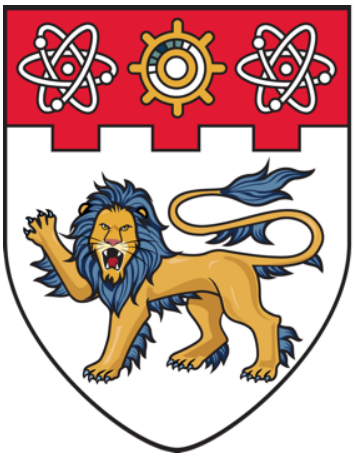

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REPORT

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Contents

1 Introduction

With the proliferation of digital text sources in recent decades, such as the Internet and the mobile phone, there is a increasing need for document image processing and optical character recognition (OCR). However, many of the original document images are distorted due to noise, under exposure, or motion blur. Because of the different types of degradation in different images, each category of them has to be treated separately. This report mainly explains the procedures applied on the given sample images, as well as the source code of the process algorithms.

2 Procedure And Algorithm

In this project, most of the algorithms are implemented by Python, while there is still one image's process requiring to use Matlab function through Matlab Python API. To binarize a color image, the first step is changing the color map from 'RGB' to 'Gray Level'. In Python, 'pillow' is one of the basic image processing libraries and is what I used for image reading and color map converting. According to 'pillow' documentation, when translating a color image to black and white, the library uses the ITU-R 601-2 luma transform:

$$L = 0.299 * R + 0.587 * G + 0.114 * B$$

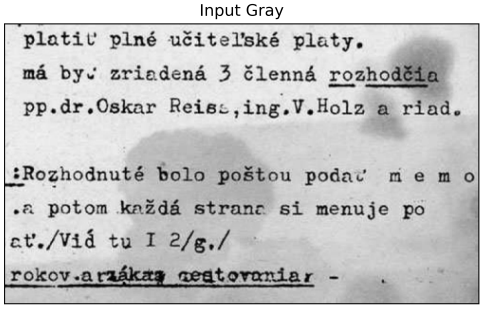
Image 1, 2, 3 have relatively high contrast between its text and background and hence can use the same way to process. In this project, I choose n-bit slicing to extract the most significant bit of gray level for each pixel. Note that 'im_{np}' is a 'numpy' array to store gray level value of images.

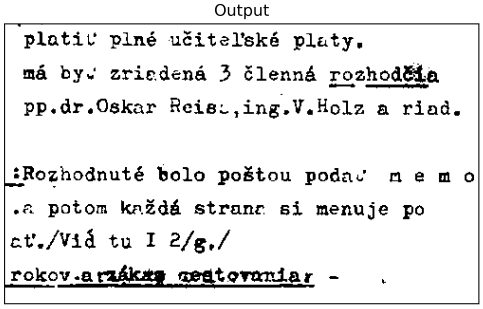
```
# Image 1, 2, 3
im_final = pp.n_bit_plane_slice(im_original_gray, 1)
```

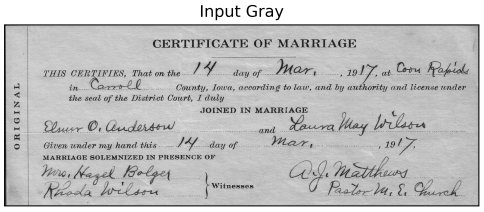
List 1: Setting For Image 1, 2, 3

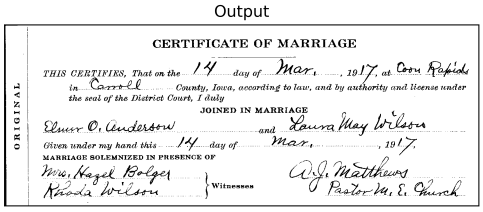
```
def n_bit_plane_slice(im_np, b=1):
    new_im = np.zeros(im_np.shape)
    im_height, im_width = im_np.shape
    for x in range(im_height):
        for y in range(im_width):
            i_n = im_np[x, y] // (2 ** (8 - b))
            i_n_1 = im_np[x, y] // (2 ** (9 - b))
            new_im[x, y] = (i_n - i_n_1 * 2) * 255
    return new_im.astype(np.uint8)
```

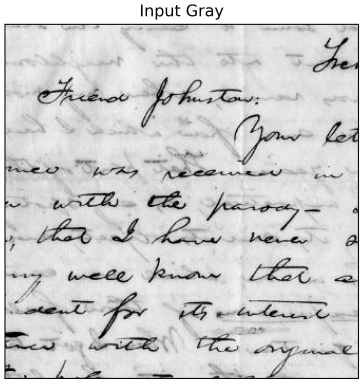
List 2: N-Bit Slicing











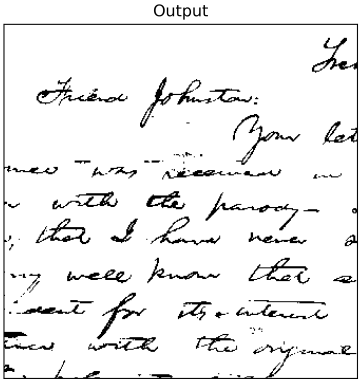


Image 4 and 5 have strong shadow on them, hence it becomes difficult for global threshold. However a local threshold using Otsu's method can improve the processed image's quality significantly. Before applying threshold, alpha-trimmed mean filter is used to remove noise and smooth the image. The local Otsu's threshold method is implemented in the 'skimage.filters.rank' library. As shown in the list below, the 'rad' variable specifies the window size of the local Otsu's threshold. One limitation of the local Otsu's threshold is that it causes black spot at output. With larger window size, this effect can be partly eliminated. However, the text resolution will also decrease. To solve this problem, it can be applied a mask like that of Image 9. Unfortunately the line mask does not work for Image 4 and 5 which have strong shadow.

```
# Image 4, 5
im_step_1 = alpha_trimmed_mean(im_original_gray, window_size=3, alpha=2)
im_final = otsu_threshold(im_step_1.astype(np.uint8), 100)
```

List 3: Setting For Image 4, 5

```
def alpha_trimmed_mean(im_np, window_size=3, alpha=2):
    pad_length = window_size // 2
    im_np_pad = np.pad(im_np, (pad_length,), 'edge')
    im_height, im_width = np.shape(im_np_pad)
    im_new = np.zeros(np.shape(im_np))
    for m in range(pad_length, im_height - pad_length):
        for n in range(pad_length, im_width - pad_length):
            window_elements = im_np_pad[m-pad_length:m+pad_length+1, n-pad_length:n+pad_length+1]
```

```
            ordered_elements = np.sort(window_elements, axis=None)
            im_new[m-pad_length, n-pad_length] = np.mean(
                ordered_elements[int(alpha/2):int(-(alpha/2))]).astype(np.uint8)
    return im_new
```

List 4: Alpha-Trimmed Mean Filtering

```
def otsu_threshold(im_np, rad):
  local_otsu = otsu(im_np, disk(rad))
  thresh_image = im_np >= local_otsu
  return np.uint8(thresh_image*255)
```

List 5: Local Otsu's Threshold

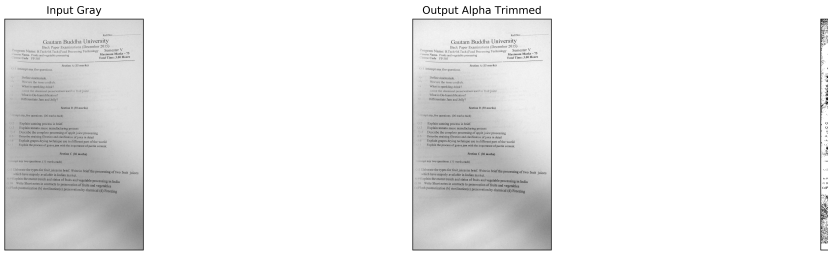


Image 6 and 7 can be processed by global threshold method. One way to implement the global threshold is k-means algorithm. However, it is better to use Lloyd algorithm to find the threshold value because the complexity of k-means algorithm is very high. To find the global threshold value through Lloyd algorithm, one can simply set the number of level equal to 2.

```
# Image 6, 7
level = 2
# 1. k-means method
# thresh = mf.k_means_thresh(im_original_gray, level)
# t = np.pad(np.uint8(thresh), (1,), 'constant', constant_values=(0, 255))
# 2. Lloyd method
t = pp.lloyd_quantize(im_original_gray, level)
im_final = pp.gray_level_window_slice(im_original_gray, t, [0, 255])
```

List 6: Setting For Image 6, 7

```
def lloyd_quantize(im_np, level=2):
    pix_count = collections.Counter(np.ravel(im_np))
```

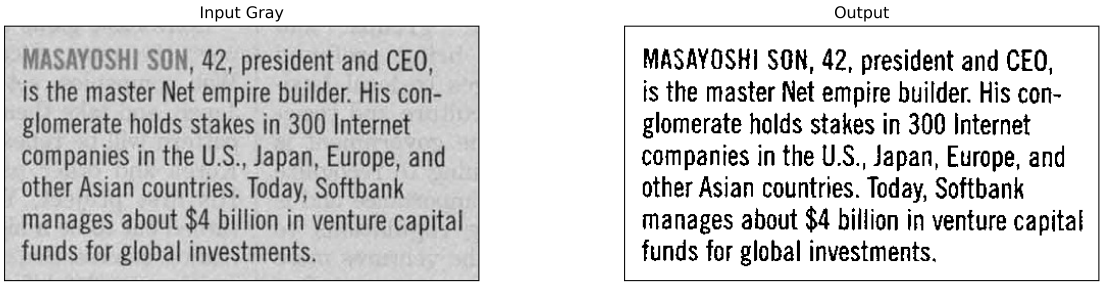
```
    pix_count_total = len(np.ravel(im_np))
    t = np.zeros([level+1])
    r = np.zeros([level])
    # Initialize t with even gray-level distribution
    for k in range(level+1):
        t[k] = k / level * 255
    while True:
        check_done = True
        for k in range(level):
            r_num = 0
            r_den = 0
            for f in range(t[k].astype(np.uint8), t[k+1].astype(np.uint8)+1):
                pf = pix_count[f] / pix_count_total
                r_num += f * pf
                r_den += pf
            r[k] = r_num / r_den
        for k in range(1, level):
            temp = round((r[k] + r[k-1]) / 2)
            if temp != t[k]:
                t[k] = temp
                check_done = False
        if check_done is True:
            break
    return t.astype(np.uint8)
```

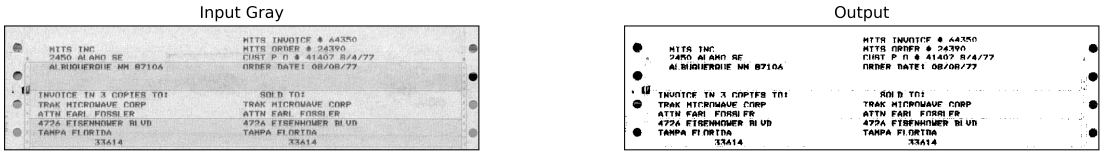
List 7: Lloyd Algorithm For Global Threshold Implementation

```
def k_means_thresh(im_np, cluster=2):
    # centroid[current centroid value:sum:count]
    centroid = np.zeros([cluster, 3])
    for k in range(cluster):
        centroid[k, 0] = (k + .5) / cluster * 255
    im_height, im_width = im_np.shape
    while True:
        check_done = True
        for m in range(im_height):
            for n in range(im_width):
                min_dist = 99999
                cent_count = 0
                target_cent = 0
                for c in range(cluster):
                    distance = abs(im_np[m,n] - centroid[c, 0])
                    if distance < min_dist:
                        min_dist = distance
                        target_cent = cent_count
                    cent_count += 1
                centroid[target_cent, 1] += im_np[m,n]
                centroid[target_cent, 2] += 1
        for c in range(cluster):
            new_cent = centroid[c, 1] / centroid[c, 2]
            if abs(centroid[c, 0] - new_cent) >= 1:
                centroid[c, 0] = new_cent
                centroid[c, 1] = 0
                centroid[c, 2] = 0
```

```
            check_done = False
    if check_done:
        break
thresh = np.zeros([cluster - 1])
for c in range(1, cluster):
    thresh[c - 1] = (centroid[c - 1, 0] + centroid[c, 0]) / 2
return thresh
```

List 8: K-means Algorithm For Global Threshold Implementation





For image 8, after trying several different methods, finally it turns out the global threshold performing better. Because of the blurred text and un-even contrast distribution, it is difficult to apply global threshold directly. Firstly, the image should be resized to 4 times larger than the original size.

```
# Image 8
im_step_1 = imresize(im_original_gray, (im_original_gray.shape[0] * 4, im_original_gray.shape[1] * 4))
level = 2
t = pp.lloyd_quantize(im_step_1, level)
im_final = pp.gray_level_window_slice(im_step_1, t, [0, 255])
```

List 9: Setting For Image 8

Image 9 uses the way which is similar to that of image 4 and 5. Before Otsu's threshold, Matlab function 'stretchlim' and 'imadjust' need to be applied for contrast stretching. The 'rad' value of the Otsu's threshold function has to be set to 30 due to the noise on the image. However, a smaller window size can cause much more black spot on the output. One way to eliminate these black spot is applying a mask of the line of text. The mask is generated by line detection method. Firstly, I applied n-bit slicing on the original image. Next, a line detection kernel can be applied on the image to get the text line position.

```
# Image 9
mat = matlab_func.MatlabFunction()
im_step_1 = mat.contrast_stretch(im_original_gray)
im_step_2 = mf.otsu_threshold(im_step_1, 30)
im_final = mf.line_mask(im_step_2, im_original_gray)
```

List 10: Setting For Image 9

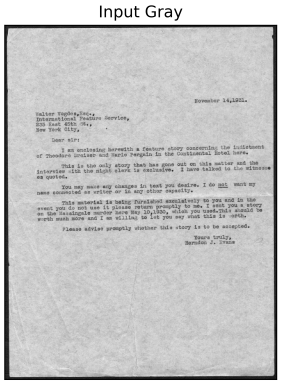
```
def contrast_stretch(self, im_np):
    im_mat = matlab.double(im_np.tolist())
    img = self.eng.mat2gray(im_mat)
    low_high = self.eng.stretchlim(img)
    out = self.eng.imadjust(img, low_high, [])
    out_np = self.mat2np(out) * 255.
    return out_np.astype(np.uint8)

def mat2np(self, in_array):
    out_array = []
    for _ in range(in_array.size[0]):
        lst = in_array._data[_::in_array.size[0]].tolist()
        out_array.append(lst)
    out_np = np.array(out_array)
    return out_np
```

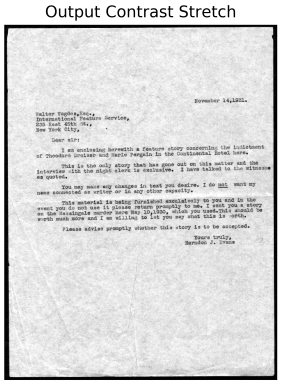
List 11: Constrast Stretching

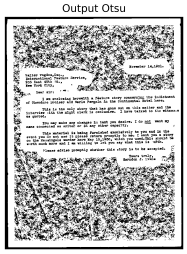
```
def line_detector(im_np, direction='|'):
    line_h = np.array([[-1,-1,-1],
                       [2,2,2],
                       [-1,-1,-1]])
    line_v = np.transpose(line_h)
    line_45p = np.array([[2,-1,-1],
                         [-1,2,-1],
                         [-1,-1,2]])
    line_45n = np.array([[-1,-1,2],
                         [-1,2,-1],
```

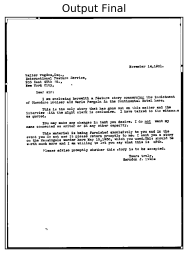
```
                    [2,-1,-1]])
    if direction == '-':
        im_out = signal.convolve2d(im_np, line_h)
    elif direction == '|':
        im_out = signal.convolve2d(im_np, line_v)
    elif direction == '+':
        g_h = signal.convolve2d(im_np,line_h)
        g_v = signal.convolve2d(im_np,line_v)
        im_out = np.sqrt(g_h**2 + g_v**2)
    elif direction == '/':
        im_out = signal.convolve2d(im_np, line_45p)
    elif direction == '\\':
        im_out = signal.convolve2d(im_np, line_45n)
    elif direction == 'X' or 'x':
        g_h = signal.convolve2d(im_np,line_45p)
        g_v = signal.convolve2d(im_np,line_45n)
        im_out = np.sqrt(g_h**2 + g_v**2)
    elif direction == '*':
        g_h = signal.convolve2d(im_np,line_h)
        g_v = signal.convolve2d(im_np,line_v)
        s_h = signal.convolve2d(im_np,line_45p)
        s_v = signal.convolve2d(im_np,line_45n)
        im_out = np.sqrt(g_h**2 + g_v**2 + s_h**2 + s_v**2)
    return im_out[1:-1, 1:-1]

def line_mask(im_np, im_np_original, window=4, eta=2):
    def _generate_mask():
        im_np_sliced = pp.n_bit_plane_slice(im_np_original, 1)
        im_mask = np.uint8(line_detector(im_np_sliced, direction='+'))
        im_height, im_width = im_mask.shape
        thresh = eta * 255 / ((window * 2) ** 2)
        for m in range(window, im_height-window, window*2):
            for n in range(window, im_width-window, window*2):
                if np.mean(im_mask[m-window:m+window, n-window:n+window].flatten()) > thresh:
                    im_mask[m-window:m+window, n-window:n+window] = 255
        return im_mask
    mask = _generate_mask()
    new_im_np = np.copy(im_np)
    im_height, im_width = new_im_np.shape
    for m in range(im_height):
        for n in range(im_width):
            if mask[m, n] == 0:
                new_im_np[m, n] = 255
    return new_im_np
```

List 12: Masked Image









3 Conclusion

In summary, the processed images have better resolution for OCR, even though some small block of text area failed the test. After experimenting different methods, what I found is that n-bit slicing can handle most of the high contrast images. Local Otsu's threshold can eliminate shadow on image, however it also bring some side effect like the black spot. Global threshold has result similar to that of n-bit slicing but perform better on low illumination image.

References

[1] GitHub (2017) Pillow [online] Available at: http://pillow.readthedocs.io/en/4.3.x/index.html

[2] GitHub (2017) Scikit-Image [online] Available at: http://scikit-image.org/docs/dev/

[3] MathWorks (2017) MATLAB API for Python
[online] Available at: https://www.mathworks.com/help/matlab/matlab-engine-for-python.html

Appendices

Souce Code Link https://github.com/seanhxx/schoolwork/tree/master/ee4476-imp/assign1
Images Link https://github.com/seanhxx/schoolwork/tree/master/ee4476-imp/assign1/export