Advanced Lane Finding

The Project

The goals / steps of this project are the following:

Compute the camera calibration matrix and distortion coefficients given a set of chessboard images. Apply a distortion correction to raw images. Use color transforms, gradients, etc., to create a thresholded binary image. Apply a perspective transform to rectify binary image ("birds-eye view"). Detect lane pixels and fit to find the lane boundary. Determine the curvature of the lane and vehicle position with respect to center. Warp the detected lane boundaries back onto the original image. Output visual display of the lane boundaries and numerical estimation of lane curvature and vehicle position.

Just import neededf Libs

In [1]:

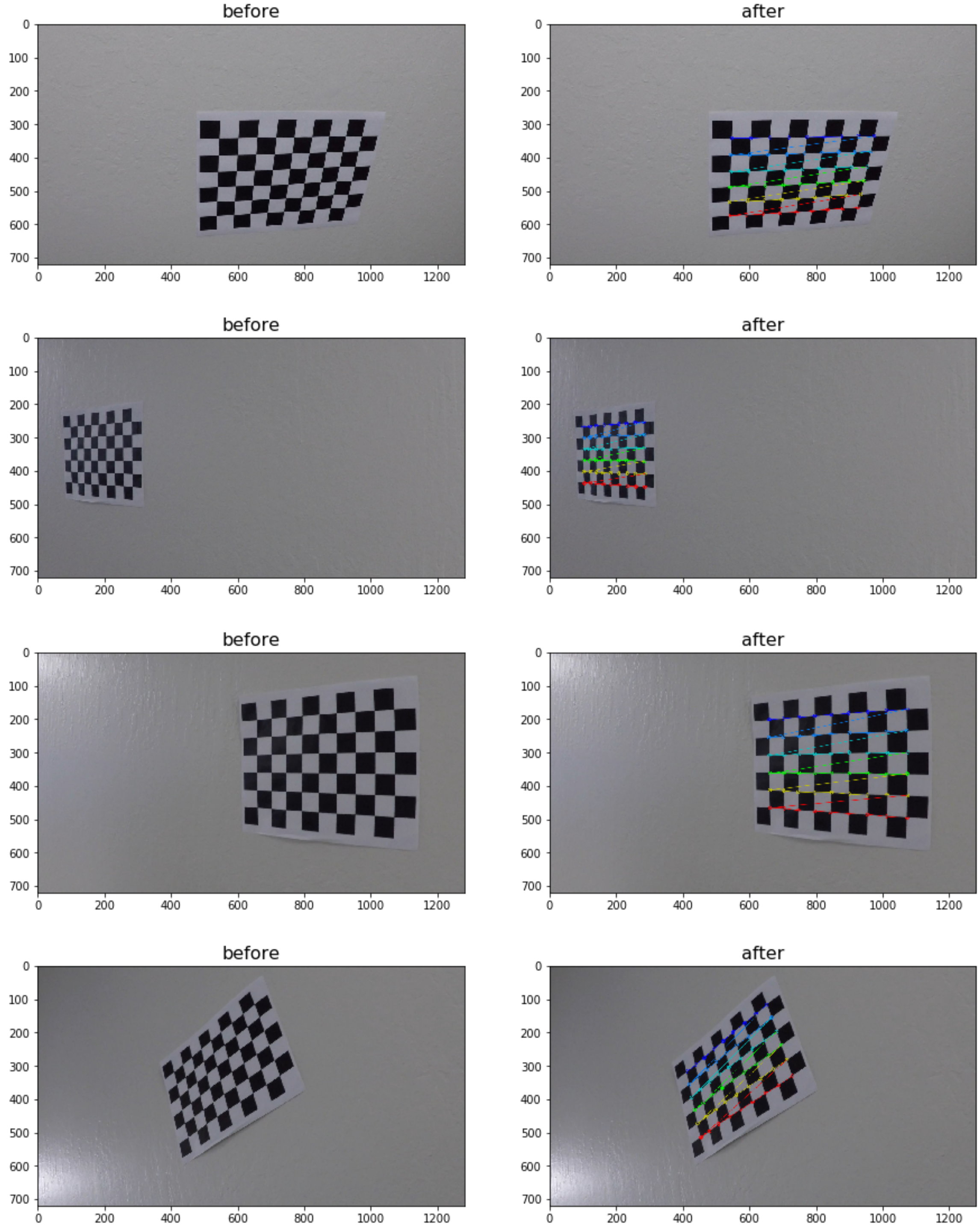
```
import numpy as np
import cv2
import matplotlib.pyplot as plt
import matplotlib.image as mpimg
import glob
```

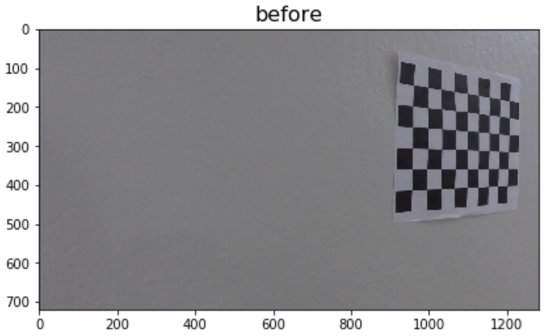
Compute the camera calibration matrix and distortion coefficients given a set of chessboard images. to do the calibration , we use many images around 20 images. I used the OpenCV functions findChessboardCorners and drawChessboardCorners to identify the locations of corners on a series of pictures of a chessboard taken from different angles.

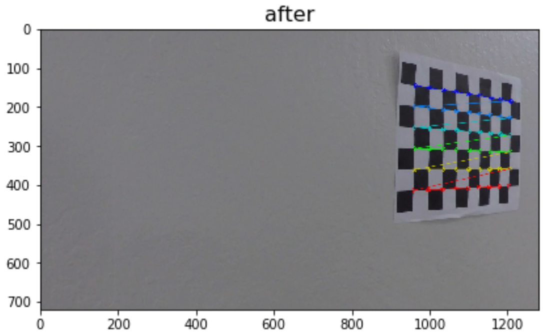
In [2]:

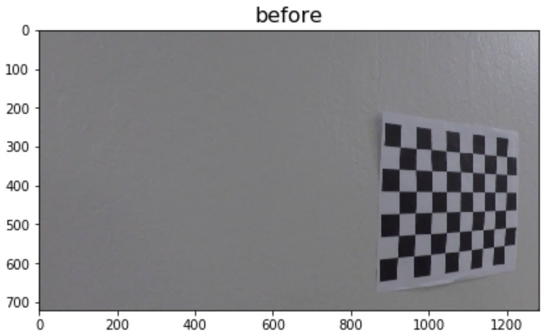
```
nx = 9
ny = 6

# Make a list of calibration images
image_pathes = glob.glob('./camera_cal/calibration*.jpg')

objpoints = []
imgpoints = []
objp =  np.zeros((6*9,3),np.float32)
objp[:,:2] =  np.mgrid[0:9,0:6].T.reshape(-1,2)

for img_path in image_pathes:
    # Convert to grayscale

    img = mpimg.imread(img_path)
    gray = cv2.cvtColor(img, cv2.COLOR_RGB2GRAY)

    # Find the chessboard corners
    ret, corners = cv2.findChessboardCorners(gray, (nx, ny), None)

    # If found, draw corners
    if ret == True:
        # Draw and display the corners
        cv2.drawChessboardCorners(img, (nx, ny), corners, ret)
        imgpoints.append(corners)
        objpoints.append(objp)
        #show images
        f, (axis1, axis2) = plt.subplots(1, 2, figsize=(15,10))
        axis1.imshow(mpimg.imread(img_path))
        axis1.set_title('before', fontsize=16)
        axis2.imshow(img)
        axis2.set_title('after', fontsize=16)
    else:
        print ("failed to find corners for " + img_path)
print (gray.shape[::-1])
print (gray.shape)
ret,cal_mtx,cal_dist,rvecs,tvecs = cv2.calibrateCamera(objpoints,imgpoints,gray.shape
[::-1],None,None)
```

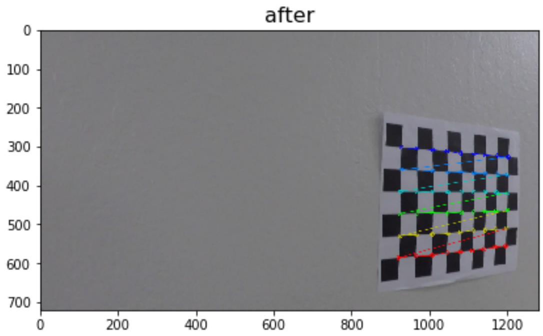
```
failed to find corners for ./camera_cal\calibration1.jpg
failed to find corners for ./camera_cal\calibration4.jpg
failed to find corners for ./camera_cal\calibration5.jpg
(1280, 720)
(720, 1280)
```

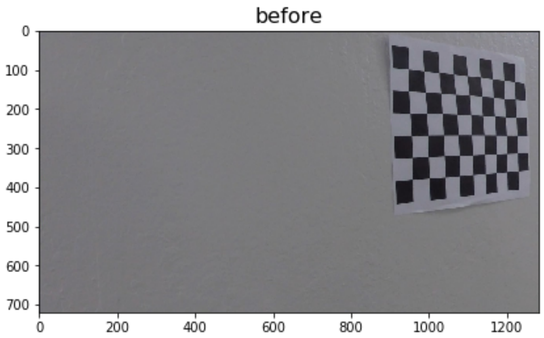


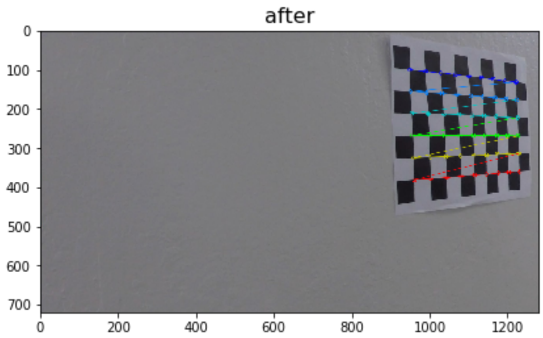

before

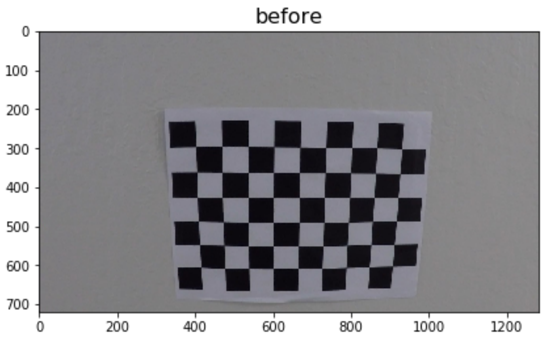

after

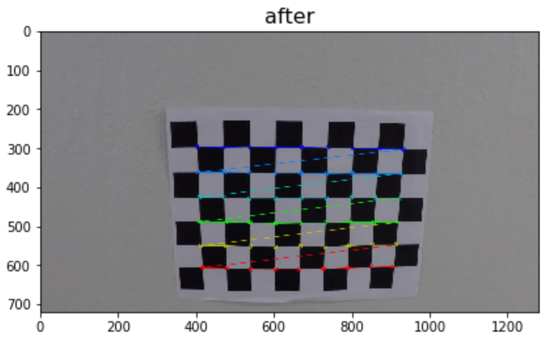

before

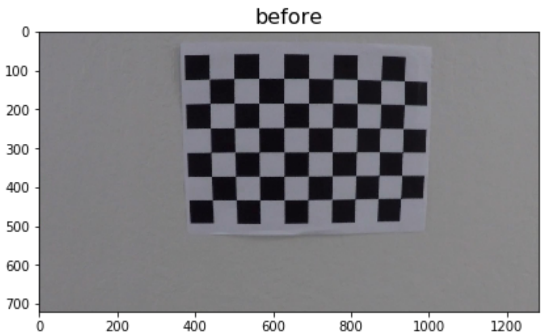

after

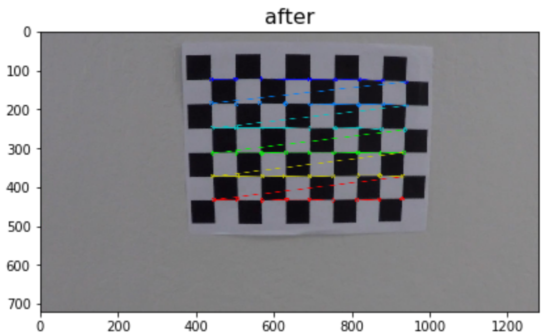

before

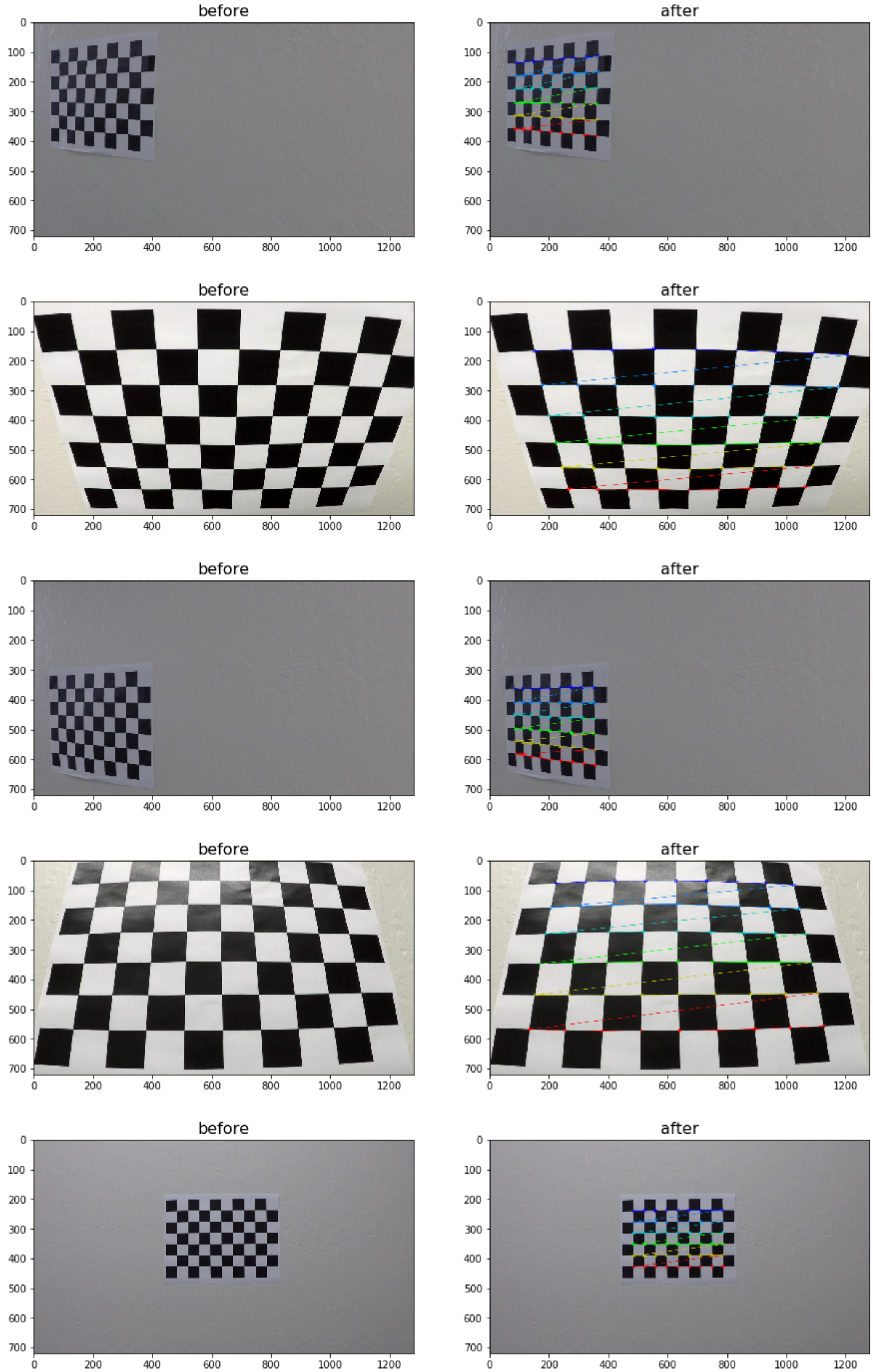

after

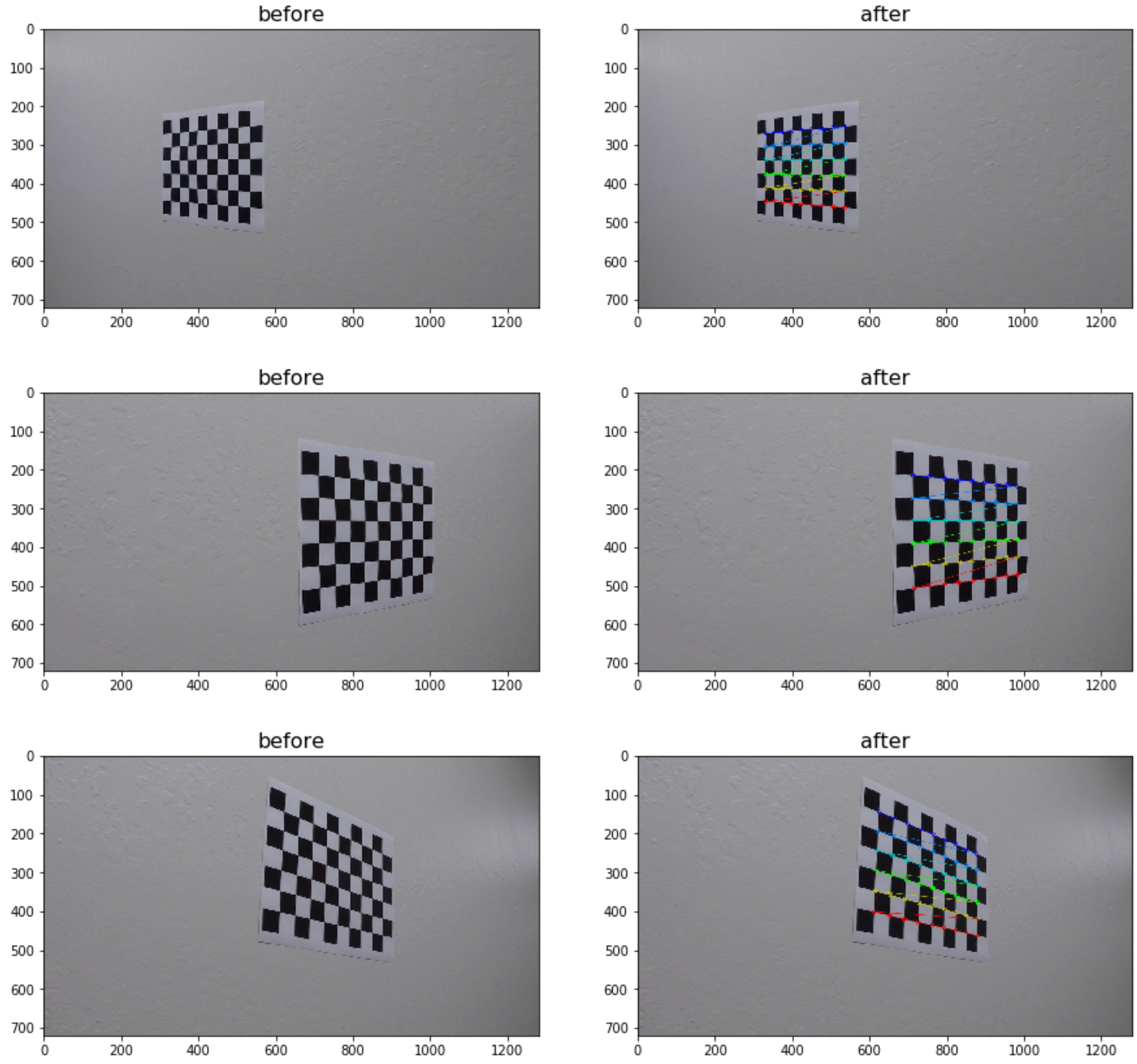

before


after


before


after


before
after
before
after
before
after
before
after
before
after
0
100
200
300
400
500
600
700
0
200
400
600
800
1000
1200



The camera calibration matrix and distortion coefficients were used with the OpenCV function undistort to remove distortion from highway driving images.

In [3]:

```
get_pathes = glob.glob('./test_images/*.jpg')
sample_image = mpimg.imread('./test_images/straight_lines1.jpg')
```

In [4]:

```
def cal_undistort(img, objpoints, imgpoints):
    gray = cv2.cvtColor(img,cv2.COLOR_BGR2GRAY)
    dst = cv2.undistort(img, cal_mtx, cal_dist, None, cal_mtx)
    return dst
```

Some helper function to show images.

In [5]:

```
def show_images(image_before, Image_after):
    f, (axis1, axis2) = plt.subplots(1, 2, figsize=(15,10))
    axis1.imshow(image_before,cmap='gray')
    axis1.set_title('before', fontsize=16)
    axis2.imshow(Image_after,cmap='gray')
    axis2.set_title('after', fontsize=16)

def show_Array_images(image_before):
    i=0
    for img in image_before:
        f, (axis1) = plt.subplots(1, 1, figsize=(15,10))
        axis1.imshow(image_before)
        axis1.set_title(++i, fontsize=16)
```

Step 2: Using thresholding teqniques just to get the white and the Yellow lanes colors.

In [6]:

```
def abs_sobel_thresh(img, orient='x', sobel_kernel=3, thresh=(0, 255)):
    # Convert to grayscale
    gray = cv2.cvtColor(img, cv2.COLOR_RGB2GRAY)
    # Apply x or y gradient with the OpenCV Sobel() function
    # and take the absolute value
    if orient == 'x':
        abs_sobel = np.absolute(cv2.Sobel(gray, cv2.CV_64F, 1, 0))
    if orient == 'y':
        abs_sobel = np.absolute(cv2.Sobel(gray, cv2.CV_64F, 0, 1))
    # Rescale back to 8 bit integer
    scaled_sobel = np.uint8(255*abs_sobel/np.max(abs_sobel))
    # Create a copy and apply the threshold
    binary_output = np.zeros_like(scaled_sobel)
    # Here I'm using inclusive (>=, <=) thresholds, but exclusive is ok too
    binary_output[(scaled_sobel >= thresh[0]) & (scaled_sobel <= thresh[1])] = 1

    # Return the result
    return binary_output
# Define a function that applies Sobel x and y,
# then computes the direction of the gradient
# and applies a threshold.
def mag_thresh(img, sobel_kernel=3, mag_thresh=(0, 50)):

    # Apply the following steps to img
    # 1) Convert to grayscale
    gray = cv2.cvtColor(img, cv2.COLOR_RGB2GRAY)
    # 2) Take the gradient in x and y separately
    abs_sobel_x = (cv2.Sobel(gray, cv2.CV_64F, 1, 0, ksize=sobel_kernel))
    abs_sobel_y = (cv2.Sobel(gray, cv2.CV_64F, 0, 1, ksize=sobel_kernel))
    # 3) Calculate the magnitude
    gradmag = np.sqrt(abs_sobel_x**2 + abs_sobel_y**2)
    # 4) Scale to 8-bit (0 - 255) and convert to type = np.uint8
    scale_factor = np.max(gradmag)/255
    gradmag = (gradmag/scale_factor).astype(np.uint8)
    binary_output = np.zeros_like(gradmag)
    binary_output[(gradmag >= mag_thresh[0]) & (gradmag <= mag_thresh[1])] = 1
    # 5) Create a binary mask where mag thresholds are met
    # 6) Return this mask as your binary_output image

    return binary_output


def dir_threshold(img, sobel_kernel=3, thresh=(0, np.pi/2)):
    # Grayscale
    gray = cv2.cvtColor(img, cv2.COLOR_RGB2GRAY)
    # Calculate the x and y gradients
    sobelx = cv2.Sobel(gray, cv2.CV_64F, 1, 0, ksize=sobel_kernel)
    sobely = cv2.Sobel(gray, cv2.CV_64F, 0, 1, ksize=sobel_kernel)
    # Take the absolute value of the gradient direction,
    # apply a threshold, and create a binary image result
    absgraddir = np.arctan2(np.absolute(sobely), np.absolute(sobelx))
    binary_output =  np.zeros_like(absgraddir)
    binary_output[(absgraddir >= thresh[0]) & (absgraddir <= thresh[1])] = 1

    # Return the binary image
    return binary_output

def color_thresholds(img, HLS_s_threshold=(90, 255), HLS_h_threshold=(15,100)):
    hls = cv2.cvtColor(img, cv2.COLOR_RGB2HLS)
```

```
    s_channel = hls[:,:,2]
    s_binary = np.zeros_like(s_channel)
    s_binary[(s_channel > HLS_s_threshold[0]) & (s_channel <= HLS_s_threshold[1])] = 1

    h_channel = hls[:,:,0]
    h_binary = np.zeros_like(h_channel)
    h_binary[(h_channel > HLS_h_threshold[0]) & (h_channel <= HLS_h_threshold[1])] = 1

    img_binary = np.zeros_like(s_channel)
    img_binary[(s_binary == 1) & (h_binary==1)] =1
    return img_binary
```

Step 3: Perspective Transform : The goal of this step is to transform the undistorted image to a "birds eye view" of the road which focuses only on the lane lines and displays them in such a way that they appear to be relatively parallel to eachother (as opposed to the converging lines you would normally see). To achieve the perspective transformation I first applied the OpenCV functions getPerspectiveTransform and warpPerspective which take a matrix of four source points on the undistorted image and remaps them to four destination points on the warped image. The source and destination points were selected manually by visualizing the locations of the lane lines on a series of test images.

In [7]:

```
def birds_eye(img, display=True, read = True):
    img_size = (img.shape[1], img.shape[0])
    offset = 0
    src = np.float32([[490, 482],[810, 482],
                      [1250, 720],[40, 720]])
    dst = np.float32([[0, 0], [1280, 0],
                     [1250, 720],[40, 720]])
    M = cv2.getPerspectiveTransform(src, dst)
    Minv = cv2.getPerspectiveTransform(dst, src)
    warped = cv2.warpPerspective(img, M, img_size)
    if display:
        f, (ax1, ax2) = plt.subplots(1, 2, figsize=(9, 6))
        f.tight_layout()
        ax1.imshow(img,cmap='gray')
        ax1.set_title('Undistorted Image', fontsize=20)
        ax2.imshow(warped,cmap='gray')
        ax2.set_title('Undistorted and Warped Image', fontsize=20)
        plt.subplots_adjust(left=0., right=1, top=0.9, bottom=0.)
        return warped , Minv
    else:
        return warped , Minv
```

Historgarm

a function to do histogram to identify the peaks / loction of the white and Yellow line to start ur search

In [8]:

```
def get_histogram(img,splot='n'):
    histogram = np.sum(birds[img.shape[0]//2:,:], axis=0)
    if splot == 'y':
        plt.plot(histogram)
        return(histogram)
    else:
        return(histogram)
```

Sliding Window

In [9]:

```
def sliding_windows(binary_warped):

    histogram = np.sum(binary_warped[int(binary_warped.shape[0]/2):,:], axis=0)
    out_img = np.dstack((binary_warped, binary_warped, binary_warped))*255
    midpoint = np.int(histogram.shape[0]/2)
    leftx_base = np.argmax(histogram[:midpoint])
    rightx_base = np.argmax(histogram[midpoint:]) + midpoint
    nwindows = 9
    window_height = np.int(binary_warped.shape[0]/nwindows)
    nonzero = binary_warped.nonzero()
    nonzeroy = np.array(nonzero[0])
    nonzerox = np.array(nonzero[1])
    leftx_current = leftx_base
    rightx_current = rightx_base
    margin = 50
    minpix = 1
    left_lane_inds = []
    right_lane_inds = []

    for window in range(nwindows):
        win_y_low = binary_warped.shape[0] - (window+1)*window_height
        win_y_high = binary_warped.shape[0] - window*window_height
        win_xleft_low = leftx_current - margin
        win_xleft_high = leftx_current + margin
        win_xright_low = rightx_current - margin
        win_xright_high = rightx_current + margin
        cv2.rectangle(out_img,(win_xleft_low,win_y_low),(win_xleft_high,win_y_high),(0,
255,0), 2)
        cv2.rectangle(out_img,(win_xright_low,win_y_low),(win_xright_high,win_y_high),(
0,255,0), 2)
        good_left_inds = ((nonzeroy >= win_y_low) & (nonzeroy < win_y_high) & (nonzerox
 >= win_xleft_low) & (nonzerox < win_xleft_high)).nonzero()[0]
        good_right_inds = ((nonzeroy >= win_y_low) & (nonzeroy < win_y_high) & (nonzero
x >= win_xright_low) & (nonzerox < win_xright_high)).nonzero()[0]
        left_lane_inds.append(good_left_inds)
        right_lane_inds.append(good_right_inds)
        if len(good_left_inds) > minpix:
            leftx_current = np.int(np.mean(nonzerox[good_left_inds]))
        if len(good_right_inds) > minpix:
            rightx_current = np.int(np.mean(nonzerox[good_right_inds]))
    left_lane_inds = np.concatenate(left_lane_inds)
    right_lane_inds = np.concatenate(right_lane_inds)
    leftx = nonzerox[left_lane_inds]
    lefty = nonzeroy[left_lane_inds]
    rightx = nonzerox[right_lane_inds]
    righty = nonzeroy[right_lane_inds]
    left_fit = np.polyfit(lefty, leftx, 2)
    right_fit = np.polyfit(righty, rightx, 2)
    ploty = np.linspace(0, binary_warped.shape[0]-1, binary_warped.shape[0] )
    left_fitx = left_fit[0]*ploty**2 + left_fit[1]*ploty + left_fit[2]
    right_fitx = right_fit[0]*ploty**2 + right_fit[1]*ploty + right_fit[2]
    out_img[nonzeroy[left_lane_inds], nonzerox[left_lane_inds]] = [0, 255, 0]
    out_img[nonzeroy[right_lane_inds], nonzerox[right_lane_inds]] = [0, 255, 0]



    return out_img, ploty, left_fitx, right_fitx, left_fit, right_fit, leftx, rightx, l
eftx_base, rightx_base
```

Curvature

Calculate crvature

In [10]:

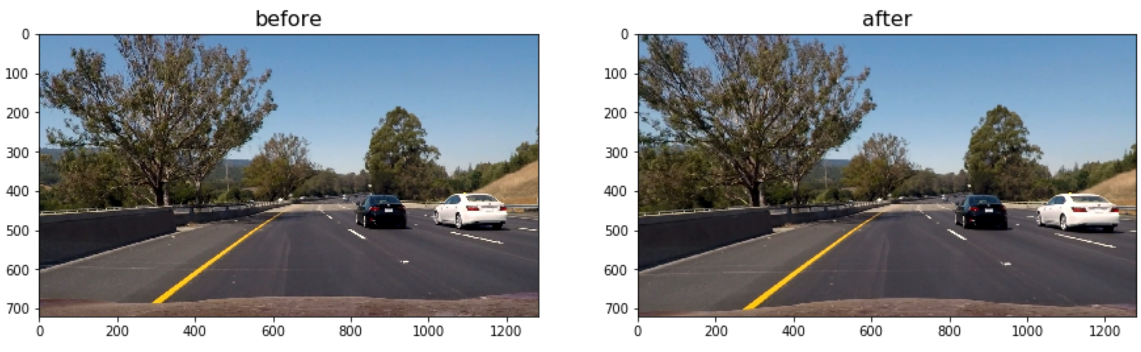
```
def roc_in_meters(ploty, left_fit, right_fit, leftx, rightx):

    ym_per_pix = 30/550
    xm_per_pix = 3.5/1000
    y_eval = np.max(ploty)
    leftx = np.array(leftx, dtype=np.float32)
    left_fit_cr = np.polyfit(leftx*ym_per_pix, leftx*xm_per_pix, 2)
    left_curverad = ((1 + (2*left_fit[0]*y_eval*ym_per_pix + left_fit[1])**2)**1.5) / np.absolute(2*left_fit_cr[0])


    return left_curverad
```

Warp the detected lane boundaries back onto the original image.

Just show a smample image after and before applying undistortion fcuntion

In [11]:

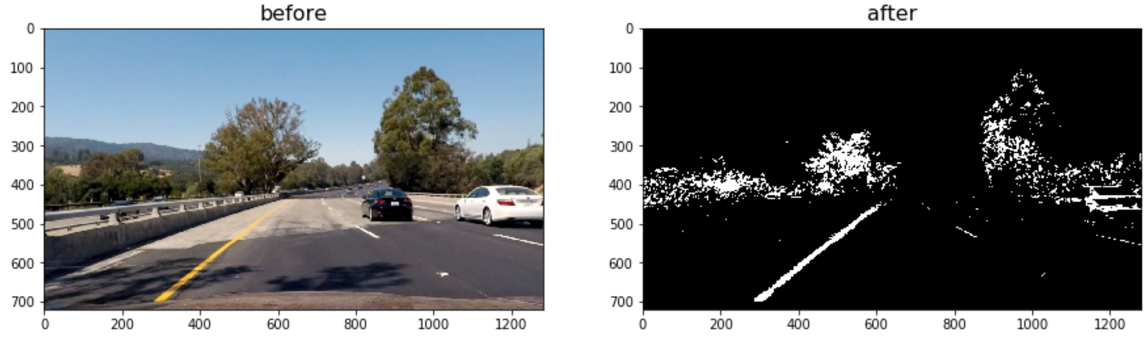
```
newimages=[]
for img_path in get_pathes:
    sample_image = mpimg.imread(img_path)
    undistorted = cal_undistort(sample_image, objpoints, imgpoints)
    newimages.append(undistorted)
show_images(sample_image,undistorted)
```



Apply the color treshold on one of the images to evaluate its efficiency

In [12]:

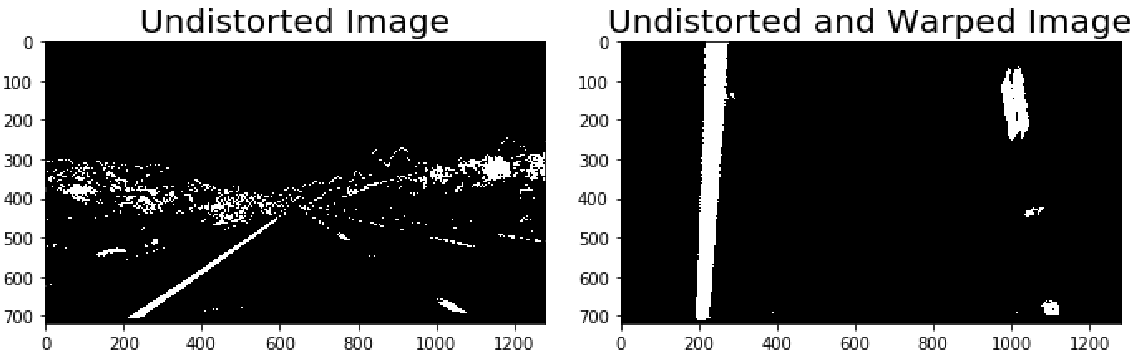
```
image = newimages[5]
color = color_thresholds(image,HLS_s_threshold=(90, 255))
show_images(image,color)
```

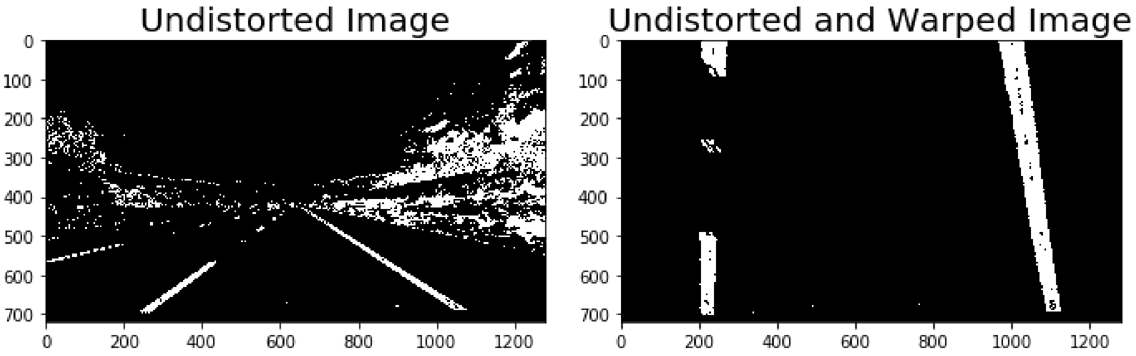


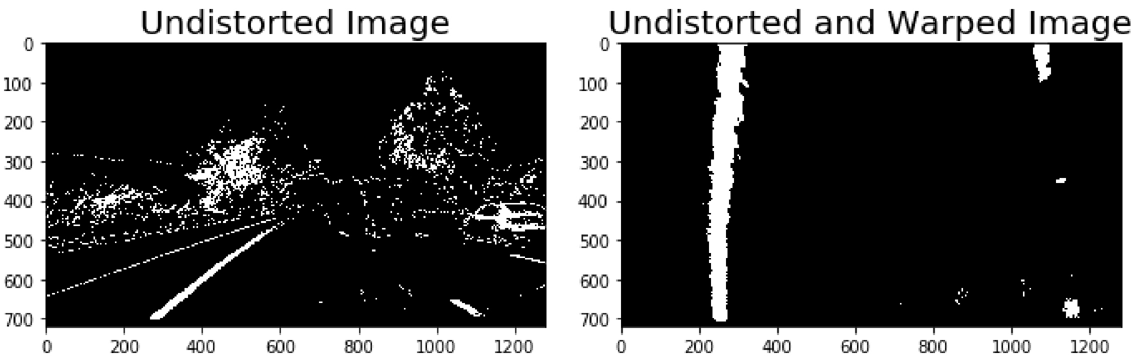
Test with the sample images , till the bird eye view

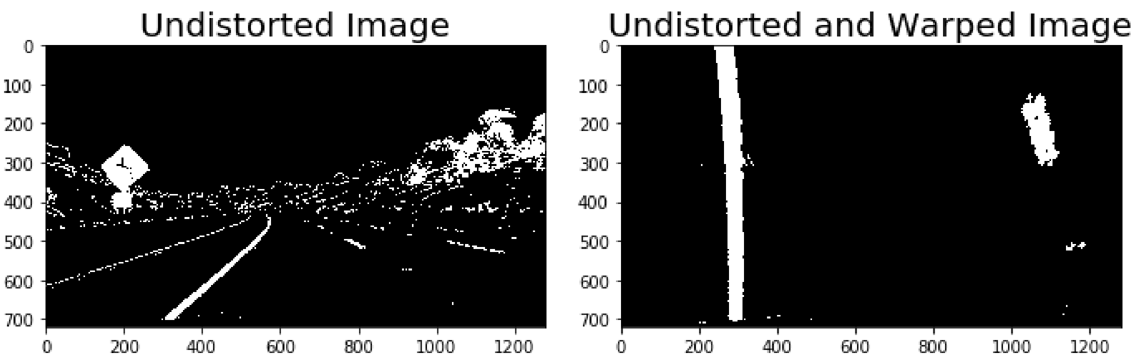
In [13]:

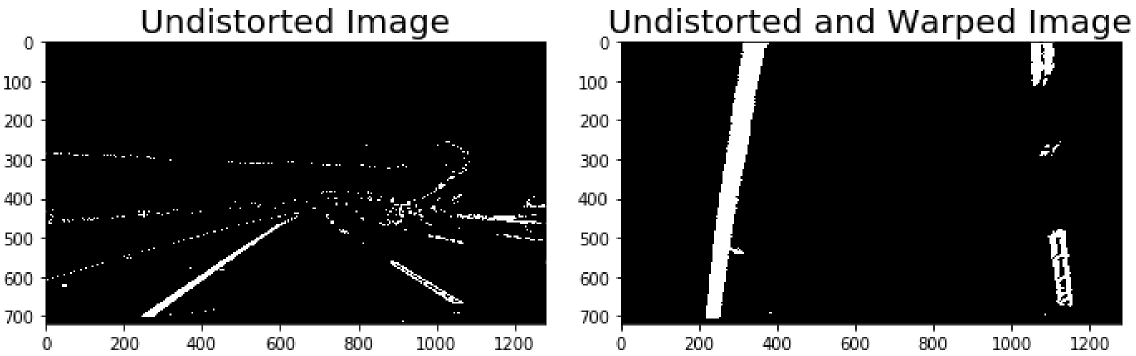
```
bird_views=[]
for image in newimages:

    gradx = abs_sobel_thresh(image, orient='x', sobel_kernel=3, thresh=(15, 255))
    grady = abs_sobel_thresh(image, orient='y', sobel_kernel=3, thresh=(35, 255))
    mag_binary = mag_thresh(image, sobel_kernel=9, mag_thresh=(60, 255))
    dir_binary = dir_threshold(image, sobel_kernel=9, thresh=(0.7, 1.1))
    color = color_thresholds(image)
    img = cv2.cvtColor(image, cv2.COLOR_RGB2GRAY)

    combined = np.zeros_like(img)

    combined[(gradx == 1) & (grady == 1) & (mag_binary == 1) | (color == 1) | (mag_bina
ry == 1) & (dir_binary == 1)] = 1
    birds,M = birds_eye(combined, display=True)

    ### experiment code
    bird_views.append(birds)
```

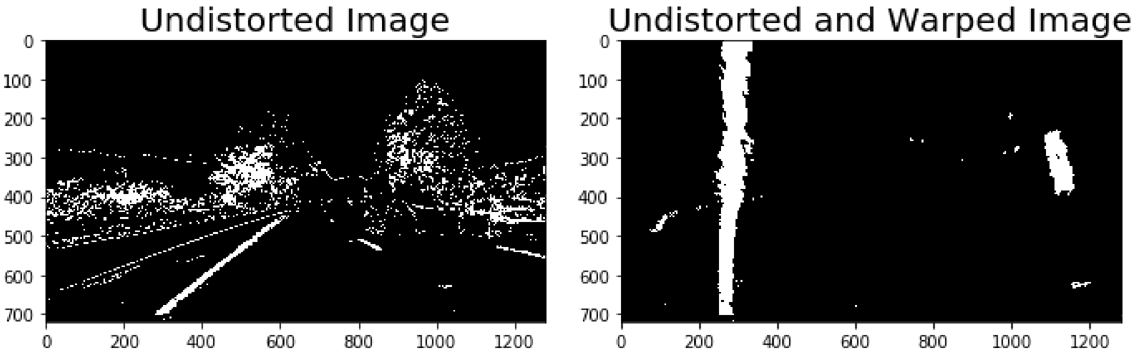

Undistorted Image
Undistorted and Warped Image

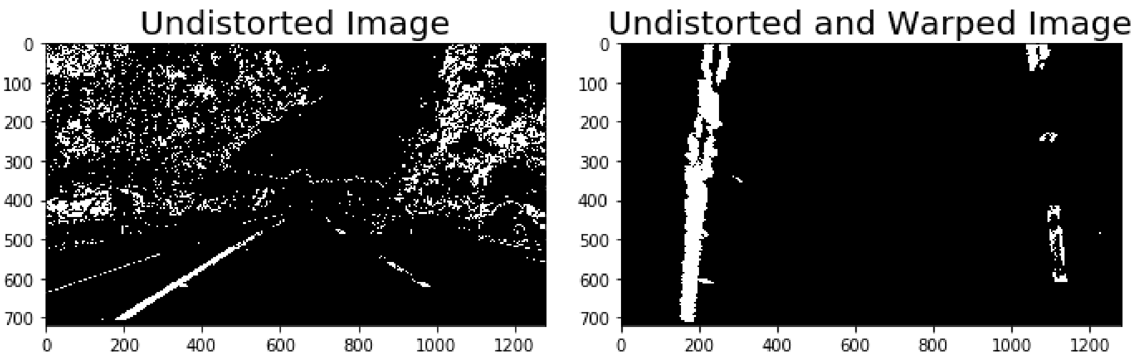

Undistorted Image
Undistorted and Warped Image

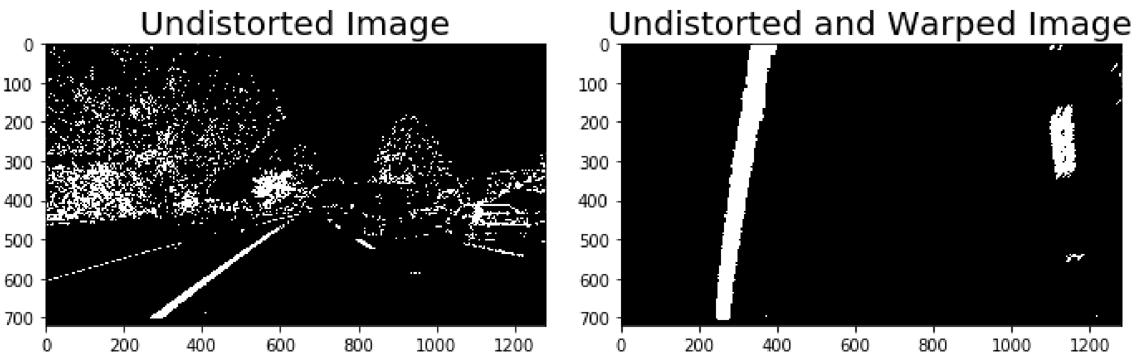

Undistorted Image
Undistorted and Warped Image


Undistorted Image
Undistorted and Warped Image









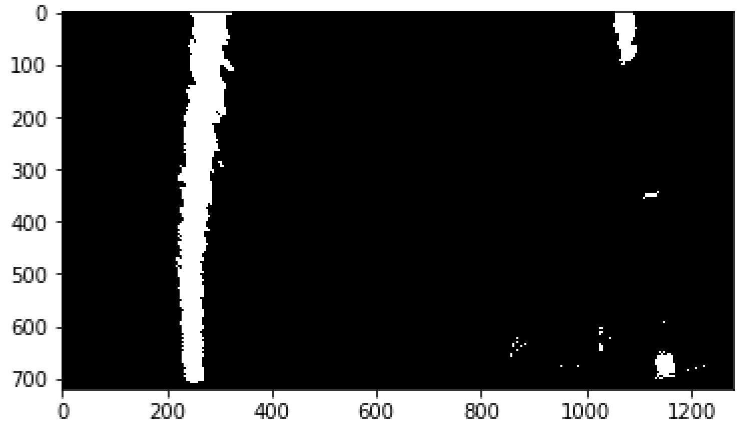
Detect lane pixels and fit to find the lane boundary.

In [14]:

```
birds = bird_views[2]
historgram =get_histogram(birds)
plt.imshow(birds, cmap='gray')
```

Out[14]:

<matplotlib.image.AxesImage at 0x1bebe4ab860>

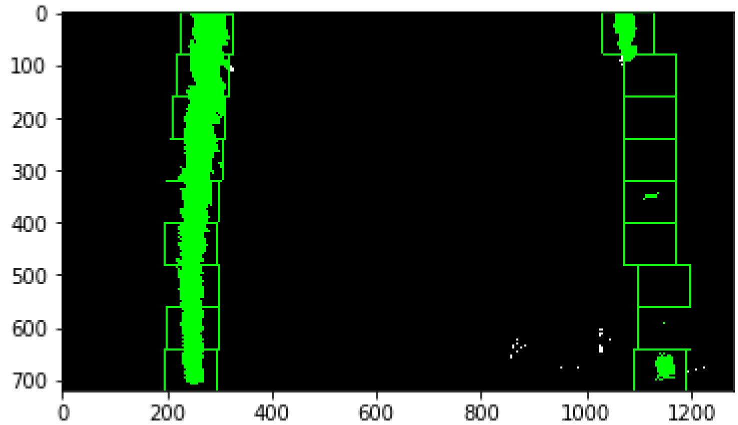


In [15]:

```
result, ploty, left_fitx, right_fitx, left_fit, right_fit, leftx, rightx, leftx_base, r
ightx_base = sliding_windows(birds)
plt.imshow(result)
```

Out[15]:

<matplotlib.image.AxesImage at 0x1bec01cd1d0>



Wrapping

In [16]:

```
def draw_lane(original_img, binary_img, l_fit, r_fit, Minv):
    new_img = np.copy(original_img)
    if l_fit is None or r_fit is None:
        return original_img
    # Create an image to draw the lines on
    warp_zero = np.zeros_like(binary_img).astype(np.uint8)
    color_warp = np.dstack((warp_zero, warp_zero, warp_zero))

    h,w = binary_img.shape
    ploty = np.linspace(0, h-1, num=h)# to cover same y-range as image
    left_fitx = l_fit[0]*ploty**2 + l_fit[1]*ploty + l_fit[2]
    right_fitx = r_fit[0]*ploty**2 + r_fit[1]*ploty + r_fit[2]

    # Recast the x and y points into usable format for cv2.fillPoly()
    pts_left = np.array([np.transpose(np.vstack([left_fitx, ploty]))])
    pts_right = np.array([np.flipud(np.transpose(np.vstack([right_fitx, ploty])))])
    pts = np.hstack((pts_left, pts_right))

    # Draw the lane onto the warped blank image
    cv2.fillPoly(color_warp, np.int_([pts]), (0,255, 0))
    cv2.polylines(color_warp, np.int32([pts_left]), isClosed=False, color=(255,0,255), 
thickness=15)
    cv2.polylines(color_warp, np.int32([pts_right]), isClosed=False, color=(0,255,255),
 thickness=15)

    # Warp the blank back to original image space using inverse perspective matrix (Min
v)
    newwarp = cv2.warpPerspective(color_warp, Minv, (w, h))
    # Combine the result with the original image
    result = cv2.addWeighted(new_img, 1, newwarp, 0.5, 0)
    return result
```

In [17]:

```
def pos_center(img_center, leftx_base, rightx_base):
    poly_center = (leftx_base + rightx_base) / 2
    diff_pix = img_center - poly_center
    xm_per_pix = 3.5/1000
    posyapos = diff_pix * xm_per_pix
    return posyapos
```

In [18]:

```
def annotate(img, left_curverad, camera):
    font = cv2.FONT_HERSHEY_COMPLEX_SMALL
    cv2.putText(img, 'Curvature: {0:6f} meters'.format(left_curverad), (10,30), font, 2
, (255,0,0), 2)
    cv2.putText(img, 'Camera Offset: {0:6f} meters'.format(camera), (10,80), font,2, (0
,0,255), 2)
```

Video Processing Pipeline:

After establishing a pipeline to process still images, the final step was to expand the pipeline to process videos frame-by-frame, to simulate what it would be like to process an image stream in real time on an actual vehicle.

My goal in developing a video processing pipeline was to create as smooth of an output as possible. To achieve this, I created a class for each of the left and right lane lines and stored features of each lane for averaging across frames.

The video pipeline first checks whether or not the lane was detected in the previous frame. If it was, then it only checks for lane pixels in close proximity to the polynomial calculated in the previous frame. This way, the pipeline does not need to scan the entire image, and the pixels detected have a high confidence of belonging to the lane line because they are based on the location of the lane in the previous frame.

In [19]:

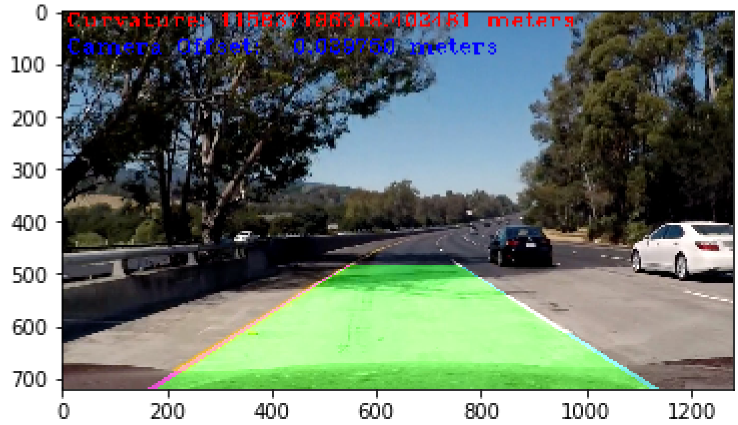
```
def pipline(img):
    img_c = np.copy(img)
    image = cal_undistort(img_c, objpoints, imgpoints)
    gradx = abs_sobel_thresh(image, orient='x', sobel_kernel=3, thresh=(15, 255))
    grady = abs_sobel_thresh(image, orient='y', sobel_kernel=3, thresh=(35, 255))
    mag_binary = mag_thresh(image, sobel_kernel=9, mag_thresh=(60, 255))
    dir_binary = dir_threshold(image, sobel_kernel=9, thresh=(0.7, 1.1))
    color = color_thresholds(image)
    img_g = cv2.cvtColor(image, cv2.COLOR_RGB2GRAY)

    combined = np.zeros_like(img_g)

    combined[(gradx == 1) & (grady == 1) & (mag_binary == 1) | (color == 1) | (mag_bina
ry == 1) & (dir_binary == 1)] = 1
    birds , Minv = birds_eye(combined, display=False)

    ### experiment code
    bird_views.append(birds)

    windows_img, ploty, left_fitx, right_fitx, left_fit, right_fit, leftx, rightx, left
x_base, rightx_base = sliding_windows(birds)
    left_curverad = roc_in_meters(ploty, left_fit, right_fit, leftx, rightx)
    center_pos =  pos_center(img.shape[1]/2,leftx_base,rightx_base)
    annotate(img, left_curverad,  center_pos)
    result = draw_lane(img ,birds,left_fit, right_fit, Minv)
    return result
```

In [20]:

```
img = mpimg.imread("test_images/test5.jpg")
result = pipline(img)
plt.imshow(result)
```

Out[20]:

```
<matplotlib.image.AxesImage at 0x1bebee85d68>
```



In [21]:

```
from moviepy.editor import VideoFileClip

video_output3 = 'Project_video_output.mp4'
video_input3 = VideoFileClip('project_video.mp4')
#video_input3.save_frame("hard_challenge01.jpeg") # saves the first frame
processed_video = video_input3.fl_image(pipline)
%time processed_video.write_videofile(video_output3, audio=False)
```

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

100%|
| 1260/1261 [07:06<00:00,  2.96it/s]

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

Wall time: 7min 6s
```

Conclusion

I was able to run the pipeline over the images, i think the result are quite okey. i think i need to optimse the pipeline more, it takes too much time to process. probably we should lower rate frames , and may be smaller or lower quality images that could seed up the processing. It took alot of time to fine tune the parameters , also i think this wont work on diffent enviroments. There should be a way to auto calibrate colors, in differnt lighting or enviroments.