Vehicle Detection

Overview

Vehicle detection using these machine learning and computer vision techniques.

- Linear SVM
- HOG(Histogram of Oriented Gradients) feature extraction
- Color space conversion
- Space binning
- Histogram of color extraction
- Sliding Window

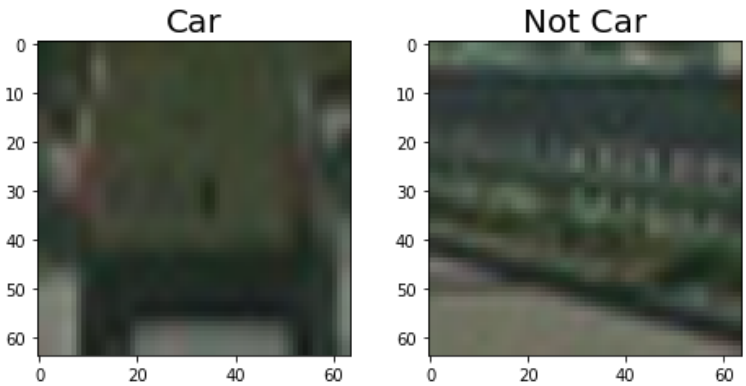
Defining utility functions

In [1]:
```
import matplotlib.image as mpimg
import matplotlib.pyplot as plt
import numpy as np
from skimage.feature import hog
from sklearn.model_selection import train_test_split
from sklearn.svm import LinearSVC
from sklearn.preprocessing import StandardScaler
from skimage.feature import hog
import glob
import time
import cv2
%matplotlib inline
```

In [2]:
```
# a function to extract features from a list of images
def extract_features(imgs, color_space='RGB', spatial_size=(32, 32),
                        hist_bins=32, orient=9,
                        pix_per_cell=8, cell_per_block=2, hog_channel=0,
                        spatial_feat=True, hist_feat=True, hog_feat=True
):
    # Create a list to append feature vectors to
    features = []
    # Iterate through the list of images
    for file in imgs:
        file_features = []
        # Read in each one by one
        image = mpimg.imread(file)
        # apply color conversion if other than 'RGB'
        if color_space != 'RGB':
            if color_space == 'HSV':
                feature_image = cv2.cvtColor(image, cv2.COLOR_RGB2HSV)
            elif color_space == 'LUV':
                feature_image = cv2.cvtColor(image, cv2.COLOR_RGB2LUV)
            elif color_space == 'HLS':
                feature_image = cv2.cvtColor(image, cv2.COLOR_RGB2HLS)
            elif color_space == 'YUV':
                feature_image = cv2.cvtColor(image, cv2.COLOR_RGB2YUV)
            elif color_space == 'YCrCb':
                feature_image = cv2.cvtColor(image, cv2.COLOR_RGB2YCrCb)
        else: feature_image = np.copy(image)

        if spatial_feat == True:
            spatial_features = bin_spatial(feature_image, size=spatial_s
ize)
            file_features.append(spatial_features)
        if hist_feat == True:
            # Apply color_hist()
            hist_features = color_hist(feature_image, nbins=hist_bins)
            file_features.append(hist_features)
        if hog_feat == True:
        # Call get_hog_features() with vis=False, feature_vec=True
            if hog_channel == 'ALL':
                hog_features = []
                for channel in range(feature_image.shape[2]):
                    hog_features.append(get_hog_features(feature_image[:
,:,channel],
                                        orient, pix_per_cell, cell_per_b
lock,
                                        vis=False, feature_vec=True))
                hog_features = np.ravel(hog_features)
            else:
                hog_features = get_hog_features(feature_image[:,:,hog_ch
annel], orient,
                            pix_per_cell, cell_per_block, vis=False, fea
ture_vec=True)
            # Append the new feature vector to the features list
            file_features.append(hog_features)
        features.append(np.concatenate(file_features))
    # Return list of feature vectors
    return features

def get_hog_features(img, orient, pix_per_cell, cell_per_block,
                        vis=False, feature_vec=True):
    # Call with two outputs if vis==True
    if vis == True:
        features, hog_image = hog(img, orientations=orient,
                                  pixels_per_cell=(pix_per_cell, pix_per
_cell),
                                  cells_per_block=(cell_per_block, cell_
per_block),
                                  transform_sqrt=False,
                                  visualise=vis. feature vector=feature
```

Collecting data

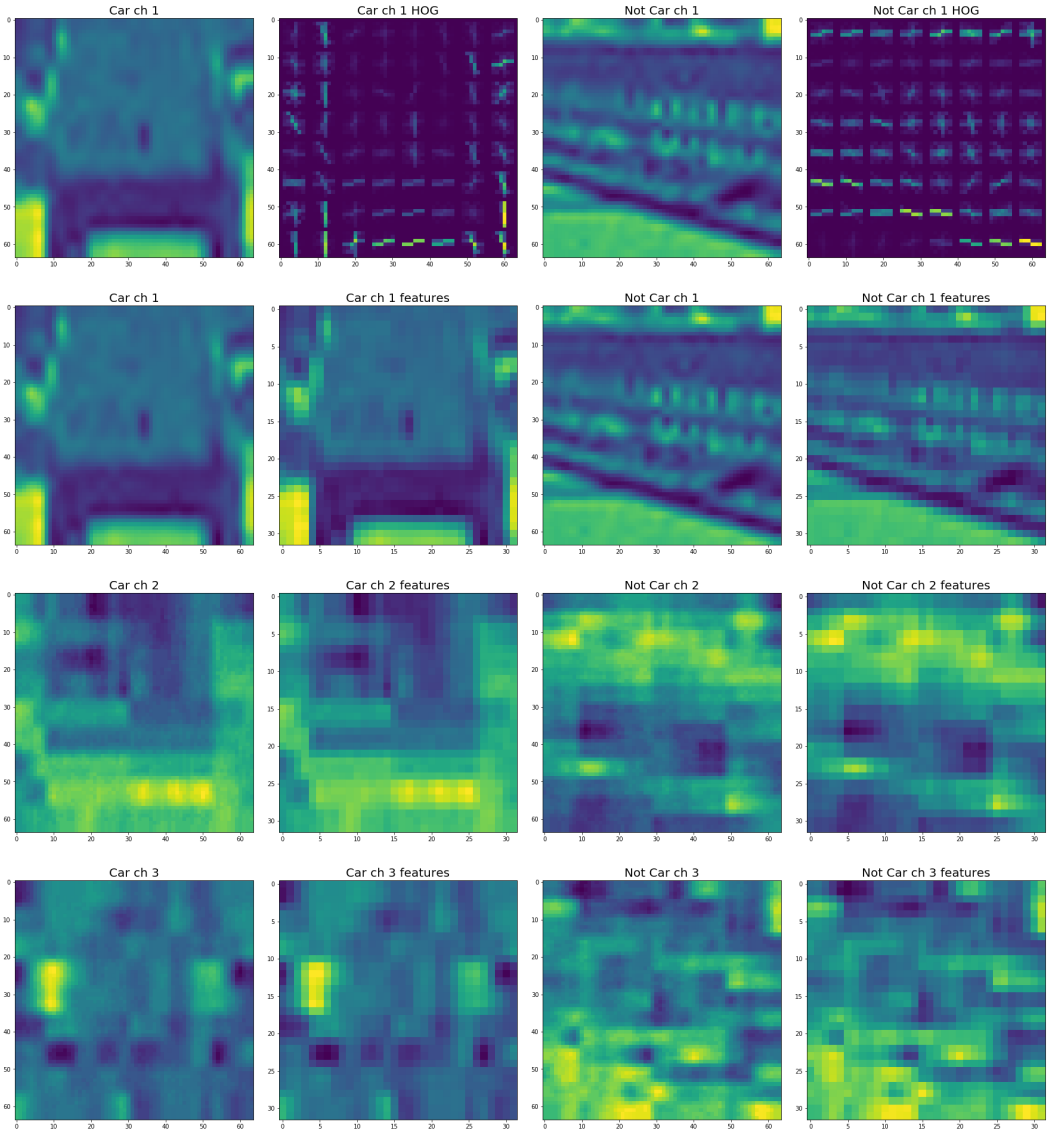
In [3]:
```
# Get image file names
images = glob.glob('./OwnCollection/*/*/*.png')
cars = []
notcars = []
all_cars = []
all_notcars = []

for image in images:
    if 'non-vehicles' in image:
        all_notcars.append(image)
    else:
        all_cars.append(image)

# Get only 1/5 of the training data to avoid overfitting
for ix, notcar in enumerate(all_notcars):
    if ix % 5 == 0:
        notcars.append(notcar)

for ix, car in enumerate(all_cars):
    if ix % 5 == 0:
        cars.append(car)

car_image = mpimg.imread(cars[5])
notcar_image = mpimg.imread(notcars[0])

def compare_images(image1, image2, image1_exp="Image 1", image2_exp="Ima
ge 2"):
    f, (ax1, ax2) = plt.subplots(1, 2, figsize=(6, 3))
    f.tight_layout()
    ax1.imshow(image1)
    ax1.set_title(image1_exp, fontsize=20)
    ax2.imshow(image2)
    ax2.set_title(image2_exp, fontsize=20)
    plt.subplots_adjust(left=0., right=1, top=0.9, bottom=0.)

compare_images(car_image, notcar_image, "Car", "Not Car")
```



Extracting features

In [4]:
```
color_space = 'YUV' # Can be RGB, HSV, LUV, HLS, YUV, YCrCb
orient = 15  # HOG orientations
pix_per_cell = 8 # HOG pixels per cell
cell_per_block = 2 # HOG cells per block
hog_channel = "ALL" # Can be 0, 1, 2, or "ALL"
spatial_size = (32, 32) # Spatial binning dimensions
hist_bins = 32    # Number of histogram bins
spatial_feat = True # Spatial features on or off
hist_feat = True # Histogram features on or off
hog_feat = True # HOG features on or off

converted_car_image = cv2.cvtColor(car_image, cv2.COLOR_RGB2YUV)
car_ch1 = converted_car_image[:,:,0]
car_ch2 = converted_car_image[:,:,1]
car_ch3 = converted_car_image[:,:,2]

converted_notcar_image = cv2.cvtColor(notcar_image, cv2.COLOR_RGB2YUV)
notcar_ch1 = converted_notcar_image[:,:,0]
notcar_ch2 = converted_notcar_image[:,:,1]
notcar_ch3 = converted_notcar_image[:,:,2]

car_hog_feature, car_hog_image = get_hog_features(car_ch1,
                                        orient, pix_per_cell, cell_per_b
lock,
                                        vis=True, feature_vec=True)

notcar_hog_feature, notcar_hog_image = get_hog_features(notcar_ch1,
                                        orient, pix_per_cell, cell_per_b
lock,
                                        vis=True, feature_vec=True)

car_ch1_features = cv2.resize(car_ch1, spatial_size)
car_ch2_features = cv2.resize(car_ch2, spatial_size)
car_ch3_features = cv2.resize(car_ch3, spatial_size)
notcar_ch1_features = cv2.resize(notcar_ch1, spatial_size)
notcar_ch2_features = cv2.resize(notcar_ch2, spatial_size)
notcar_ch3_features = cv2.resize(notcar_ch3, spatial_size)

def show_images(image1, image2, image3, image4,  image1_exp="Image 1", i
mage2_exp="Image 2", image3_exp="Image 3", image4_exp="Image 4"):
    f, (ax1, ax2, ax3, ax4) = plt.subplots(1, 4, figsize=(24, 9))
    f.tight_layout()
    ax1.imshow(image1)
    ax1.set_title(image1_exp, fontsize=20)
    ax2.imshow(image2)
    ax2.set_title(image2_exp, fontsize=20)
    ax3.imshow(image3)
    ax3.set_title(image3_exp, fontsize=20)
    ax4.imshow(image4)
    ax4.set_title(image4_exp, fontsize=20)
    plt.subplots_adjust(left=0., right=1, top=0.9, bottom=0.)

show_images(car_ch1, car_hog_image, notcar_ch1, notcar_hog_image, "Car c
h 1", "Car ch 1 HOG", "Not Car ch 1", "Not Car ch 1 HOG")
show_images(car_ch1, car_ch1_features, notcar_ch1, notcar_ch1_features,
"Car ch 1", "Car ch 1 features", "Not Car ch 1", "Not Car ch 1 features"
)
show_images(car_ch2, car_ch2_features, notcar_ch2, notcar_ch2_features,
"Car ch 2", "Car ch 2 features", "Not Car ch 2", "Not Car ch 2 features"
)
show_images(car_ch3, car_ch3_features, notcar_ch3, notcar_ch3_features,
"Car ch 3", "Car ch 3 features", "Not Car ch 3", "Not Car ch 3 features"
)
```

```
/usr/local/lib/python3.5/dist-packages/skimage/feature/_hog.py:119: skima
ge_deprecation: Default value of `block_norm`==`L1` is deprecated and wil
l be changed to `L2-Hys` in v0.15
  'be changed to `L2-Hys` in v0.15', skimage_deprecation)
```



Training classifier

In [5]:
```
car_features = extract_features(cars, color_space=color_space,
                        spatial_size=spatial_size, hist_bins=hist_bins,
                        orient=orient, pix_per_cell=pix_per_cell,
                        cell_per_block=cell_per_block,
                        hog_channel=hog_channel, spatial_feat=spatial_fe
at,
                        hist_feat=hist_feat, hog_feat=hog_feat)
notcar_features = extract_features(notcars, color_space=color_space,
                        spatial_size=spatial_size, hist_bins=hist_bins,
                        orient=orient, pix_per_cell=pix_per_cell,
                        cell_per_block=cell_per_block,
                        hog_channel=hog_channel, spatial_feat=spatial_fe
at,
                        hist_feat=hist_feat, hog_feat=hog_feat)

X = np.vstack((car_features, notcar_features)).astype(np.float64)
# Fit a per-column scaler
X_scaler = StandardScaler().fit(X)
# Apply the scaler to X
scaled_X = X_scaler.transform(X)

# Define the labels vector
y = np.hstack((np.ones(len(car_features)), np.zeros(len(notcar_features)
)))

# Split up data into randomized training and test sets
rand_state = np.random.randint(0, 100)
X_train, X_test, y_train, y_test = train_test_split(
    scaled_X, y, test_size=0.2, random_state=rand_state)

print('Using:',orient,'orientations',pix_per_cell,
    'pixels per cell and', cell_per_block,'cells per block')
print('Feature vector length:', len(X_train[0]))
# Use a linear SVC
svc = LinearSVC()
# Check the training time for the SVC
t=time.time()
svc.fit(X_train, y_train)
t2 = time.time()
print(round(t2-t, 2), 'Seconds to train SVC...')
# Check the score of the SVC
print('Test Accuracy of SVC = ', round(svc.score(X_test, y_test), 4))
# Check the prediction time for a single sample
t=time.time()
```

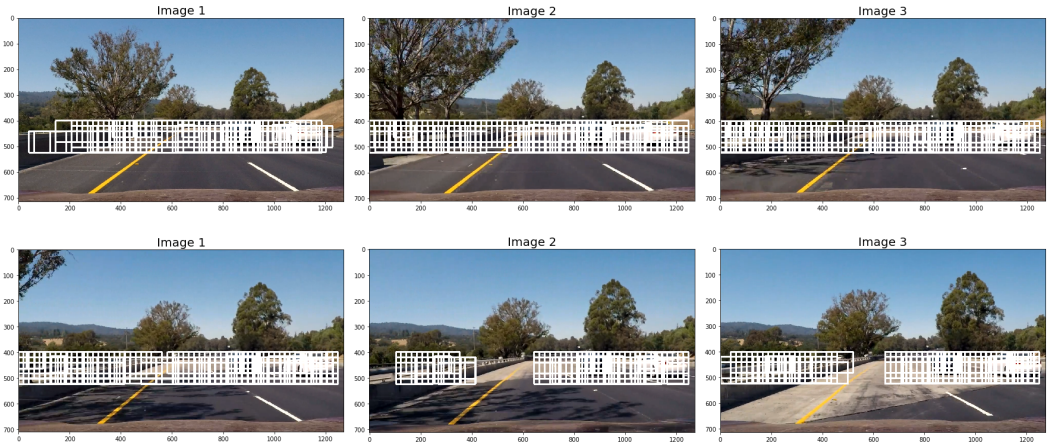
```
/usr/local/lib/python3.5/dist-packages/skimage/feature/_hog.py:119: skima
ge_deprecation: Default value of `block_norm`==`L1` is deprecated and wil
l be changed to `L2-Hys` in v0.15
  'be changed to `L2-Hys` in v0.15', skimage_deprecation)
```

```
Using: 15 orientations 8 pixels per cell and 2 cells per block
Feature vector length: 11988
1.22 Seconds to train SVC...
Test Accuracy of SVC =  0.9659
```

Sliding window

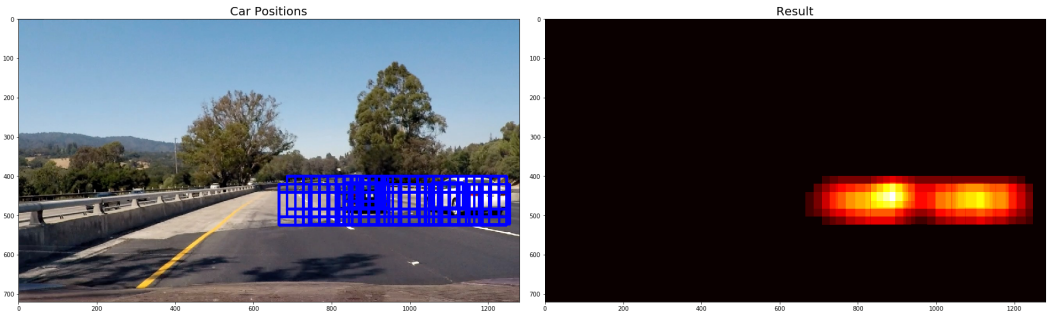
In [6]:
```
def convert_color(img, conv='RGB2YCrCb'):
    if conv == 'RGB2YCrCb':
        return cv2.cvtColor(img, cv2.COLOR_RGB2YCrCb)
    if conv == 'BGR2YCrCb':
        return cv2.cvtColor(img, cv2.COLOR_BGR2YCrCb)
    if conv == 'RGB2LUV':
        return cv2.cvtColor(img, cv2.COLOR_RGB2LUV)
    if conv == 'RGB2YUV':
        return cv2.cvtColor(img, cv2.COLOR_RGB2YUV)

def find_cars(img, ystart, ystop, scale, svc, X_scaler, orient, pix_per_
cell, cell_per_block, spatial_size, hist_bins):

    draw_img = np.copy(img)
    img = img.astype(np.float32)/255

    img_tosearch = img[ystart:ystop,:,:]  # sub-sampling
    ctrans_tosearch = convert_color(img_tosearch, conv='RGB2YUV')
    if scale != 1:
        imshape = ctrans_tosearch.shape
        ctrans_tosearch = cv2.resize(ctrans_tosearch, (np.int(imshape[1]
/scale), np.int(imshape[0]/scale)))

    ch1 = ctrans_tosearch[:,:,0]
    ch2 = ctrans_tosearch[:,:,1]
    ch3 = ctrans_tosearch[:,:,2]

    # Define blocks and steps as above
    nxblocks = (ch1.shape[1] // pix_per_cell) - cell_per_block + 1
    nyblocks = (ch1.shape[0] // pix_per_cell) - cell_per_block + 1
    nfeat_per_block = orient*cell_per_block**2

    # 64 was the orginal sampling rate, with 8 cells and 8 pix per cell
    window = 64
    nblocks_per_window = (window // pix_per_cell) - cell_per_block + 1
    #nblocks_per_window = (window // pix_per_cell)-1

    cells_per_step = 2  # Instead of overlap, define how many cells to s
tep
    nxsteps = (nxblocks - nblocks_per_window) // cells_per_step
    nysteps = (nyblocks - nblocks_per_window) // cells_per_step

    # Compute individual channel HOG features for the entire image
    hog1 = get_hog_features(ch1, orient, pix_per_cell, cell_per_block, v
is=False, feature_vec=False)
    hog2 = get_hog_features(ch2, orient, pix_per_cell, cell_per_block, v
is=False, feature_vec=False)
    hog3 = get_hog_features(ch3, orient, pix_per_cell, cell_per_block, v
is=False, feature_vec=False)

    bboxes = []
    for xb in range(nxsteps):
        for yb in range(nysteps):
            ypos = yb*cells_per_step
            xpos = xb*cells_per_step
            # Extract HOG for this patch
            hog_feat1 = hog1[ypos:ypos+nblocks_per_window, xpos:xpos+nbl
ocks_per_window].ravel()
            hog_feat2 = hog2[ypos:ypos+nblocks_per_window, xpos:xpos+nbl
ocks_per_window].ravel()
            hog_feat3 = hog3[ypos:ypos+nblocks_per_window, xpos:xpos+nbl
ocks_per_window].ravel()
            hog_features = np.hstack((hog_feat1, hog_feat2, hog_feat3))

            xleft = xpos*pix_per_cell
            ytop = ypos*pix_per_cell

            # Extract the image patch
```

```
/usr/local/lib/python3.5/dist-packages/skimage/feature/_hog.py:119: skima
ge_deprecation: Default value of `block_norm`==`L1` is deprecated and wil
l be changed to `L2-Hys` in v0.15
  'be changed to `L2-Hys` in v0.15', skimage_deprecation)
```



Creating heatmap

In [7]:
```
from scipy.ndimage.measurements import label


def add_heat(heatmap, bbox_list):
    # Iterate through list of bboxes
    for box in bbox_list:
        # Add += 1 for all pixels inside each bbox
        # Assuming each "box" takes the form ((x1, y1), (x2, y2))
        heatmap[box[0][1]:box[1][1], box[0][0]:box[1][0]] += 1

    # Return updated heatmap
    return heatmap# Iterate through list of bboxes

def apply_threshold(heatmap, threshold):
    # Zero out pixels below the threshold
    heatmap[heatmap <= threshold] = 0
    # Return thresholded map
    return heatmap

def draw_labeled_bboxes(img, labels):
    # Iterate through all detected cars
    for car_number in range(1, labels[1]+1):
        # Find pixels with each car_number label value
        nonzero = (labels[0] == car_number).nonzero()
        # Identify x and y values of those pixels
        nonzeroy = np.array(nonzero[0])
        nonzerox = np.array(nonzero[1])
        # Define a bounding box based on min/max x and y
        bbox = ((np.min(nonzerox), np.min(nonzeroy)), (np.max(nonzerox),
np.max(nonzeroy)))
        # Draw the box on the image
        cv2.rectangle(img, bbox[0], bbox[1], (0,0,255), 6)
    # Return the image
    return img

heat = np.zeros_like(output_image[:,:,0]).astype(np.float)
# Add heat to each box in box list
heat = add_heat(heat, bboxes)

# Apply threshold to help remove false positives
threshold = 1
heat = apply_threshold(heat, threshold)

# Visualize the heatmap when displaying
heatmap = np.clip(heat, 0, 255)

# Find final boxes from heatmap using label function
labels = label(heatmap)
draw_img = draw_labeled_bboxes(np.copy(image), labels)

def show_images(image1, image2,  image1_exp="Image 1", image2_exp="Image
2"):
    f, (ax1, ax2) = plt.subplots(1, 2, figsize=(24, 9))
    f.tight_layout()
    ax1.imshow(image1)
    ax1.set_title(image1_exp, fontsize=20)
    ax2.imshow(image2, cmap='hot')
    ax2.set_title(image2_exp, fontsize=20)
    plt.subplots_adjust(left=0., right=1, top=0.9, bottom=0.)

show_images(output_image, heatmap, "Car Positions", "Result")
```



More heatmaps

In [8]:
```
def get_heatmap(bboxes):
    threshold = 1
    heat = np.zeros_like(output_image[:,:,0]).astype(np.float)
    heat = add_heat(heat, bboxes)
    heat = apply_threshold(heat, threshold)
    heatmap = np.clip(heat, 0, 255)
    return heatmap

def show_images(image1, image2,  image1_exp="Image 1", image2_exp="Image
2"):
    f, (ax1, ax2) = plt.subplots(1, 2, figsize=(24, 9))
    f.tight_layout()
    ax1.imshow(image1)
    ax1.set_title(image1_exp, fontsize=20)
    ax2.imshow(image2, cmap='hot')
    ax2.set_title(image2_exp, fontsize=20)
    plt.subplots_adjust(left=0., right=1, top=0.9, bottom=0.)

heatmap1 = get_heatmap(bboxes1)
heatmap2 = get_heatmap(bboxes2)
heatmap3 = get_heatmap(bboxes3)
heatmap4 = get_heatmap(bboxes4)
heatmap5 = get_heatmap(bboxes5)
heatmap6 = get_heatmap(bboxes6)
show_images(output_image1, heatmap1)
show_images(output_image2, heatmap2)
show_images(output_image3, heatmap3)
show_images(output_image4, heatmap4)
show_images(output_image5, heatmap5)
show_images(output_image6, heatmap6)
```

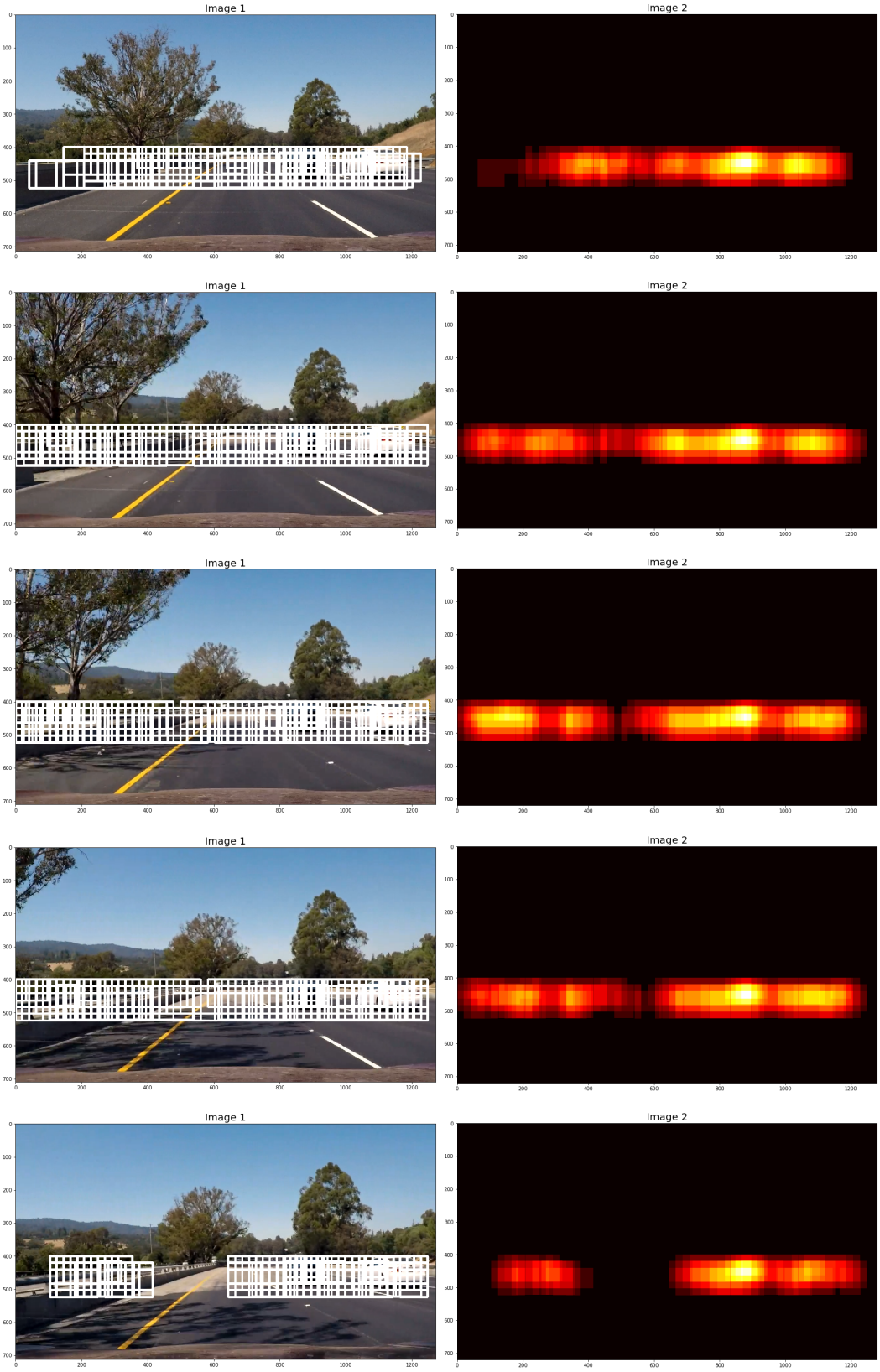
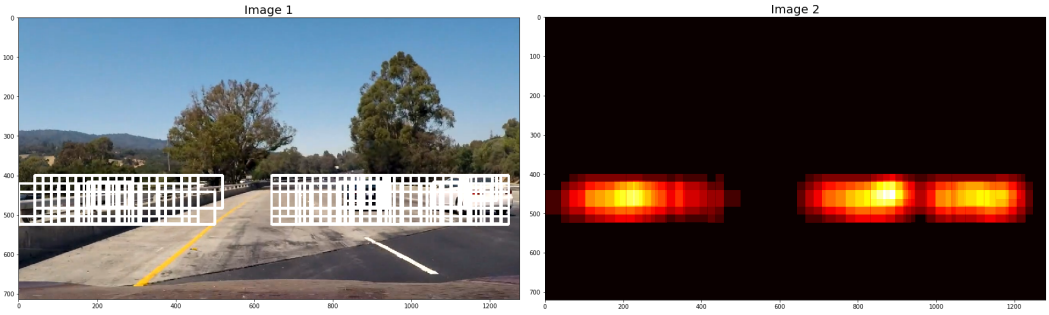


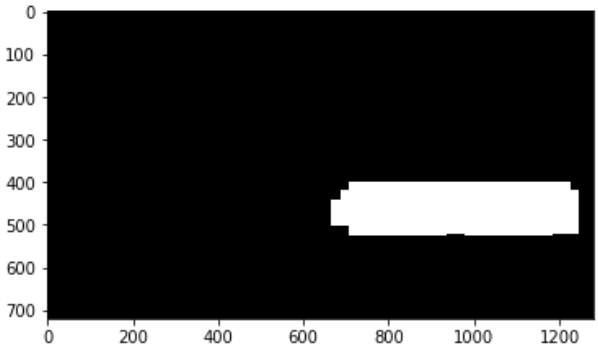
Image 1
Image 2
Image 1
Image 2
Image 1
Image 2
Image 1
Image 2
Image 1
Image 2



Labeled image

In [9]:
```
plt.imshow(labels[0], cmap='gray')
```

Out[9]: <matplotlib.image.AxesImage at 0x7f477e5ea3c8>



Resulting bonding boxes

In [10]:
```
plt.imshow(draw_img)
```

Out[10]: <matplotlib.image.AxesImage at 0x7f477e5a4c50>

Applying to video

In [11]:
```
from collections import deque
history = deque(maxlen = 8)

def detect_cars(image):
    bboxes = []
    ystart = 400
    ystop = 500
    out_img, bboxes1 = find_cars(image, ystart, ystop, 1.0, svc, X_scale
r, orient, pix_per_cell, cell_per_block, spatial_size, hist_bins)
    ystart = 400
    ystop = 500
    out_img, bboxes2 = find_cars(image, ystart, ystop, 1.3, svc, X_scale
r, orient, pix_per_cell, cell_per_block, spatial_size, hist_bins)
    ystart = 410
    ystop = 500
    out_img, bboxes3 = find_cars(out_img, ystart, ystop, 1.4, svc, X_sca
ler, orient, pix_per_cell, cell_per_block, spatial_size, hist_bins)
    ystart = 420
    ystop = 556
    out_img, bboxes4 = find_cars(out_img, ystart, ystop, 1.6, svc, X_sca
ler, orient, pix_per_cell, cell_per_block, spatial_size, hist_bins)
    ystart = 430
    ystop = 556
    out_img, bboxes5 = find_cars (out_img, ystart, ystop, 1.8, svc, X_sc
aler, orient, pix_per_cell, cell_per_block, spatial_size, hist_bins)
    ystart = 430
    ystop = 556
    out_img, bboxes6 = find_cars (out_img, ystart, ystop, 2.0, svc, X_sc
aler, orient, pix_per_cell, cell_per_block, spatial_size, hist_bins)
    ystart = 440
    ystop = 556
    out_img, bboxes7 = find_cars (out_img, ystart, ystop, 1.9, svc, X_sc
aler, orient, pix_per_cell, cell_per_block, spatial_size, hist_bins)
    ystart = 400
    ystop = 556
    out_img, bboxes8 = find_cars (out_img, ystart, ystop, 1.3, svc, X_sc
aler, orient, pix_per_cell, cell_per_block, spatial_size, hist_bins)
    ystart = 400
    ystop = 556
    out_img, bboxes9 = find_cars (out_img, ystart, ystop, 2.2, svc, X_sc
aler, orient, pix_per_cell, cell_per_block, spatial_size, hist_bins)
    ystart = 500
    ystop = 656
    out_img, bboxes10 = find_cars (out_img, ystart, ystop, 3.0, svc, X_s
caler, orient, pix_per_cell, cell_per_block, spatial_size, hist_bins)
    bboxes.extend(bboxes1)
    bboxes.extend(bboxes2)
    bboxes.extend(bboxes3)
    bboxes.extend(bboxes4)
    bboxes.extend(bboxes5)
    bboxes.extend(bboxes6)
    bboxes.extend(bboxes7)
    bboxes.extend(bboxes8)
    bboxes.extend(bboxes9)
    bboxes.extend(bboxes10)

    heat = np.zeros_like(out_img[:,:,0]).astype(np.float)
    # Add heat to each box in box list
    heat = add_heat(heat, bboxes)

    # Apply threshold to help remove false positives
    threshold = 1
    heat = apply_threshold(heat, threshold)

    # Visualize the heatmap when displaying
    current_heatmap = np.clip(heat, 0, 255)
    history.append(current_heatmap)
```

```
/usr/local/lib/python3.5/dist-packages/skimage/feature/_hog.py:119: skima
ge_deprecation: Default value of `block_norm`==`L1` is deprecated and wil
l be changed to `L2-Hys` in v0.15
  'be changed to `L2-Hys` in v0.15', skimage_deprecation)
```

Out[11]: `<matplotlib.image.AxesImage at 0x7f477e671be0>`

In [12]:
```
import imageio
imageio.plugins.ffmpeg.download()
from moviepy.editor import VideoFileClip
from IPython.display import HTML
```

In [13]:
```
history = deque(maxlen = 8)
output = 'test_result.mp4'
clip = VideoFileClip("test_video.mp4")
video_clip = clip.fl_image(detect_cars)
%time video_clip.write_videofile(output, audio=False)
```

```
[MoviePy] >>>> Building video test_result.mp4
[MoviePy] Writing video test_result.mp4

 97%|█████████▋| 38/39 [01:09<00:01,  1.78s/it]

[MoviePy] Done.
[MoviePy] >>>> Video ready: test_result.mp4

CPU times: user 1min 9s, sys: 473 ms, total: 1min 9s
Wall time: 1min 11s
```

In [ ]:
```
history = deque(maxlen = 8)
output = 'result.mp4'
clip = VideoFileClip("project_video.mp4")
video_clip = clip.fl_image(detect_cars)
%time video_clip.write_videofile(output, audio=False)
```

```
[MoviePy] >>>> Building video result.mp4
[MoviePy] Writing video result.mp4

 59%|█████▉    | 741/1261 [23:47<17:37,  2.03s/it]
```