HW04

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1 Computer Vision - HW04 - 98722278

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1.1 1 Implementation of Canny Edge Detector

1. Gaussian Noise
2. Gradient Intensification
3. Non-Max Suppression
4. Thresholding

```
In [1]: import cv2
        import numpy as np
        from scipy import ndimage
        from PIL import Image

        import matplotlib.pyplot as plt

        import time
        %matplotlib inline
```

```
In [2]: def open_image(path):
            """
            Open an image using PIL library
```

```
            :param path: path to image file-like
            :return: PIL image object
            """
            image = Image.open(path)
            return image
```

In [3]:
```
def show_image(image, cmap='gray'):
    """
    Show PIL image or numpy image in default viewer of OS

    :param image: image data
    :param cmap: color map of input numpy array
    :return: None
    """
    if str(type(image)).__contains__('PIL'):
        image.show()
    elif str(type(image)).__contains__('numpy'):
        if cmap=='gray':
            Image.fromarray(np.uint8(image), mode='L').show()
        elif cmap == 'bw':
            size = image.shape[::-1]
            data_bytes = np.packbits(image, axis=1)
            Image.frombytes(mode='1', size=size, data=data_bytes).show()
        else:
            raise ValueError('color map is invalid.')
    else:
        raise ValueError('Input t is not valid.')
```

In [4]:
```
class ToGrayscale:
    """
    Get and PIL image or numpy n-dim array as image and convert it to grayscale image
    """

    def __init__(self):
        pass

    def __call__(self, image):
        """
        Get and PIL image or numpy n-dim array as image and convert it to grayscale im

        :param image: input image data
        :return: Grayscale image of input type
        """
        if str(type(image)).__contains__('PIL'):
            image = image.convert('L')
        elif str(type(image)).__contains__('numpy'):
            image = np.dot(image[..., :3], [0.2989, 0.5870, 0.1140])
```

```
            else:
                raise ValueError('Input type is not valid.')
            return image
```

1.1.1 1.A Gaussian Noise

```
In [5]: class GaussianNoise:
            def __init__(self, size=5, std=1):
                self.size = size
                self.std = std

            def _gaussian(self, r2):
                """
                Sample one instance from gaussian distribution regarding
                given squared-distance:r2, standard-deviation:std and general-constant:k

                :param r: squared distance from center of gaussian distribution
                :param std: standard deviation

                :return: A sampled number obtained from gaussian
                """
                return np.exp(-r2/(2.*self.std**2)) / (2.*np.pi*self.std**2)

            def _gaussian_kernel(self):
                """
                Creates a gaussian kernel regarding given size and std.
                Note that to define interval with respect to the size,
                I used linear space sampling which may has
                lower accuracy from renowned libraries.

                :param std: standard deviation value
                :param size: size of the output kernel
                :return: A gaussian kernel with size of (size*size)
                """
                self.size = int(self.size) // 2
                x, y = np.mgrid[-self.size:self.size+1, -self.size:self.size+1]
                distance = x**2+ y**2
                kernel = self._gaussian(r2=distance)
                return kernel

            def __call__(self, image):
                """
                Applies gaussian noise on the given image

                :param image: Input image in grayscale mode numpy ndarray or cv2 image
                :param size: Size of the gaussian kernel
                :param std: Standard deviation value for gaussian kernel
                """
```

```
            return ndimage.convolve(image, self._gaussian_kernel())
```

In [9]:
```
image = cv2.imread('images/cameraman.jpg', cv2.IMREAD_GRAYSCALE)
gaussian_noise = GaussianNoise()
image_blurred = gaussian_noise(image)

# plotting
fig, ax = plt.subplots(nrows=1, ncols=2, figsize=(20, 15))
ax[0].set_title('original')
ax[1].set_title('blurred')
ax[0].imshow(image, cmap='gray')
ax[1].imshow(image_blurred, cmap='gray')
```

Out[9]:
```
<matplotlib.image.AxesImage at 0x17c7aad22e8>
```

1.1.2 1.B Gradient Intensity

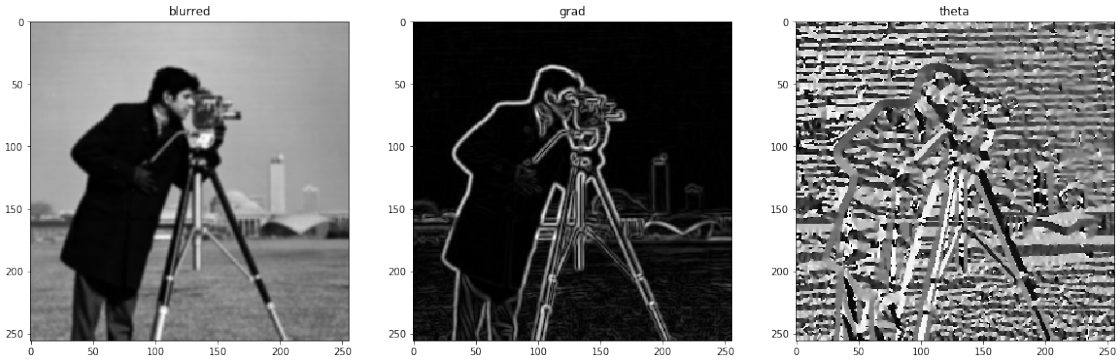
In [6]:
```
class GradientIntensity:
    """
    We use Sobel filters to convolve over image (numpy ndarray) to calculate gradient
    horizontal and vertical directions. Finally returns magnitude G and slope theta as

    G = sqrt(Ix^2 + Iy^2)

    theta = arctan(Ix/Iy)

    We use these Sobel filters as default:

    Kx =
```

```
        [[-1 0 1],
        [-2 0 2],
        [-1 0 1]]

        Ky =
        [[1 2 1],
        [0 0 0],
        [-1 -2 -1]]

        """

        def __init__(self, hf=None, vf=None, init=True):
            """
            Initialize filters

            :param hf: Horizontal filter matrix -> numpy ndarray
            :param vf: Vertical filter matrix -> numpy ndarray
            :param init: whether initialize Sobel filters or initialize using user provide
            """

            if not init:
                self.hf = hf
                self.vf = vf
            else:
                self.hf = np.array(
                    [[-1, 0, 1],
                     [-2, 0, 2],
                     [-1, 0, 1]])

                self.vf = np.array(
                    [[1, 2, 1],
                     [0, 0, 0],
                     [-1, -2, -1]])

        def __call__(self, x):
            if not str(type(x)).__contains__('numpy'):
                raise ValueError('Invalid input. Please provide numpy ndarray image.')
            Ix = ndimage.filters.convolve(x, self.hf)
            Iy = ndimage.filters.convolve(x, self.vf)

            G = np.sqrt(np.power(Ix, 2)  + np.power(Iy, 2))
            G = G / G.max() * 255
            theta = np.arctan2(Iy, Ix)

            return G, theta
```

In [11]:
```
to_grayscale = ToGrayscale()
image = np.array(to_grayscale(open_image('images/cameraman.jpg')), dtype=float)  # th
```

```
gaussian_noise = GaussianNoise()
image_blurred = gaussian_noise(image)
gradient_intensity = GradientIntensity()
image_grad, image_theta = gradient_intensity(image_blurred)

# plotting
fig, ax = plt.subplots(nrows=1, ncols=3, figsize=(20, 15))
ax[0].set_title('blurred')
ax[1].set_title('grad')
ax[2].set_title('theta')
ax[0].imshow(image_blurred, cmap='gray')
ax[1].imshow(image_grad, cmap='gray')
ax[2].imshow(image_theta, cmap='gray')
```

Out[11]: <matplotlib.image.AxesImage at 0x17c7ac28550>



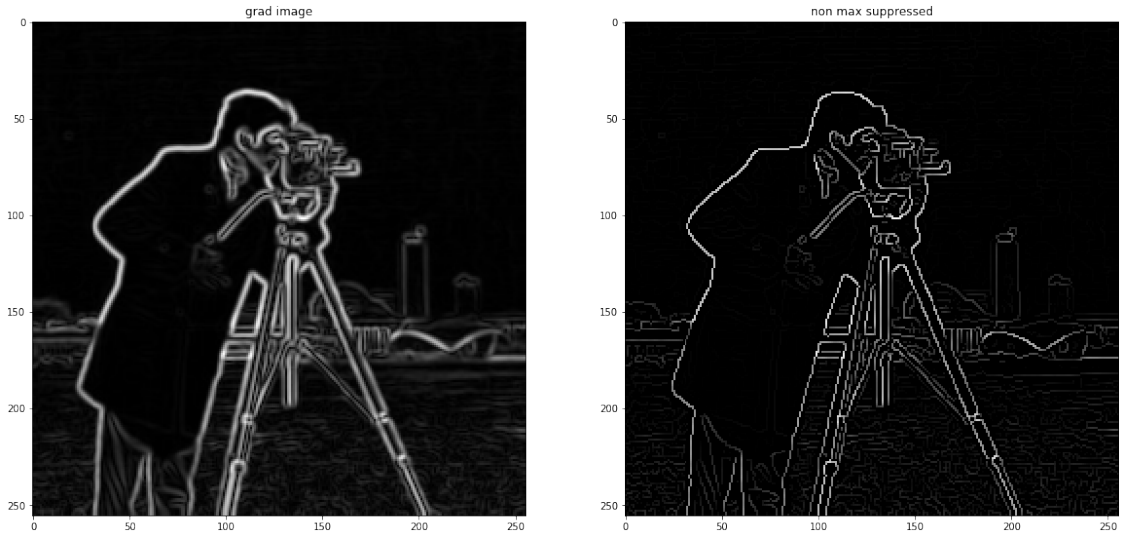
1.1.3 1.C Non-Max Suppression

In [7]:
```
class NonMaxSuppression:
    """
    Get gradient of image w.r.t the filters and degree of gradients (theta) and keep
    most intensified pixel in each direction.
    Note: d_prime = d-180
    """

    def __init__(self):
        pass

    def __call__(self, grad_img, grad_dir):
        """
        Get non-max suppressed image by preserving most intensified pixels

        :param grad_img: Gradient image gathered by convolving filters on original ima
        :param grad_dir: Gradient directions gathered by convolving filters on origina
```

```
            :return: Soft-edge numpy ndarray image
            """

            z = np.zeros(shape=grad_img.shape, dtype=np.int32)

            for h in range(grad_img.shape[0]):
                for v in range(grad_img.shape[1]):
                    degree = self.__angle__(grad_dir[h][v])

                    try:
                        if degree == 0:
                            if grad_img[h][v] >= grad_img[h][v - 1] and grad_img[h][v] >= g
                                z[h][v] = grad_img[h][v]
                        elif degree == 45:
                            if grad_img[h][v] >= grad_img[h - 1][v + 1] and grad_img[h][v]
                                z[h][v] = grad_img[h][v]
                        elif degree == 90:
                            if grad_img[h][v] >= grad_img[h - 1][v] and grad_img[h][v] >= g
                                z[h][v] = grad_img[h][v]
                        elif degree == 135:
                            if grad_img[h][v] >= grad_img[h - 1][v - 1] and grad_img[h][v]
                                z[h][v] = grad_img[h][v]
                    except IndexError as exc:
                        # Handle boundary index errors
                        pass
            return z

        @staticmethod
        def __angle__(a):
            """
            Convert gradient directions in radian to 4 possible direction in degree system

            :param a: Radian value of gradient direction numpy ndarray matrix
            :return: A int within {0, 45, 90, 135}
            """
            angle = np.rad2deg(a) % 180
            if (0 <= angle < 22.5) or (157.5 <= angle < 180):
                angle = 0
            elif 22.5 <= angle < 67.5:
                angle = 45
            elif 67.5 <= angle < 112.5:
                angle = 90
            elif 112.5 <= angle < 157.5:
                angle = 135
            return angle
```

In [21]:
```
non_max_suppression = NonMaxSuppression()
image_non_max = non_max_suppression(image_grad, image_theta)
```

```
# plotting
fig, ax = plt.subplots(nrows=1, ncols=2, figsize=(20, 15))
ax[0].imshow(image_grad, cmap='gray')
ax[1].imshow(image_non_max, cmap='gray')
ax[0].set_title('grad image')
ax[1].set_title('non max suppressed')
plt.show()
```

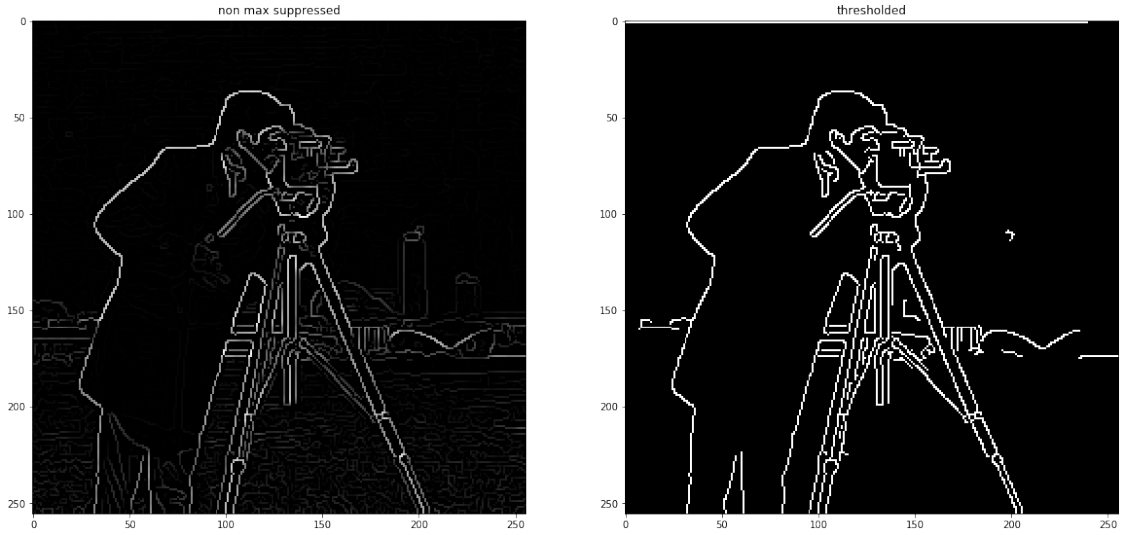


1.1.4 1.D Thresholding

```
In [8]: class Thresholding:
            def __init__(self, high_threshold = 90, low_threshold = 30):
                self.high_threshold = high_threshold
                self.low_threshold = low_threshold
                self.weak = 29
                self.strong = 255
                self.flag = self.weak*9

            def _threshold_image(self, image):
                thresholded = np.empty(image.shape)
                thresholded[np.where(image>self.high_threshold)] = self.strong
                thresholded[np.where(((image>self.low_threshold) & (image<=self.high_threshold)
                return thresholded

            def __call__(self, image):
                thresholded = self._threshold_image(image)
                for i in range(thresholded.shape[0]):
                    for j in range(thresholded.shape[1]):
```

```
                    if thresholded[i, j] == self.weak:
                        if np.sum(thresholded[i-1:i+2, j-1:j+2]) > self.flag:
                            thresholded[i ,j] = self.strong
                        else:
                            thresholded[i ,j] = 0
            return thresholded
```

In [32]:
```
thresholding = Thresholding()
thresholded = thresholding(image_non_max)

# plotting
fig, ax = plt.subplots(nrows=1, ncols=2, figsize=(20, 15))
ax[0].imshow(image_non_max, cmap='gray')
ax[1].imshow(thresholded, cmap='gray')
ax[0].set_title('non max suppressed')
ax[1].set_title('thresholded')

plt.show()
```



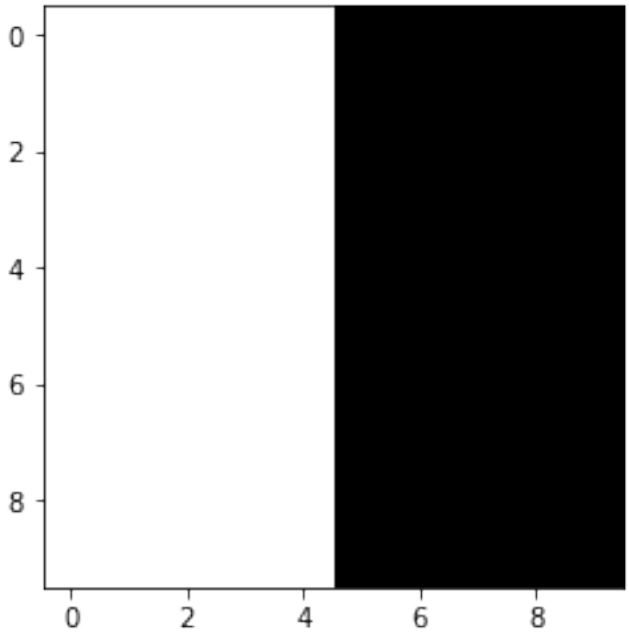
In [26]:
```
image = cv2.imread('images/cameraman.jpg', 0).astype(float)
image_blurred = GaussianNoise()(image)
image_grad, image_theta = GradientIntensity()(image_blurred)
image_suppressed = NonMaxSuppression()(image_grad, image_theta)
image_final = Thresholding()(image_suppressed)

# plotting
fig, ax = plt.subplots(nrows=1, ncols=2, figsize=(20, 15))
ax[0].imshow(image, cmap='gray')
ax[1].imshow(image_final, cmap='gray')
```

```
ax[0].set_title('input')
ax[1].set_title('canny edges')

plt.show()
```

1.2 2 Straight Line Detector

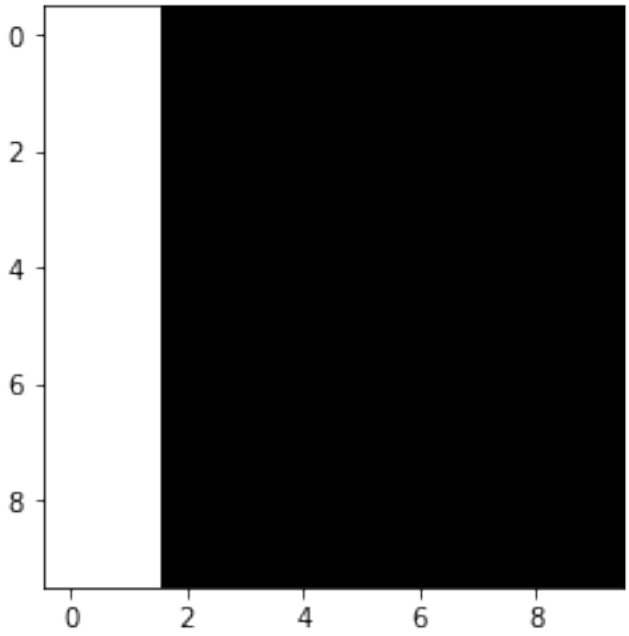
1. Assign each edge to a direction
2. Getting edgelets using connected components
3. Compute straightness and theta
4. Threshold
5. Test

```
In [52]: image = np.ones((10, 10), dtype=np.float) * 255
         image[:, 5:] = 0
         plt.imshow(image, cmap='gray')
         image_blurred = GaussianNoise()(image)
         image_grad, image_theta = GradientIntensity()(image_blurred)
         image_suppressed = NonMaxSuppression()(image_grad, image_theta)
         image_final = Thresholding()(image_suppressed)
         image_final[image_final <= 0] = 0
         image_final[image_final > 0] = 255
         image_final = image_final.astype(np.uint8)
```



1.2.1 2.A Assign each edge to a direction

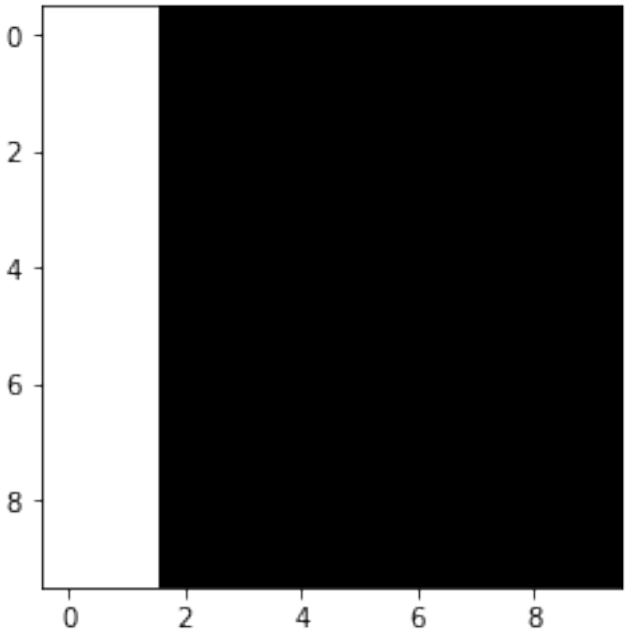
```
In [53]: def assign_direction(grad_directions):
             """
             Assign each gradian direction to one of 4 discrete values

             :param grad_directions: theta values of gradients of canny edge detector
             :return: Directions using degrees only in 4 discrete values
             """
             angle = np.rad2deg(grad_directions) % 180
             angle[np.logical_or(np.logical_and(angle < 22.5, 0 <= angle),
                                 np.logical_and(angle <= 180, 157.5 <= angle))] = 0
             angle[np.logical_and(angle < 67.5, 22.5 <= angle)] = 45
             angle[np.logical_and(angle < 112.5, 67.5 <= angle)] = 90
             angle[np.logical_and(angle < 157.5, 112.5 <= angle)] = 135
             return angle.astype(np.uint8)
         directions = assign_direction(image_theta)
         plt.imshow(directions, cmap='gray')

Out[53]: <matplotlib.image.AxesImage at 0x1c5e325ebe0>
```



1.2.2 2.B Getting edgelets using connected components

In [54]:
```
from scipy.ndimage import measurements

ANGLES = [0, 45, 90, 135]

def get_connected_components(directions, angles):
    """
    Computes connected components of each direction in angles

    :param direction: Direction of gradients matrix
    :param angles: possible angles of given direction matrix
    """
    structure = np.array([[0,1,0], [1,1,1], [0,1,0]])  # + form connected components
    connected_components = {}
    for a in ANGLES:
        connected_components[str(a)] = measurements.label((directions == a)*1)[0]
    return connected_components

connected_components = get_connected_components(directions, ANGLES)
plt.imshow(connected_components['90'], cmap='gray')
```

Out[54]:
```
<matplotlib.image.AxesImage at 0x1c5e32b28d0>
```



1.2.3 2.C Compute straightness and theta

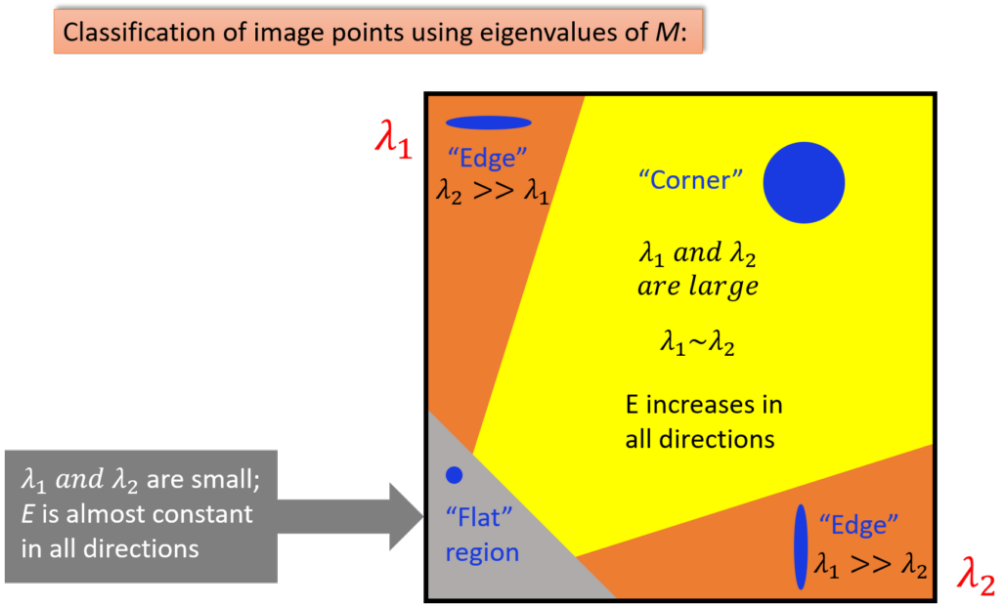
```
In [55]: def raw_moment(data, iord, jord):
             nrows, ncols = data.shape
             y, x = np.mgrid[:nrows, :ncols]
             data = data * x**iord * y**jord
             return data.sum()

         def intertial_axis(data):
             """
             Calculates the covariance matrix of image

             :param image: data
             :return: covariance matrix
             """
             data_sum = data.sum()
             m10 = raw_moment(data, 1, 0)
             m01 = raw_moment(data, 0, 1)
             x_bar = m10 / (data_sum+1e-10)
             y_bar = m01 / (data_sum+1e-10)
             u11 = (raw_moment(data, 1, 1) - x_bar * m01) / (data_sum+1e-10)
             u20 = (raw_moment(data, 2, 0) - x_bar * m10) / (data_sum+1e-10)
             u02 = (raw_moment(data, 0, 2) - y_bar * m01) / (data_sum+1e-10)
             cov = np.array([[u20, u11], [u11, u02]])
             return cov
```

```
        def get_cov_matrices(connected_components, angles):
            """
            Computes covariance matrix of given connected components of direction of gradient
            :param connected_components: connected_components dictionary of gradient directio
            :param angles: possible angles of given direction matrix
            """

            cov_matrices = {}
            for a in ANGLES:
                n_components = np.max(connected_components[str(a)])
                cov_comp = np.zeros((n_components, 2, 2))
                for i in range(n_components):
                     cov_comp[i,:,:] = intertial_axis(connected_components[str(a)]==i)
                cov_matrices[str(a)] = cov_comp
            return cov_matrices

        cov_matrices = get_cov_matrices(connected_components, ANGLES)
        cov_matrices['90']
```

```
Out[55]: array([[  2.50000000e-01,   1.12496679e-11],
                [  1.12496679e-11,   8.25000000e+00]])
```

```
In [56]: def get_eigens(cov_matrices, angles):
             """
             Computes eigen vector and eigen values of covariance matrices for each direction
             :param cov_matrices: covariance matrices of connected components
             :param angles: possible angles of given direction matrix
             """

             eigvals = {}
             eigvecs = {}
             for a in ANGLES:
                 n_components = cov_matrices[str(a)].shape[0]
                 eigvals_comp = np.zeros((n_components, 2,))
                 eigvecs_comp = np.zeros((n_components, 2, 2))
                 for i in range(n_components):
                     eigvals_comp[i,:], eigvecs_comp[i,:,:]= np.linalg.eigh(cov_matrices[str(a
                 eigvals[str(a)], eigvecs[str(a)] = eigvals_comp, eigvecs_comp
             return eigvals, eigvecs

         eigvals, eigvecs = get_eigens(cov_matrices, ANGLES)
```

```
In [57]: def get_theta_conf(eigvals, eigvecs, angles):
             """
             Computes theta(direction) and confidence degrees of lines using eigen matrices
```



eigen value interpretation

```
        :param eignvecs: Eigen vectors of covariance matrix of each direction
        :param eignvals: Eigen values of covariance matrix of each direction
        :param angles: possible angles of given direction matrix
        """

        thetas = {}
        confidences = {}

        for a in ANGLES:
            n_components = eigvals[str(a)].shape[0]
            thetas_comp = np.zeros((n_components, 1))
            confidences_comp = np.zeros((n_components, 1))
            for i in range(n_components):
                thetas_comp[i,:] = np.rad2deg(np.arctan2(eigvecs[str(a)][i][1,1], eigvecs
                confidences_comp[i,:] = eigvals[str(a)][i][1] / (eigvals[str(a)][i][0]+1e-
            thetas[str(a)] = thetas_comp
            confidences[str(a)] = confidences_comp
        return thetas, confidences

    thetas, confidences = get_theta_conf(eigvals, eigvecs, ANGLES)
    print(thetas['90'][0])
    print(confidences['90'][0])
```

```
89.9999999999
```

```
32.999999987
```

1.2.4 2.D Threshold

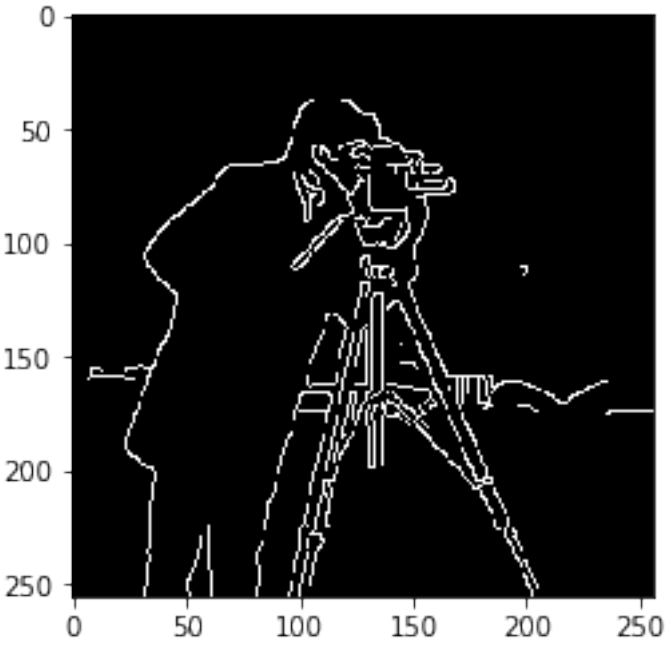
In [58]:
```
threshold = 5

def threshold_conf(confidences, threshold, angles):
    """
    Thresholds each confidence of each direction for all directions in angles

    :param confidences: confidence degrees of lines using eigen matrices
    :param threshold: threshold value for confidence score
    :param angle: possible angles of given direction matrix
    """

    strong_confs = {}
    for a in ANGLES:
        n_components = confidences[str(a)].shape[0]
        strong_conf_comp = np.zeros((n_components, 1))
        for i in range(n_components):
            strong_conf_comp[i,:] = 1 if confidences[str(a)][i] > threshold else 0
        strong_confs[str(a)] = strong_conf_comp
    return strong_confs

strong_confs = threshold_conf(confidences, threshold, ANGLES)
strong_confs
```

Out[58]:
```
{'0': False, '45': False, '90': True, '135': False}
```

1.2.5 2.E Test

In [59]:
```
image = cv2.imread('images/cameraman.jpg', 0).astype(float)
image_blurred = GaussianNoise()(image)
image_grad, image_theta = GradientIntensity()(image_blurred)
image_suppressed = NonMaxSuppression()(image_grad, image_theta)
image_final = Thresholding()(image_suppressed)
image_final[image_final< 1] = 0
image_final[image_final> 1] = 255
image_final = image_final.astype(np.uint8)
plt.imshow(image_final, cmap='gray')
```

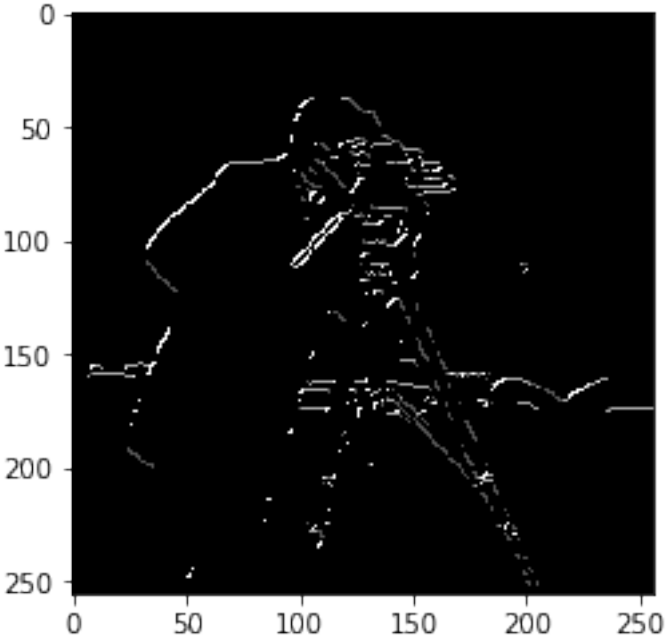
Out[59]:
```
<matplotlib.image.AxesImage at 0x1c5e330d390>
```



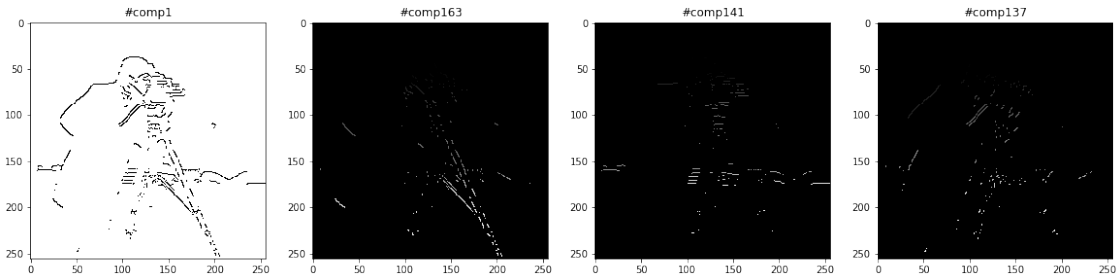

```
In [60]: from copy import deepcopy
         image_ = deepcopy(image_final)
```

```
In [121]: directions = assign_direction(image_theta)
          directions = np.multiply(directions, image_final==255)  # mask out non-edge directio
          plt.imshow(directions, cmap='gray')
```

```
Out[121]: <matplotlib.image.AxesImage at 0x1c5e4afd240>
```



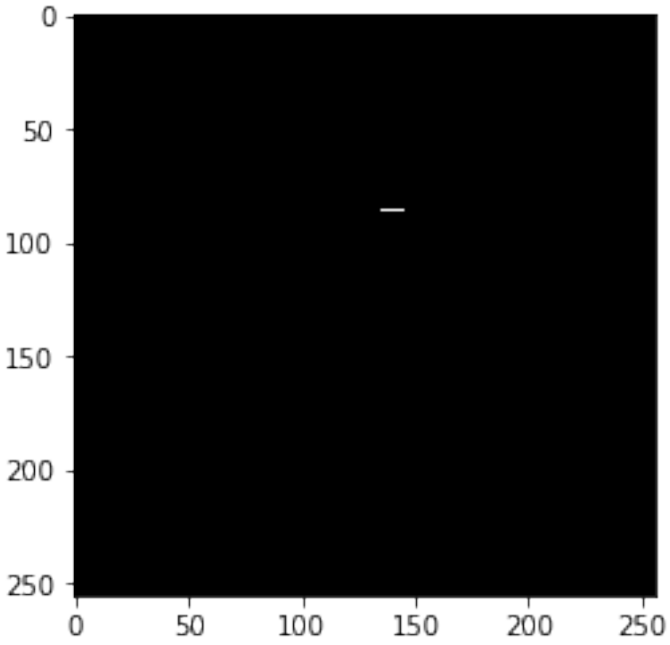
```
In [85]: ANGLES = [0, 45, 90, 135]
         connected_components = get_connected_components(directions, ANGLES)

         plt.figure(figsize=(20, 20))

         for i,a in enumerate(ANGLES):
             plt.subplot(1,4, int(i+1))
             plt.imshow(connected_components[str(a)], cmap='gray')
             plt.title('#comp'+str(np.max(connected_components[str(a)])))
```




```
In [123]: cov_matrices = get_cov_matrices(connected_components, ANGLES)
          eigvals, eigvecs = get_eigens(cov_matrices, ANGLES)

In [125]: thetas, confidences = get_theta_conf(eigvals, eigvecs, ANGLES)

          print('thetas:')
          for a in ANGLES:
              print(thetas[str(a)].shape)
          print('\n\nconfidences:')
          for a in ANGLES:
              print(confidences[str(a)].shape)
```

```
thetas:
(1, 1)
(163, 1)
(141, 1)
(137, 1)


confidences:
(1, 1)
(163, 1)
(141, 1)
(137, 1)
```

```
In [255]: threshold = np.mean([np.mean(confidences[str(a)]) for a in ANGLES])/10
          strong_confs = threshold_conf(confidences, threshold, ANGLES)

          for a in ANGLES:
              print('# of connected components with enough conf for {} degree: {}'.format(a, in

# of connected components with enough conf for 0 degree: 0
# of connected components with enough conf for 45 degree: 8
# of connected components with enough conf for 90 degree: 61
# of connected components with enough conf for 135 degree: 4


In [256]: connected_components['90'].shape

Out[256]: (256, 256)

In [257]: strong_confs['90'].nonzero()[0]

Out[257]: array([  1,   2,   3,   4,   5,   6,   7,  10,  11,  15,  19,  20,  21,
                  22,  25,  27,  28,  29,  31,  34,  36,  37,  38,  39,  43,  46,
                  47,  48,  50,  51,  52,  53,  55,  57,  59,  61,  68,  75,  76,
                  77,  78,  81,  82,  91,  92,  93,  94,  95,  96,  97, 100, 103,
                 108, 112, 116, 120, 123, 124, 125, 127, 135], dtype=int64)

In [303]: plt.imshow(connected_components['90']==46, cmap='gray')

Out[303]: <matplotlib.image.AxesImage at 0x1c5e96e4e10>
```



```
In [305]: plt.imshow(connected_components['45']==51, cmap='gray')
```

```
Out[305]: <matplotlib.image.AxesImage at 0x1c5e9796f28>
```