ^2)- a measure of how much a set of points is spread out, defined as the mean distance^2 from a point to the set's center.

A good threshold:

- Minimizes within-group variance = resemblance among class points.
- Maximizes between-group variance = separation between class centers.





Class Variance - formula

For some threshold t:

Background <= t, low gray levels

Foreground > t, high gray levels

mean_back – mean of the Background pixels

mean_fore – mean of the Foreground pixels

w_back – number of Background pixels

w_fore – number of Foreground pixels

var_between = w_back * w_fore * (mean_back - mean_fore)**2

The Otsu threshold is the threshold that maximizes the **var_between** over all possible thresholds.

Otsu threshold - Code

```
def otsu_thrd(im):
    hist = histogram(im)
    sum_all = 0
    # sum the values of all background pixels
    for t in range(256):
        sum_all += t * hist[t]

    sum_back, w_back, w_for, var_max, threshold =  0, 0, 0, 0, 0
    total = height*width
```

Otsu threshold - Code

```
# go over all possible thresholds
for t in range(256):
  # update weights
   w_back += hist_data[t]
    if (w_back == 0):      continue
   w_fore = total - w_back
   if (w_fore == 0) :      break
  # calculate classes means
   sum_back += t * hist_data[t]
   mean_back = sum_back / w_back
   mean_fore = (sum_all - sum_back) / w_fore
   # Calculate Between Class Variance
   var_between = w_back * w_fore * (mean_back - mean_fore)**2
```

```
   # a new maximum is found?
   if (var_between > var_max):
     var_max = var_between
     threshold = t

return threshold
```

Otsu threshold - Run

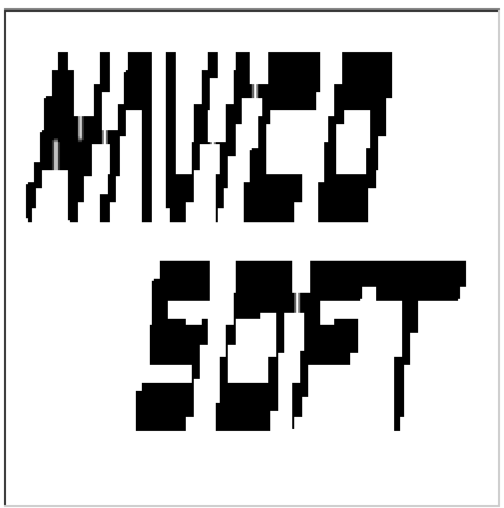
```
>>> im = Image.open('lena.bmp')
>>> th = otsu_thrd(im)
>>> th
97
>>> out_im = segment(im, th)
>>> out_im.show()
```

Otsu threshold - Run

Threshold = 149

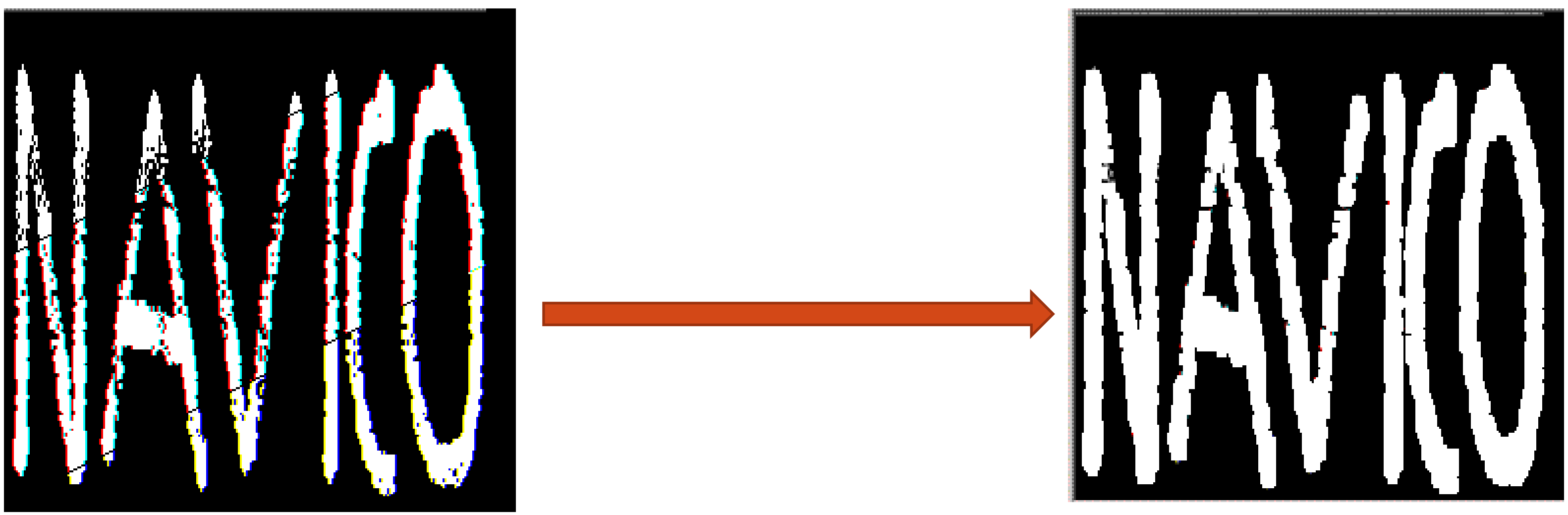
Morphological Operators

- **Morphology** is a technique for the analysis and processing of geometrical structures
- Erosion of the binary image *A* – erode away the boundaries of regions of forground pixels (white pixels), such that areas of forground pixels shrink, and holes grow.



Morphological Operators

- Dilation - enlarge the boundaries of regions of forground pixels, such that areas of forground pixels grow and holes shrink.



Morphological Operators - Code

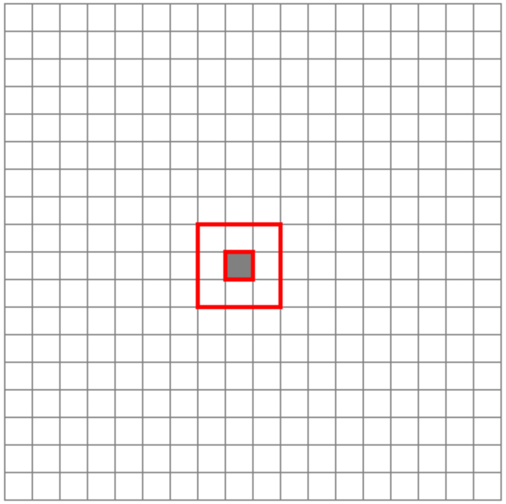
Framework:

```
def morphological(im, operator = min, nx = 5, ny = 5):
    width, height = im.size
    out_im = Image.new('L',(width, height), 'white')
    in_pix = im.load()
    out_pix = out_im.load()

    for y in range(height):
        for x in range(width):
            nlst = neighbours(in_pix, width, height, x, y, nx, ny)
            out_pix[x, y] = operator(nlst)
    return out_im
```

Morphological Operators - Code

Create a pixel's environment:

```
def neighbours(pix,  width, height, x, y, nx=1, ny=1):
    nlst = []
    for yy in range(max(y-ny, 0), min(y+ny+1, height)):
        for xx in range(max(x-nx, 0), min(x+nx+1, width)):
            nlst.append(pix[xx, yy])
    return nlst
```



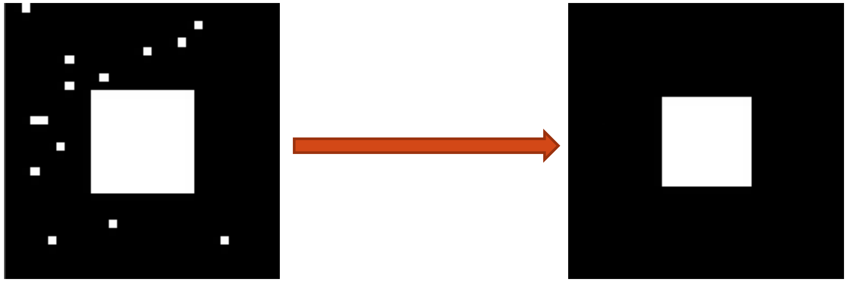
Morphological Operators - Code

Erosion and dilation:

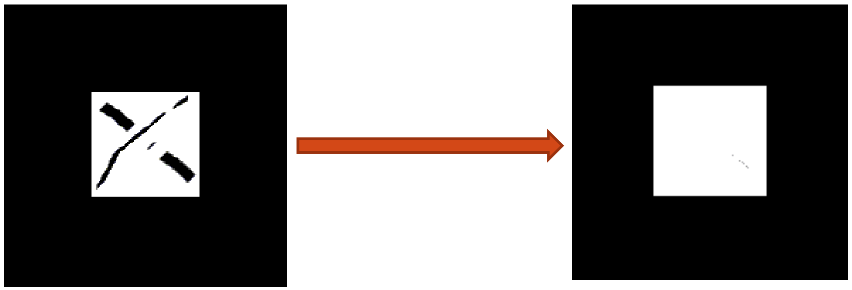
```
def erosion(im, nx = 5, ny = 5):
    return morphological(im, min, nx, ny)

def dilation(im, nx = 5, ny = 5):
    return morphological(im, max, nx, ny)
```

Morphological Operators - Run

```
im = Image.open('square1.bmp')
out = erosion(im)
out.show()
```



```
Image.open('square4.bmp')
out = dilation(im)
out.show()
```



Dilation for Edge Detection

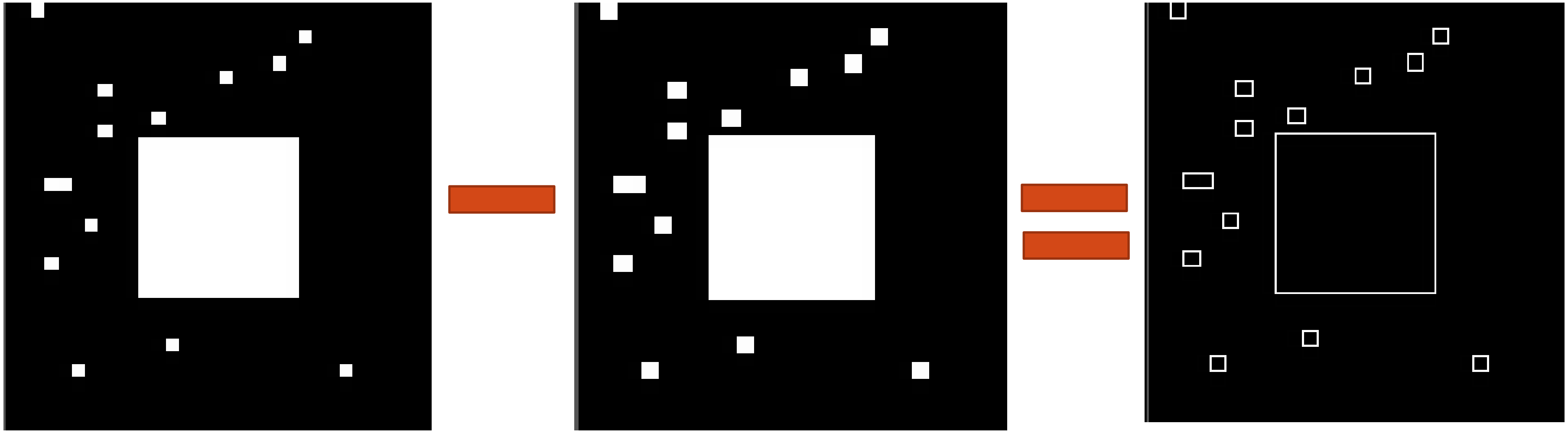
```
# find the differences between two images
def diff(im1, im2):
    out = Image.new('L', im1.size, 'white')
    out_pix = out.load()
    p1 = im1.load()
    p2 = im2.load()
    width, height = im1.size

    for x in range(width):
        for y in range(height):
            out_pix[x, y] = abs(p1[x, y] - p2[x, y])

    return out
```

Dilation for Edge Detection

im1 = Image.open('square1.bmp')

im2 = dilation(im, 1, 1)

edges = diff(im, im2)



Denoising

- We want to "clean" these pictures from noise:

Suggestions?

Denoising - Mean

- Take 1: Smoothing

Use the morphological framework with *mean*:

```
def mean(lst):
    return sum(lst)/float(len(lst))
def denoise_mean(im, nx = 5, ny = 5):
    return morphological(im, mean, nx, ny)
```

Denoising - Median

- Take 2: Median

```
def median(lst, min_val = 0, max_val = 255):
    lst.sort()
    return lst[len(lst)/2]
def denoise_median(im, nx = 5, ny = 5):
    return morphological(im, median, nx, ny)
```

Denoising - Median

- Can we do better?
- Idea – the ‘salt’ is (almost) white, the ‘pepper’ is (almost) black.

We can change very bright or very dark pixels only!

To calculate the median, we will use only neighboring pixels that are not close to the pixel we change.

→The noisy pixels surrounded by ‘normal’ pixels will be fixed.

→Continue iteratively

Denoising – Bounded Median

```
def median(lst, min_val = 0, max_val = 255):
    lst.sort()
    new_lst = [i for i in lst if (i >= min_val and i <= max_val)]
    if new_lst:
        return new_lst[len(new_lst)/2]
    else:
        return lst[len(lst)/2]
```

```
def fix_white(lst, k = 200):
    center = len(lst)/2
    if lst[center] > k:
        return median(lst, max_val = k)
    else:
        return lst[center]

def fix_black(lst, b = 50):
    center = len(lst)/2
    if lst[center] < b:
        return median(lst, min_val = b)
    else:
        return lst[center]
```

Denoising – Bounded Median

```
def denoise_bounded_median(im, nx = 3, ny = 3):
    for i in range(3):
        im = morphological(im, fix_white, nx, ny)
        im = morphological(im, fix_black, nx, ny)
    return im
```

Denoising – Bounded Median