Object Detection (due Saturday 3/9/2019)

In this assignment, you will develop an object detector based on gradient features and sliding window classification. A set of test images and ***hogvis.py*** are provided in the Canvas assignment directory

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In [1]:
```
import numpy as np
import matplotlib.pyplot as plt
```

1. Image Gradients [20 pts]

Write a function that takes a grayscale image as input and returns two arrays the same size as the image, the first of which contains the magnitude of the image gradient at each pixel and the second containing the orientation.

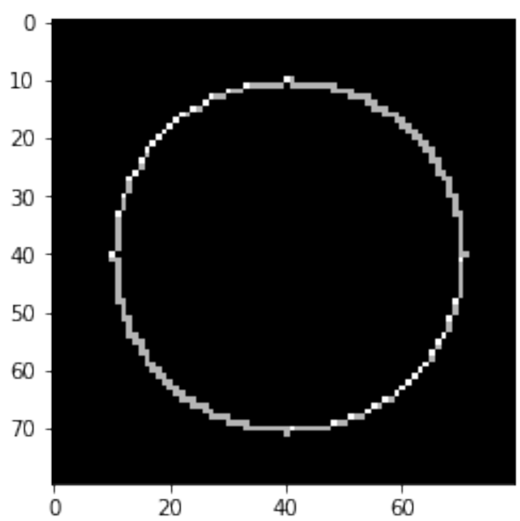
Your function should filter the image with the simple x- and y-derivative filters described in class. Once you have the derivatives you can compute the orientation and magnitude of the gradient vector at each pixel. You should use ***scipy.ndimage.correlate*** with the 'nearest' option in order to nicely handle the image boundaries.

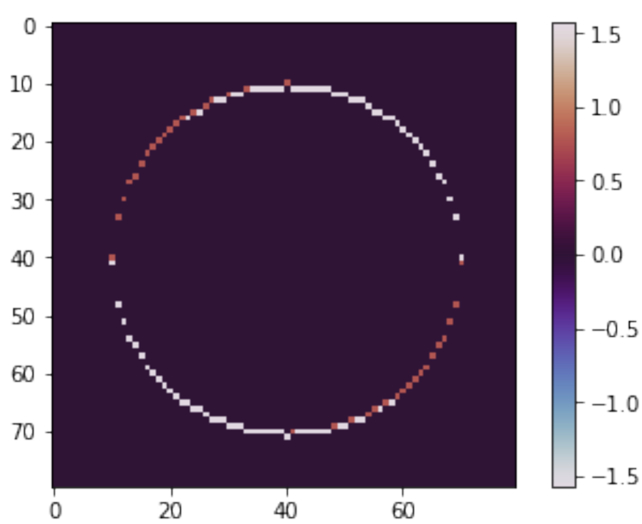
Include a visualization of the output of your gradient calculate for a small test image. For displaying the orientation result, please uses a cyclic colormap such as "hsv" or "twilight". (see [https://matplotlib.org/tutorials/colors/colormaps.html (https://matplotlib.org/tutorials/colors/colormaps.html)](https://matplotlib.org/tutorials/colors/colormaps.html))

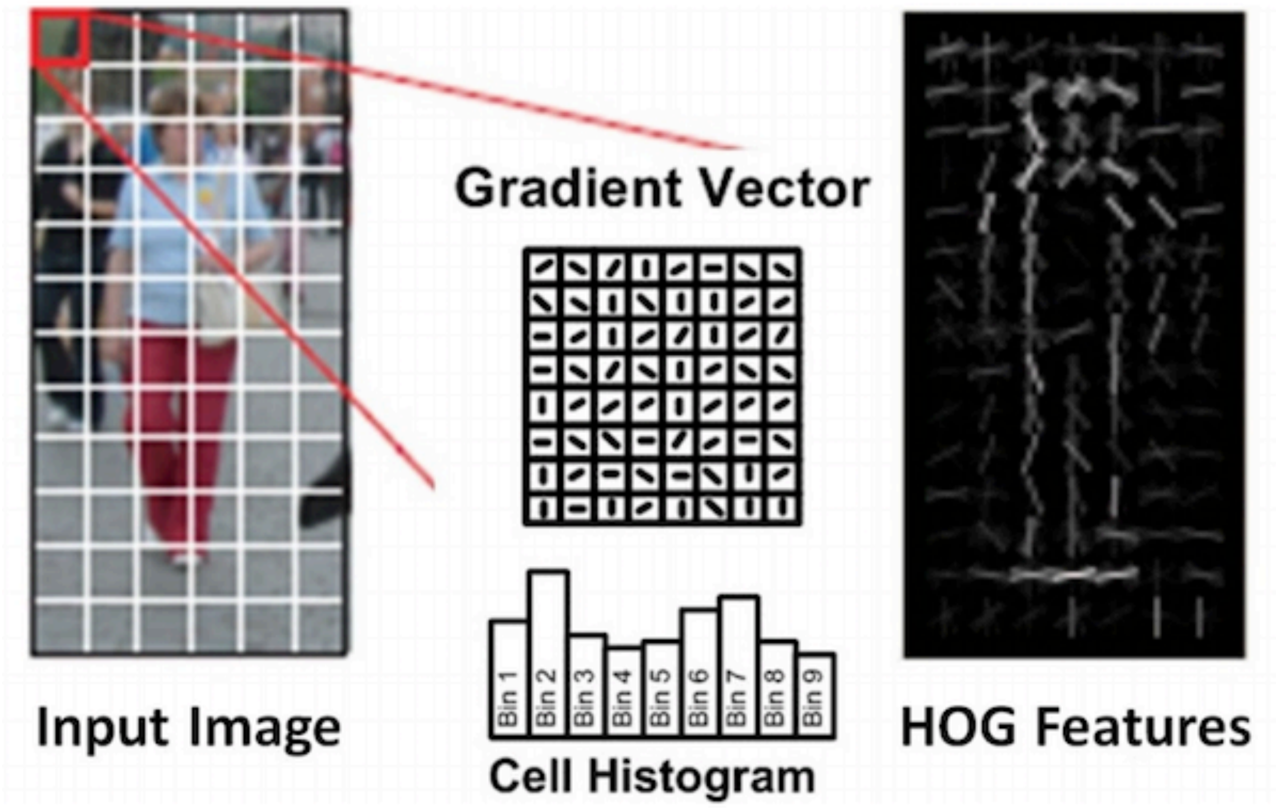
In [2]:
```
#we will only use:  scipy.ndimage.correlate
from scipy import ndimage

def mygradient(image):
    """
    This function takes a grayscale image and returns two arrays of
    same size, one containing the magnitude of the gradient, the sec
    containing the orientation of the gradient.


    Parameters
    ----------
    image : 2D float array of shape HxW
         An array containing pixel brightness values

    Returns
    -------
    mag : 2D float array of shape HxW
        gradient magnitudes

    ori : 2Dfloat array of shape HxW
        gradient orientations in radians
    """
    xk = np.array([[-1,1]])
    yk = np.array([[-1],[1]])

    # your code goes here
    mag = np.zeros(image.shape)
    ori = np.zeros(image.shape)

    dx = ndimage.correlate(image,xk,mode="nearest")
    dy = ndimage.correlate(image,yk,mode="nearest")

    mag = np.sqrt(np.square(dx) + np.square(dy))
    ori = np.arctan(dy/(dx+1.e-16))

    return (mag,ori)
```

In [3]:

```python
#
# Demonstrate your mygradient function here by loading in a grayscal
# image, calling mygradient, and visualizing the resulting magnitude
# and orientation images. For visualizing orientation image, I sugge
# using the hsv or twilight colormap.
#

[yy,xx] = np.mgrid[-40:40,-40:40]
image = np.array((xx*xx+yy*yy<=30*30),dtype=float)

(mag,ori) = mygradient(image)

#visualize results.
plt.imshow(mag,cmap=plt.cm.gray)
plt.show()

plt.imshow(ori,cmap=plt.cm.twilight)
plt.colorbar()
plt.show()


```







2. Histograms of Gradient Orientations [25 pts]

Write a function that computes gradient orientation histograms over each 8x8 block of pixels in an image. Your function should bin the orientation into 9 equal sized bins between -pi/2 and pi/2. The input of your function will be an image of size HxW. The output should be a three-dimensional array ***ohist*** whose size is (H/8)x(W/8)x9 where ***ohist[i,j,k]*** contains the count of how many edges of orientation k fell in block (i,j). If the input image dimensions are not a multiple of 8, you should use ***np.pad*** with the ***mode=edge*** option to pad the width and height up to the nearest integer multiple of 8.

To determine if a pixel is an edge, we need to choose some threshold. I suggest using a threshold that is 10% of the maximum gradient magnitude in the image. Since each 8x8 block will contain a different number of edges, you should normalize the resulting histogram for each block to sum to 1 (i.e., ***np.sum(ohist,axis=2)*** should be 1 at every location).

I would suggest your function loops over the orientation bins. For each orientation bin you'll need to identify those pixels in the image whose magnitude is above the threshold and whose orientation falls in the given bin. You can do this easily in numpy using logical operations in order to generate an array the same size as the image that contains Trues at the locations of every edge pixel that falls in the given orientation bin and is above threshold. To collect up pixels in each 8x8 spatial block you can use the function ***ski.util.view_as_windows(..., (8,8),step=8)*** and ***np.count_nonzeros*** to count the number of edges in each block.

Test your code by creating a simple test image (e.g. a white disk on a black background), computing the descriptor and using the provided function ***hogvis*** to visualize it.

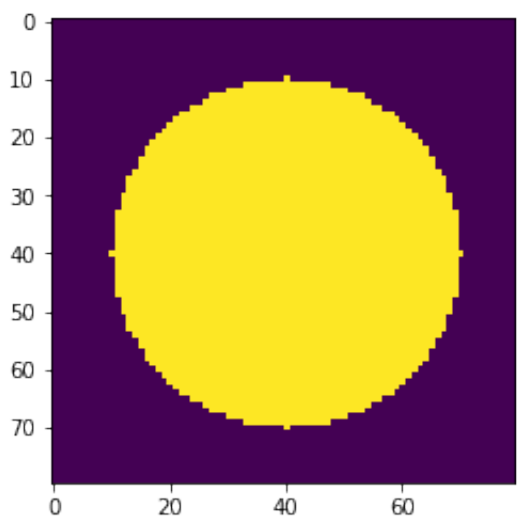
Note: in the discussion above I have assumed 8x8 block size and 9 orientations. In your code you should use the parameters ***bsize*** and ***norient*** in place of these constants.

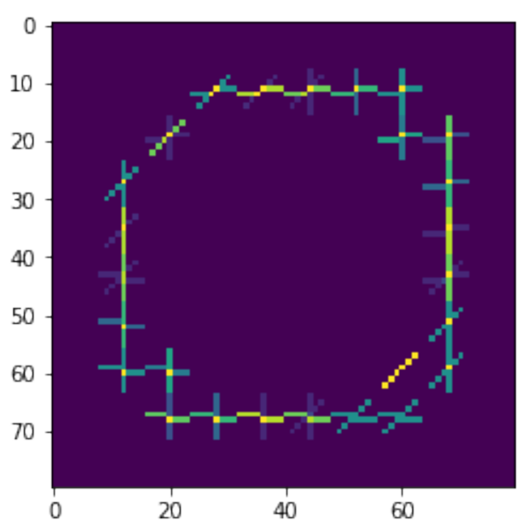
In [4]:

```
#we will only use:  ski.util.view_as_windows for computing hog descr
import skimage as ski
import math

def hog(image,bsize=8,norient=9):

    """
    This function takes a grayscale image and returns a 3D array
    containing the histogram of gradient orientations descriptor (HO
    We follow the convention that the histogram covers gradients sta
    with the first bin at -pi/2 and the last bin ending at pi/2.

    Parameters
    ----------
    image : 2D float array of shape HxW
         An array containing pixel brightness values

    bsize : int
        The size of the spatial bins in pixels, defaults to 8

    norient : int
        The number of orientation histogram bins, defaults to 9

    Returns
    -------
    ohist : 3D float array of shape (H/bsize,W/bsize,norient)
        edge orientation histogram

    """
    # determine the size of the HOG descriptor
    (h,w) = image.shape
    h2 = int(np.ceil(h/float(bsize)))
    w2 = int(np.ceil(w/float(bsize)))
    ohist = np.zeros((h2,w2,norient))
    # pad the input image on right and bottom as needed so that it
    # is a multiple of bsize
    pw = (0,int(bsize*w2-w))
    ph = (0,int(bsize*h2-h))
    image = np.pad(image,(ph,pw),'symmetric')
    # make sure we did the padding correctly
    assert(image.shape==(h2*bsize,w2*bsize))

    # compute image gradients
    (mag,ori) = mygradient(image)
    ori=-ori

    # choose a threshold which is 10% of the maximum gradient magnit
    thresh = 0.1*np.max(mag)

    # separate out pixels into orientation channels, dividing the ra
    # [-pi/2,pi/2] into norient equal sized bins and count how many
    # as a sanity check, make sure every pixel gets assigned to at m
    h = h2*bsize
    w = w2*bsize

    bin0 = -math.pi/2
    bin_ = math.pi/norient
    bincount = np.zeros((h2*bsize,w2*bsize))

    for i in range(norient):
        #create a binary image containing 1s for pixels at the ith
```

```
        #orientation where the magnitude is above the threshold.
        B = np.zeros((h,w))
        B = (ori<=bin0+bin_)*(ori>=bin0)*(mag>thresh)
        bin0=bin0+bin_

        #sanity check
        bincount = bincount + B
        #pull out non-overlapping bsize x bsize blocks
        chblock = ski.util.view_as_windows(B,(bsize,bsize),step=bsiz
        #sum up the count for each block and store the results
        sum_block = np.count_nonzero(chblock,axis=(-1,2))
        ohist[:,:,i] = sum_block

    assert(np.all(bincount<=1))
    # lastly, normalize the histogram so that the sum along the orie
    # note: don't divide by 0! If there are no edges in a block (i.e
    # is 0) then your code should leave all the values as zero.
    k = np.sum(ohist,axis=2)
    for i in range(norient):
        ohist[:,:,i]=ohist[:,:,i]/(k+1.e-16)

    assert(ohist.shape==(h2,w2,norient))
    return ohist
```

In [5]:
```
#provided function for visualizing hog descriptors
import hogvis as hogvis

#
# generate a simple test image... a 80x80 image
# with a circle of radius 30 in the center
#
[yy,xx] = np.mgrid[-40:40,-40:40]
im = np.array((xx*xx+yy*yy<=30*30),dtype=float)
#
# display the image and the output of hogvis
#

plt.imshow(im)
plt.show()

h =hog(im,bsize=8,norient=9)
h2 = hogvis.hogvis(h,bsize=8,norient=9)

plt.imshow(h2)
plt.show()

```





3. Detection [25 pts]

Write a function that takes a template and an image and returns the top detections found in the image. Your function should follow the definition given below.

In your function you should first compute the histogram-of-gradient-orientation feature map for the image, then correlate the template with the feature map. Since the feature map and template are both three dimensional, you will want to filter each orientation separately and then sum up the results to get the final response. If the image of size HxW then this final response map will be of size (H/8)x(W/8).

When constructing the list of top detections, your code should implement non-maxima suppression so that it doesn't return overlapping detections. You can do this by sorting the responses in descending order of their score. Every time you add a detection to the list to return, check to make sure that the location of this detection is not too close to any of the detections already in the output list. You can estimate the overlap by computing the distance between a pair of detections and checking that the distance is greater than say 70% of the width of the template.

Your code should return the locations of the detections in terms of the original image pixel coordinates (so if your detector had a high response at block **[i,j]** in the response map, then you should return **(8i,8j)** as the pixel coordinates).

I have provided a function for visualizing the resulting detections which you can use to test your detect function. Please include some visualization of a simple test case.

In [6]:

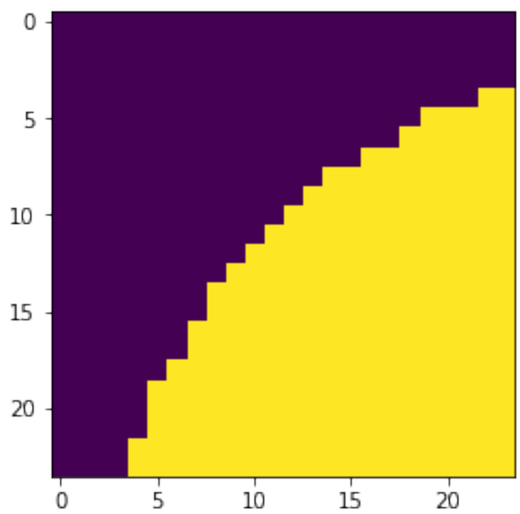
```
#we will only use:  scipy.ndimage.correlate
from scipy import ndimage

def detect(image,template,ndetect=5,bsize=8,norient=9):

    """
    This function takes a grayscale image and a HOG template and
    returns a list of detections where each detection consists
    of a tuple containing the coordinates and score (x,y,score)

    Parameters
    ----------
    image : 2D float array of shape HxW
         An array containing pixel brightness values

    template : a 3D float array
        The HOG template we wish to match to the image

    ndetect : int
        Number of detections to return

    bsize : int
        The size of the spatial bins in pixels, defaults to 8

    norient : int
        The number of orientation histogram bins, defaults to 9

    Returns
```

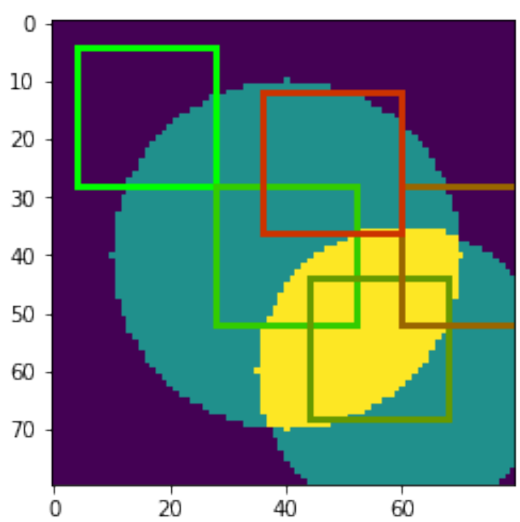
```
    -------
    detections : a list of tuples of length ndetect
        Each detection is a tuple (x,y,score)

    """

    # norient for the template should match the norient parameter pa
    assert(template.shape[2]==norient)

    fmap = hog(image,bsize=bsize,norient=norient)

    #cross-correlate the template with the feature map to get the to
    resp = np.zeros((fmap.shape[0],fmap.shape[1]))
    for i in range(norient):
        resp = resp + ndimage.correlate(fmap[:,:,i],template[:,:,i],

    #sort the values in resp in descending order.
    # val[i] should be ith largest score in resp
    # ind[i] should be the index at which it occurred so that val[i]
    val = np.sort(resp, axis=None)[::-1]  #sorted response values
    ind = np.argsort(resp.flatten())[::-1]

    #work down the list of responses from high to low, to generate a
    # list of ndetect top scoring matches which do not overlap
    w=resp.shape[1]
    detcount = 0
    i = 0
    detections = []
    while ((detcount < ndetect) and (i < len(val))):
        # convert 1d index into 2d index
        yb = ind[i]//w
        xb = ind[i]%w
        assert(val[i]==resp[yb,xb]) #make sure we did indexing corre

        #covert block index to pixel coordinates based on bsize
        xp = xb*bsize
        yp = yb*bsize

        #check if this detection overlaps any detections that we've
        #to the list. compare the x,y coordinates of this detection
        #coordinates of the detections already in the list and see i
        #by checking if the distance between them is less than 70% o
        # width/height
        y = [detections[y][1] for y in range(len(detections))]
        x = [detections[x][0] for x in range(len(detections))]
        overlap = np.any(np.sqrt(np.square(xp-x)+np.square(yp-y)) <

        #if the detection doesn't overlap then add it to the list
        if not overlap:
            detcount = detcount + 1
            detections.append((xp,yp,val[i]))
        i=i+1

    if (len(detections) < ndetect):
        print('WARNING: unable to find ',ndetect,' non-overlapping d

    return detections
```

In [7]:
```
import matplotlib.patches as patches

def plot_detections(image,detections,tsize_pix):
    """
    This is a utility function for visualization that takes an image
    a list of detections and plots the detections overlayed on the i
    as boxes.

    Color of the bounding box is based on the order of the detection
    the list, fading from green to red.

    Parameters
    ----------
    image : 2D float array of shape HxW
         An array containing pixel brightness values

    detections : a list of tuples of length ndetect
        Detections are tuples (x,y,score)

    tsize_pix : (int,int)
        The height and width of the box in pixels

    Returns
    -------
    None

    """
    ndetections = len(detections)

    plt.imshow(image)
    ax = plt.gca()
    w = tsize_pix[1]
    h = tsize_pix[0]
    red = np.array([1,0,0])
    green = np.array([0,1,0])
    ct = 0
    for (x,y,score) in detections:
        xc = x-(w//2)
        yc = y-(h//2)
        col = (ct/ndetections)*red + (1-(ct/ndetections))*green
        rect = patches.Rectangle((xc,yc),w,h,linewidth=3,edgecolor=c
        ax.add_patch(rect)
        ct = ct + 1

    plt.show()
```

In [8]:
```
#
# sketch of some simple test code, modify as needed
#

#create a synthetic image
[yy,xx] = np.mgrid[-40:40,-40:40]
im1 = np.array((xx*xx+yy*yy<=30*30),dtype=float)
[yy,xx] = np.mgrid[-60:20,-60:20]
im2 = np.array((xx*xx+yy*yy<=25*25),dtype=float)
im = 0.5*im1+0.5*im2


#compute feature map with default parameters
fmap = hog(im)
```

```

#extract a 3x3 template
template = fmap[1:4,1:4,:]

plt.imshow(im[8:32,8:32])
plt.show()

#run the detect code
detections = detect(im,template,ndetect=5)

#visualize results.
plot_detections(im,detections,(24,24))

# visually confirm that:
#   1. top detection should be the same as the location where we sel
#   2. multiple detections do not overlap too much
```





---

4. Learning Templates [15 pts]

The final step is to implement a function to learn a template from positive and negative examples. Your code should take a collection of cropped positive and negative examples of the object you are interested in detecting, extract the features for each, and generate a template by taking the average positive template minus the average negative template.

In [9]:
```
def learn_template(posfiles,negfiles,tsize=np.array([16,16]),bsize=8
```

```
    """
    This function takes a list of positive images that contain cropp
    examples of an object + negative files containing cropped backgr
    and a template size. It produces a HOG template and generates vi
    of the examples and template

    Parameters
    ----------
    posfiles : list of str
         Image files containing cropped positive examples

    negfiles : list of str
        Image files containing cropped negative examples

    tsize : (int,int)
        The height and width of the template in blocks

    Returns
    -------
    template : float array of size tsize x norient
        The learned HOG template

    """

    #compute the template size in pixels
    #corresponding to the specified template size (given in blocks)
    tsize_pix=bsize*tsize

    #figure to show positive training examples
    pltct = 1

    #accumulate average positive and negative templates
    pos_t = np.zeros((tsize[0],tsize[1],norient),dtype=float)
    for file in posfiles:
        #load in a cropped positive example
        img = plt.imread(file)
        if (img.dtype == np.uint8):
            img = img.astype(float) / 256

        #convert to grayscale and resize to fixed dimension tsize_pi
        #using skimage.transform.resize if needed.
        if (img.shape[-1]==3):
            img = np.mean(img[:,:,:3],axis=-1)

        img = ski.transform.resize(img,(tsize[0]*bsize,tsize[1]*bsiz

        #display the example. if you want to train with a large # of
        #you may want to modify this, e.g. to show only the first 5.
        plt.imshow(img,cmap=plt.cm.gray)
        plt.show()

        #extract feature
        fmap = hog(img,bsize,norient)

        f = hogvis.hogvis(fmap,bsize=8,norient=9)
        plt.imshow(f)
        plt.show()

        #compute running average
        pos_t = pos_t + fmap[:tsize[0],:tsize[1],:]

```

```
    pos_t = (1/len(posfiles))*pos_t

    # repeat same process for negative examples
    neg_t = np.zeros((tsize[0],tsize[1],norient),dtype=float)
    for file in negfiles:

        img = plt.imread(file)
        if (img.dtype == np.uint8):
            img = img.astype(float) / 256

        if (img.shape[-1]==3):
            img = np.mean(img[:,:,:3],axis=-1)
        img = ski.transform.resize(img,(tsize[0]*bsize,tsize[1]*bsiz

        plt.imshow(img,cmap=plt.cm.gray)
        plt.show()

        fmap = hog(img,bsize,norient)
        f = hogvis.hogvis(fmap,bsize=8,norient=9)
        plt.imshow(f)
        plt.show()

        neg_t = neg_t+fmap[:tsize[0],:tsize[1],:]

    neg_t = (1/len(negfiles))*neg_t

    # now construct our template as the average positive minus avera
    template = pos_t - neg_t


    return template

```

In [ ]:

```

```

5. Experiments [15 pts]

Test your detection by training a template and running it on a test image.

In your experiments and writeup below you should include: (a) a visualization of the positive and negative patches you use to train the template and corresponding hog feature, (b) the detection results on the test image. You should show (a) and (b) for ***two different object categories***, the provided face test images and another category of your choosing (e.g. feel free to experiment with detecting cat faces, hands, cups, chairs or some other type of object). Additionaly, please include results of testing your detector where there are at least 3 objects to detect (this could be either 3 test images which each have one or more objects, or a single image with many (more than 3) objects). Your test image(s) should be distinct from your training examples. Finally, write a brief (1 paragraph) discussion of where the detector works well and when it fails. Describe some ways you might be able to make it better.

NOTE 1: You will need to create the cropped test examples to pass to your ***learn_template***. You can do this by cropping out the examples by hand (e.g. using an image editing tool). You should attempt to crop them out in the most consistent way possible, making sure that each example is centered with the same size and aspect ratio. Negative examples can be image patches that don't contain the object of interest. You should crop out negative examples with roughly the same resolution as the positive examples.

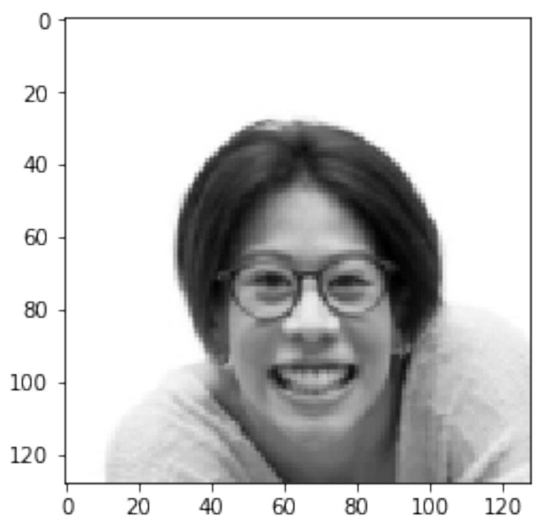
NOTE 2: For the best result, you will want to test on images where the object is the same size as your template. I recommend using the default ***bsize*** and ***norient*** parameters for all your experiments. You will likely want to modify the template size as needed

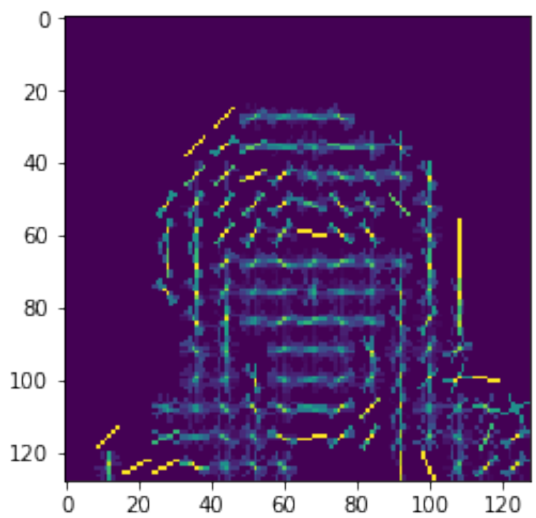
Experiment 1: Face detection

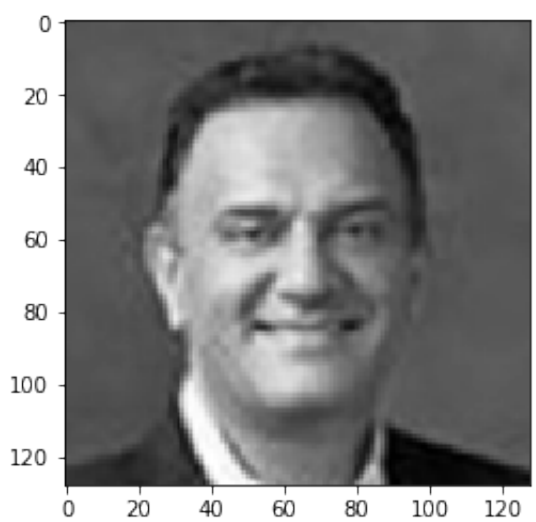
In [10]:
```
# assume template is 16x16 blocks, you may want to adjust this
# for objects of different size or aspect ratio.
# compute image a template size
bsize=8
tsize=np.array([16,16])  #height and width in blocks
tsize_pix = bsize*tsize  #height and width in pixels

path="/Users/zhouhaochen/Desktop/assign4/asignment4_files/images/fac
path2="/Users/zhouhaochen/Desktop/assign4/asignment4_files/images/fa

posfiles = (path+'f1.jpg',path+'f2.jpg',path+"f3.jpg",path+"f4.jpg",
negfiles = (path2+'b1.jpg',path2+'b2.jpg',path2+'b3.jpg')

# call learn_template to learn and visualize the template and traini
template = learn_template(posfiles,negfiles,tsize=tsize)

# call detect on one or more test images, visualizing the result wit
I = plt.imread("/Users/zhouhaochen/Desktop/assign4/asignment4_files/

if (I.dtype == np.uint8):
    I = I.astype(float) / 256
if (I.shape[-1]==3):
    I = np.mean(I[:,:,:3],axis=-1)

```

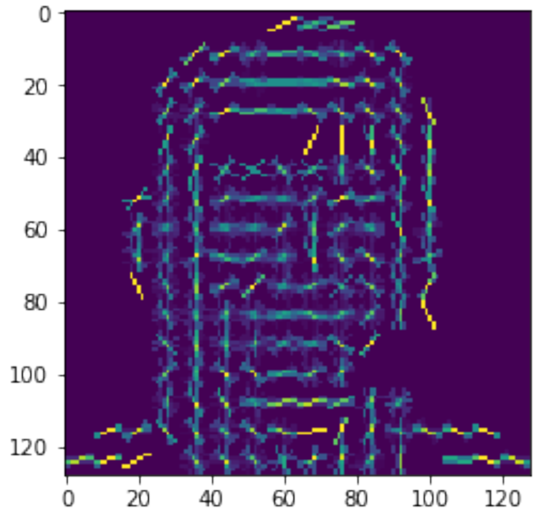
```
detections = detect(I,template,ndetect=4,bsize=8,norient=9)
plot_detections(I,detections,tsize_pix)

```

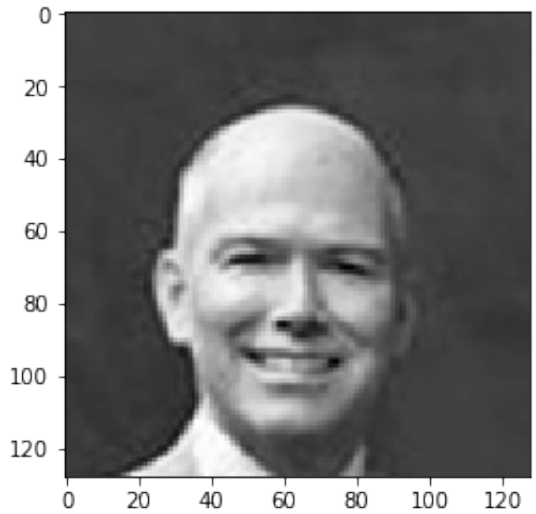
```
/Users/zhouhaochen/anaconda3/lib/python3.7/site-packages/skimage/trans
form/_warps.py:105: UserWarning: The default mode, 'constant', will be
changed to 'reflect' in skimage 0.15.
  warn("The default mode, 'constant', will be changed to 'reflect' in
"
/Users/zhouhaochen/anaconda3/lib/python3.7/site-packages/skimage/trans
form/_warps.py:110: UserWarning: Anti-aliasing will be enabled by defa
ult in skimage 0.15 to avoid aliasing artifacts when down-sampling ima
ges.
  warn("Anti-aliasing will be enabled by default in skimage 0.15 to "
```

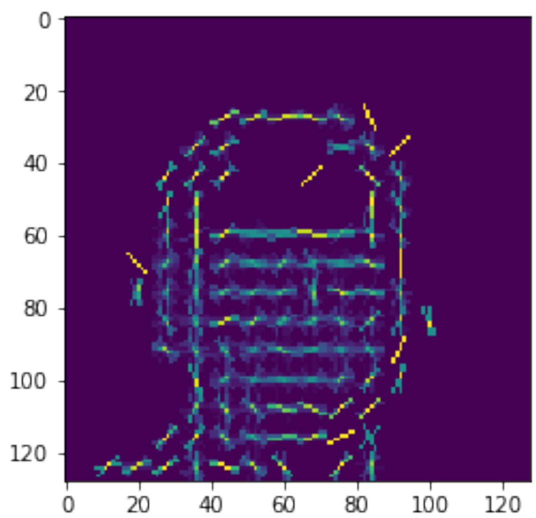


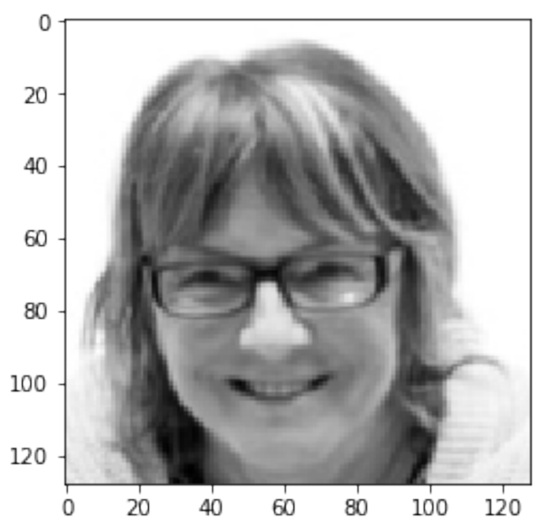





0
20
40
60
80
100
120
0 20 40 60 80 100 120


0
20
40
60
80
100
120
0 20 40 60 80 100 120


0
20
40
60
80
100
120
0 20 40 60 80 100 120


0
20
40
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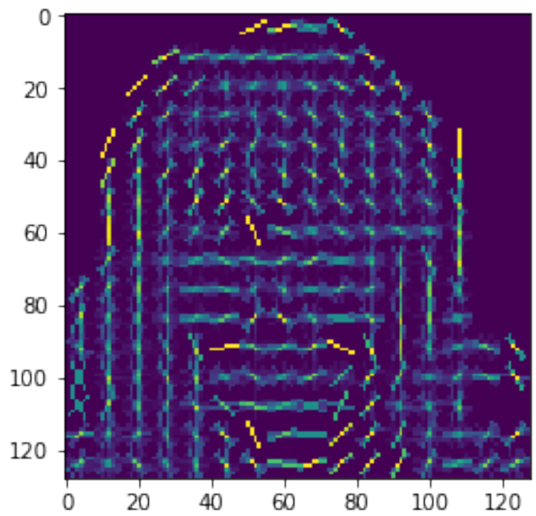
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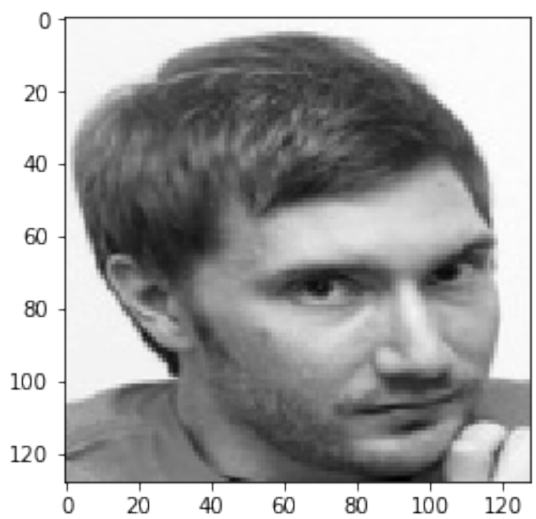
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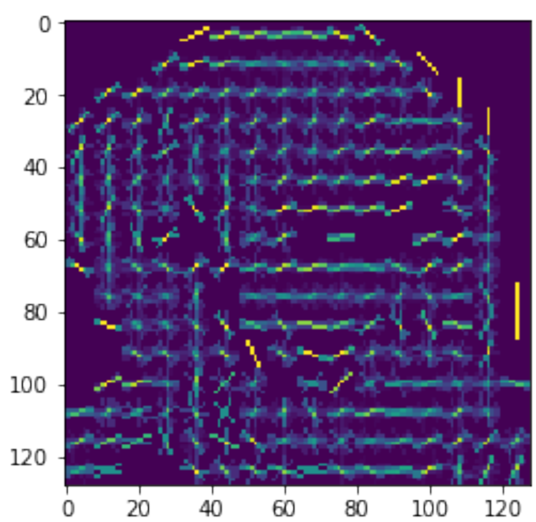
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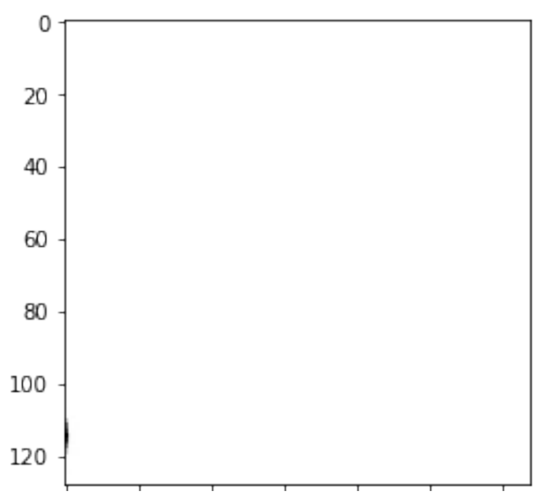
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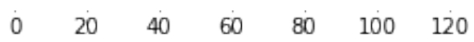
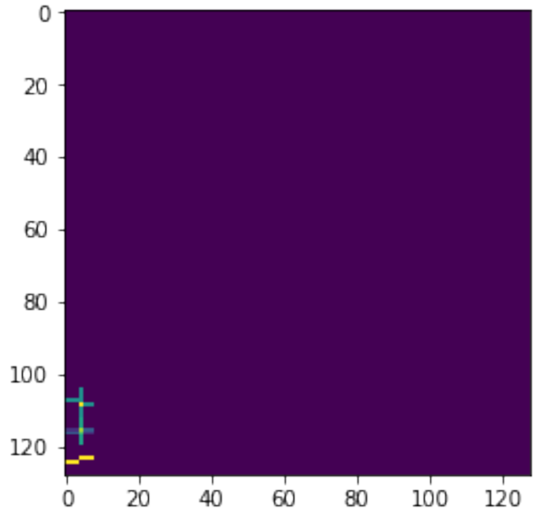
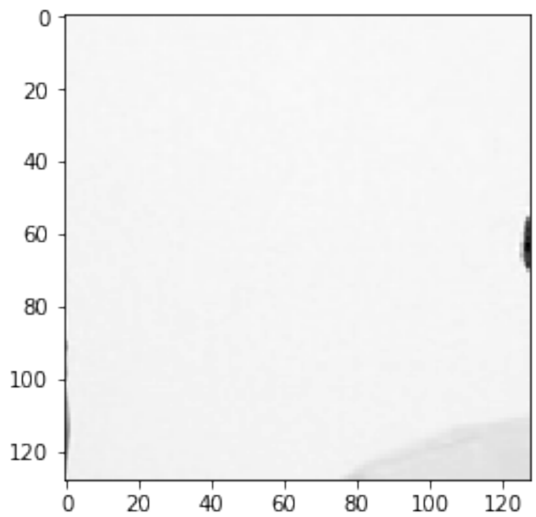
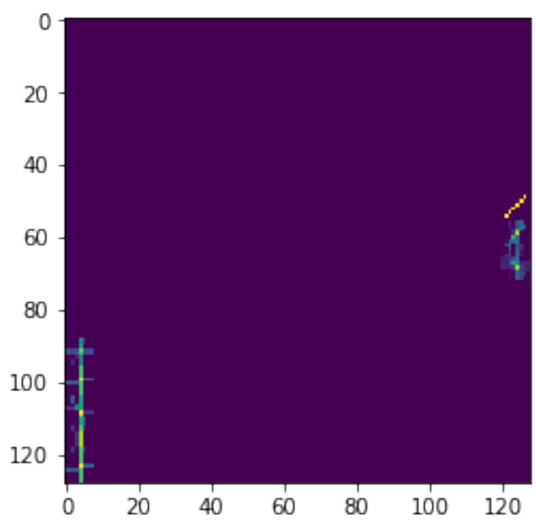
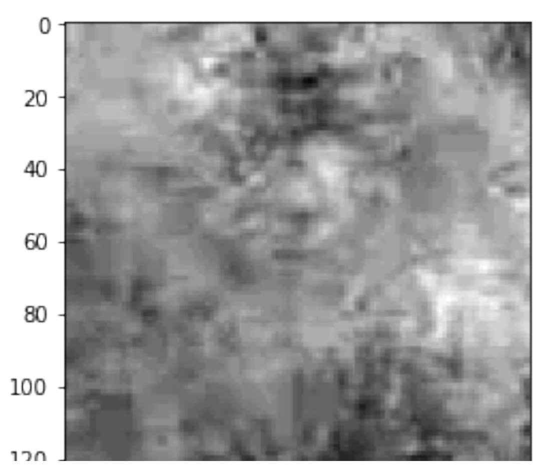
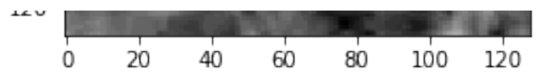


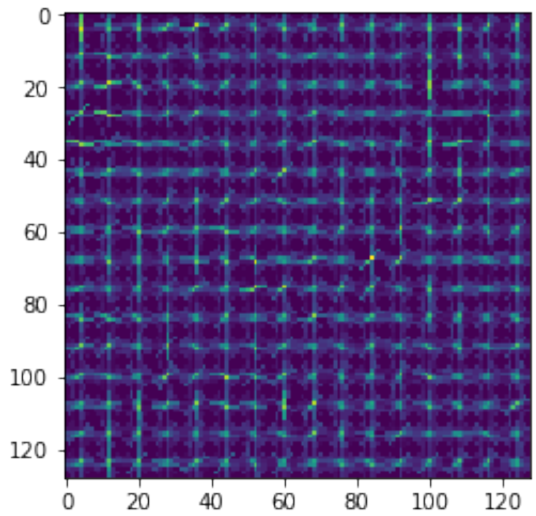


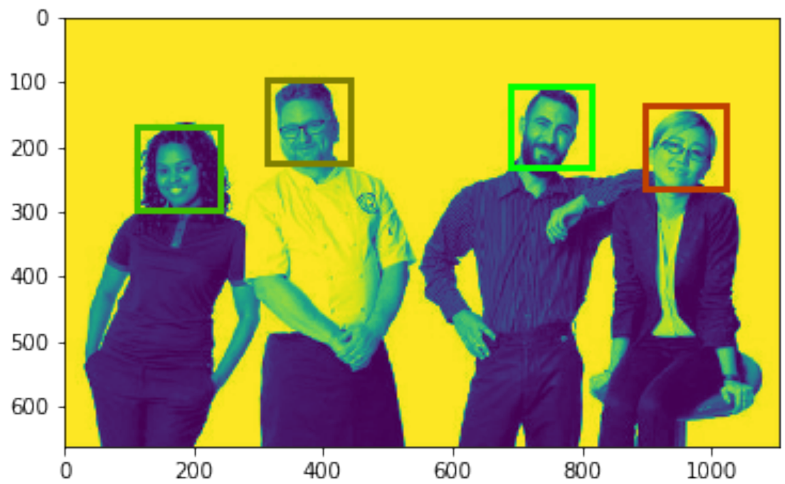








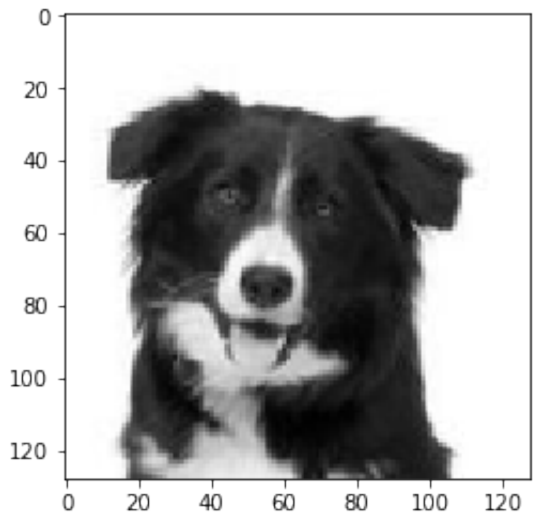


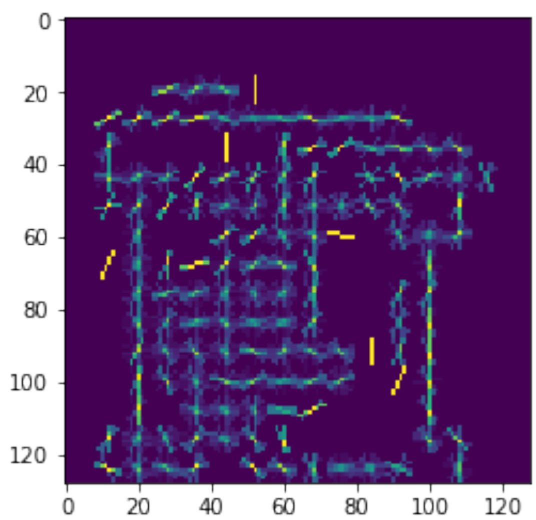


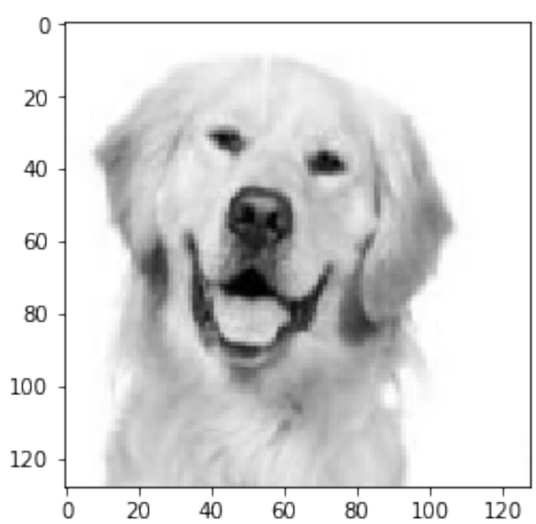
Experiment 2: ??? detection

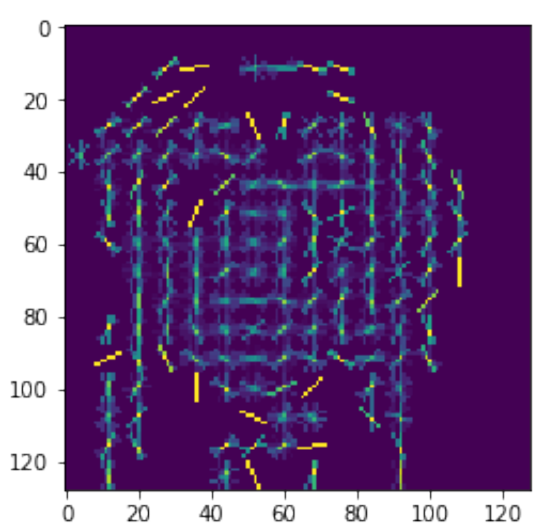
In [11]:

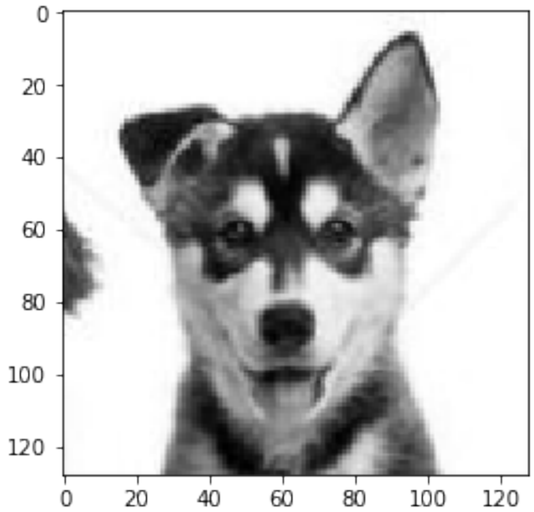
```
# assume template is 16x16 blocks, you may want to adjust this
# for objects of different size or aspect ratio.
# compute image a template size
bsize=8
tsize=np.array([16,16])  #height and width in blocks
tsize_pix = bsize*tsize  #height and width in pixels
path="/Users/zhouhaochen/Desktop/assign4/asignment4_files/images/dog
path2="/Users/zhouhaochen/Desktop/assign4/asignment4_files/images/do
posfiles = (path+"d1.jpg",path+"d2.jpg",path+"d3.jpg",path+"d4.jpg",
negfiles = (path2+'b1.jpg',path2+'b1.jpg')

# call learn_template to learn and visualize the template and traini
template = learn_template(posfiles,negfiles,tsize=tsize)

# call detect on one or more test images, visualizing the result wit
I = plt.imread("/Users/zhouhaochen/Desktop/assign4/asignment4_files/
if (I.dtype == np.uint8):
    I = I.astype(float) / 256
if (I.shape[-1]==3):
    I = np.mean(I[:,:,:3],axis=-1)

detections = detect(I,template,ndetect=6,bsize=8,norient=9)
plot_detections(I,detections,tsize_pix)
```







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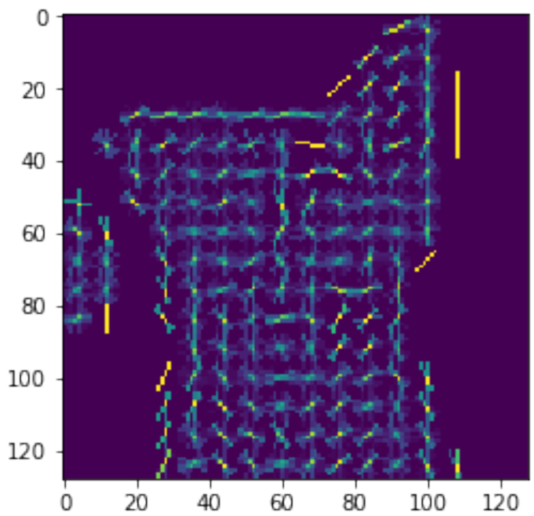
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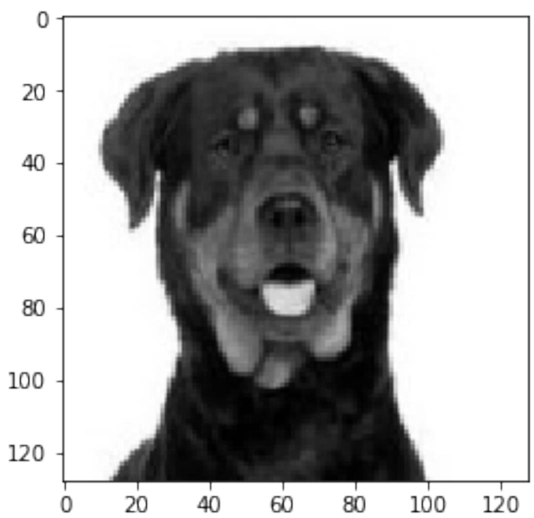
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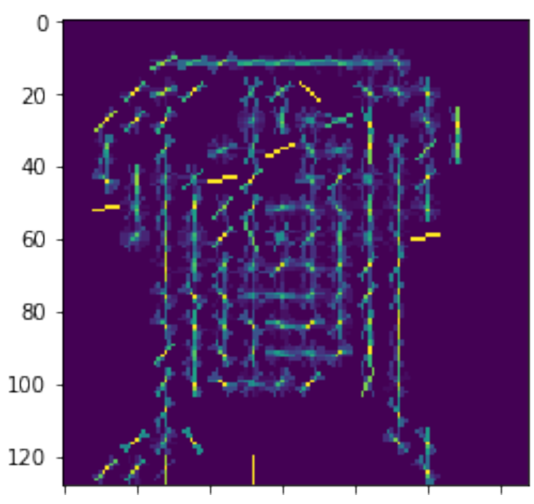
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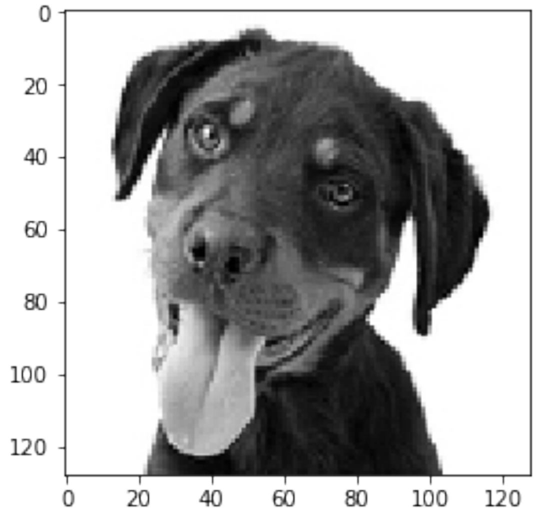

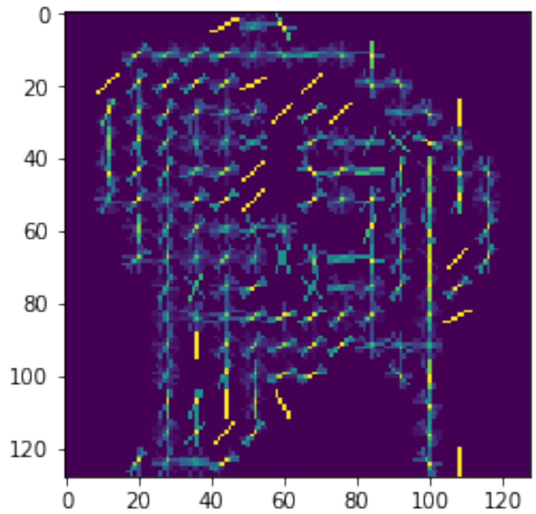

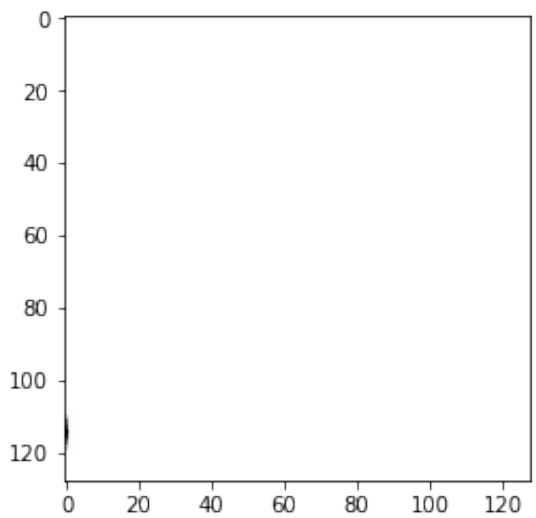

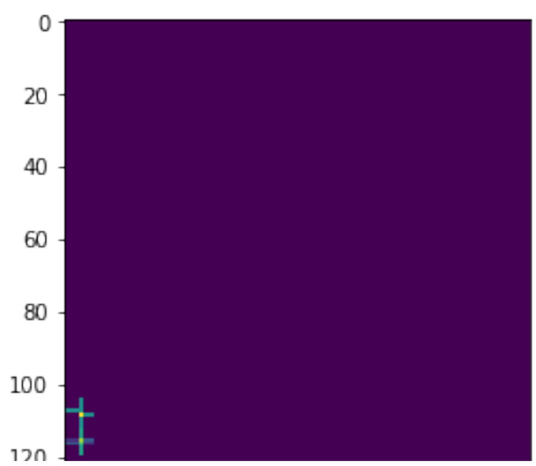

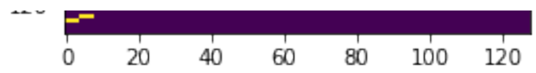

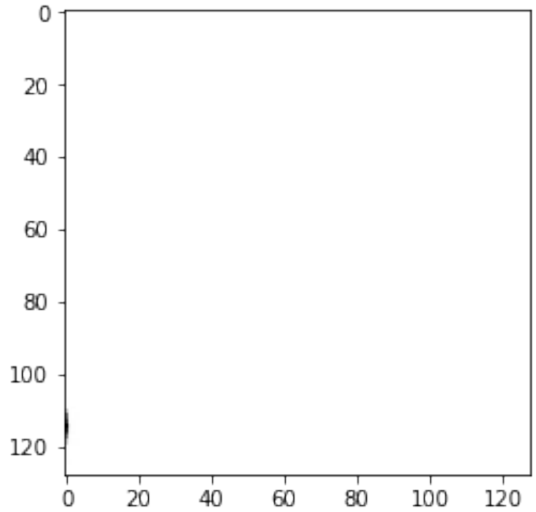

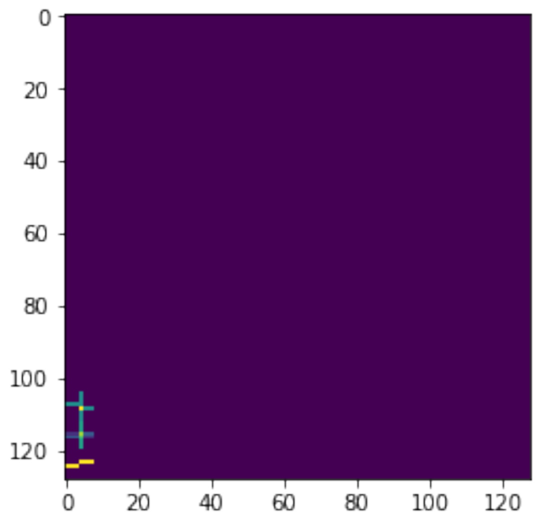

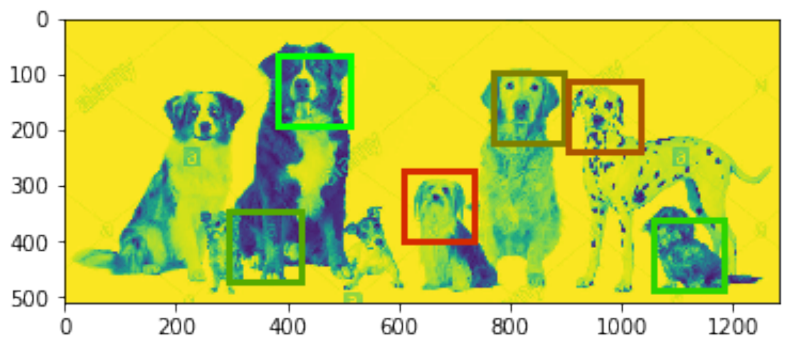

In [ ]:

If the size of the detected objects in the test image are too small or large when comparing to the size of the bounding box, the detector will fail. For example, some dogs' faces are really small in the test image and cannot be caught by the bounding box correctly. If the size of the bounding box can be automatically changed with the size of the detected objects, the result will be better. In addition, if the positive image has a different orientation with the detected image, the detector will also fail. If they have the same orientation, that will lead to a good result. We may need more positive images or templates to train our detector.

In [ ]: