Finding lane lines for self-driving cars

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PyData Berlin 2017

About me

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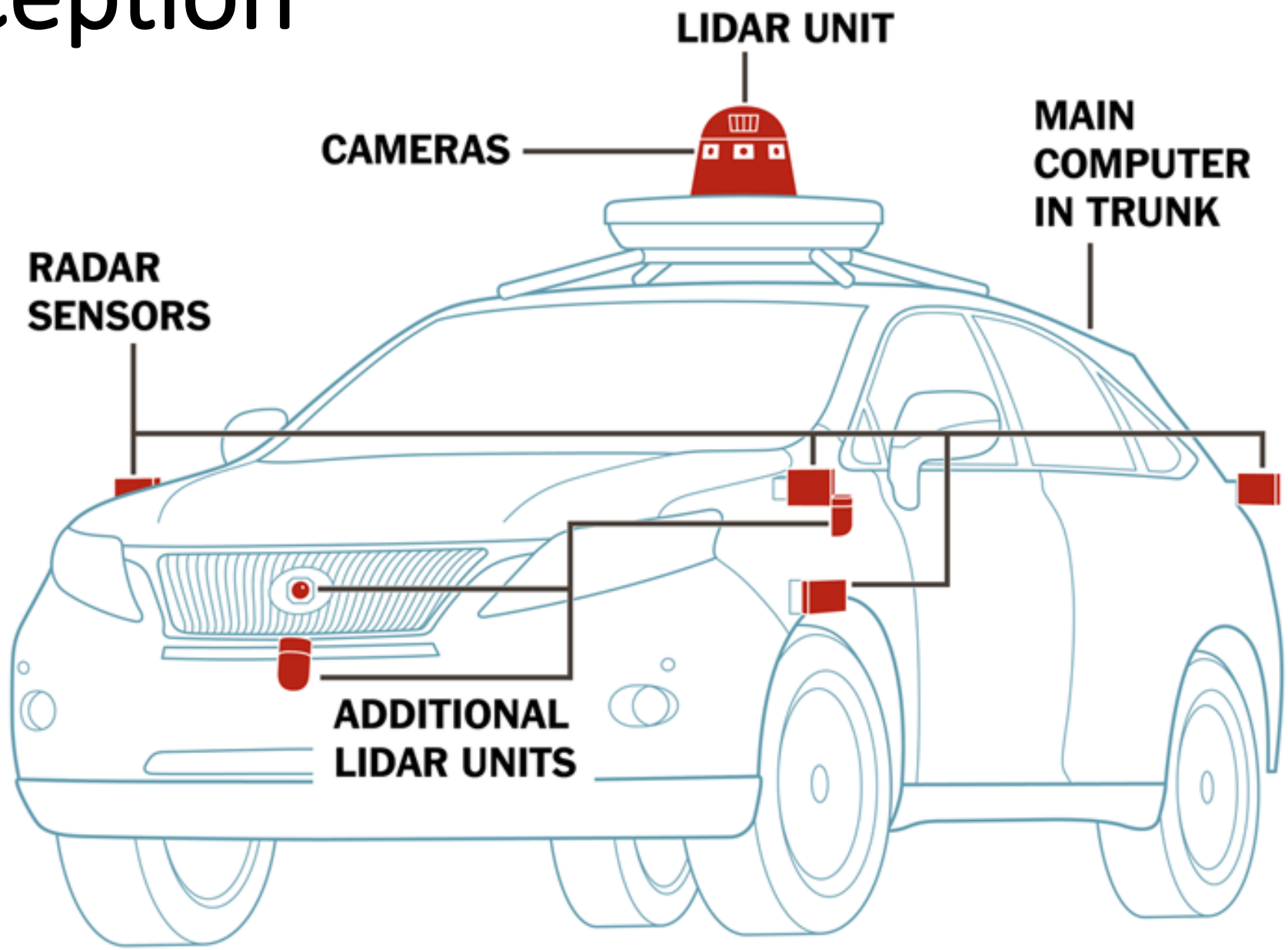
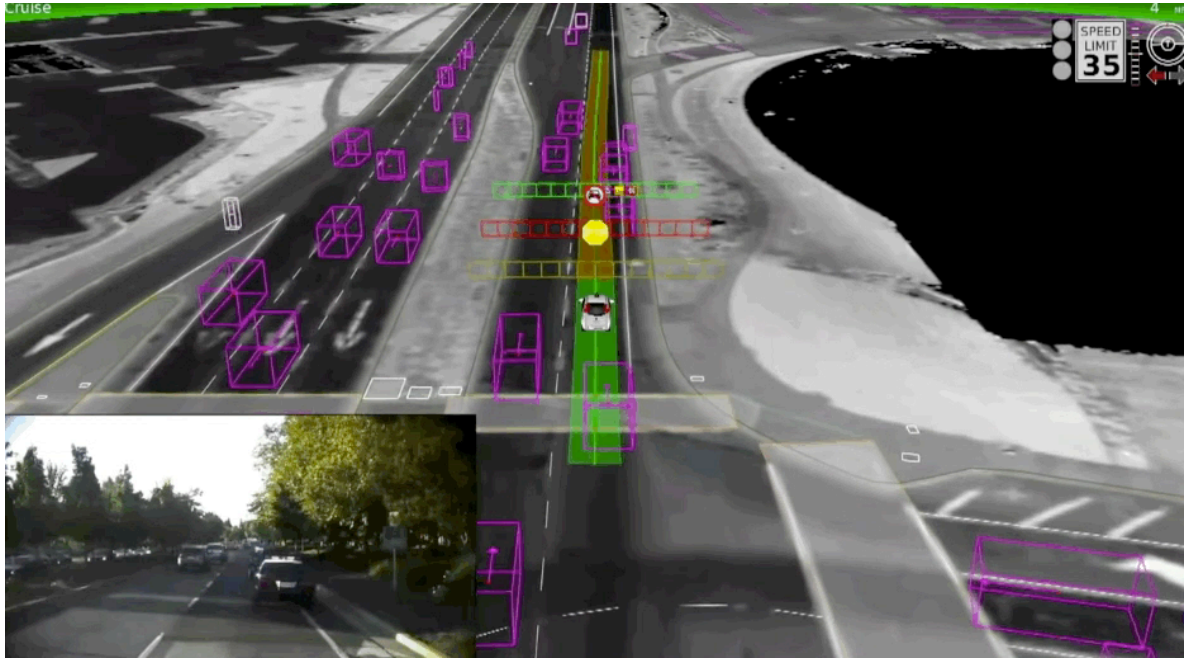
alteryx

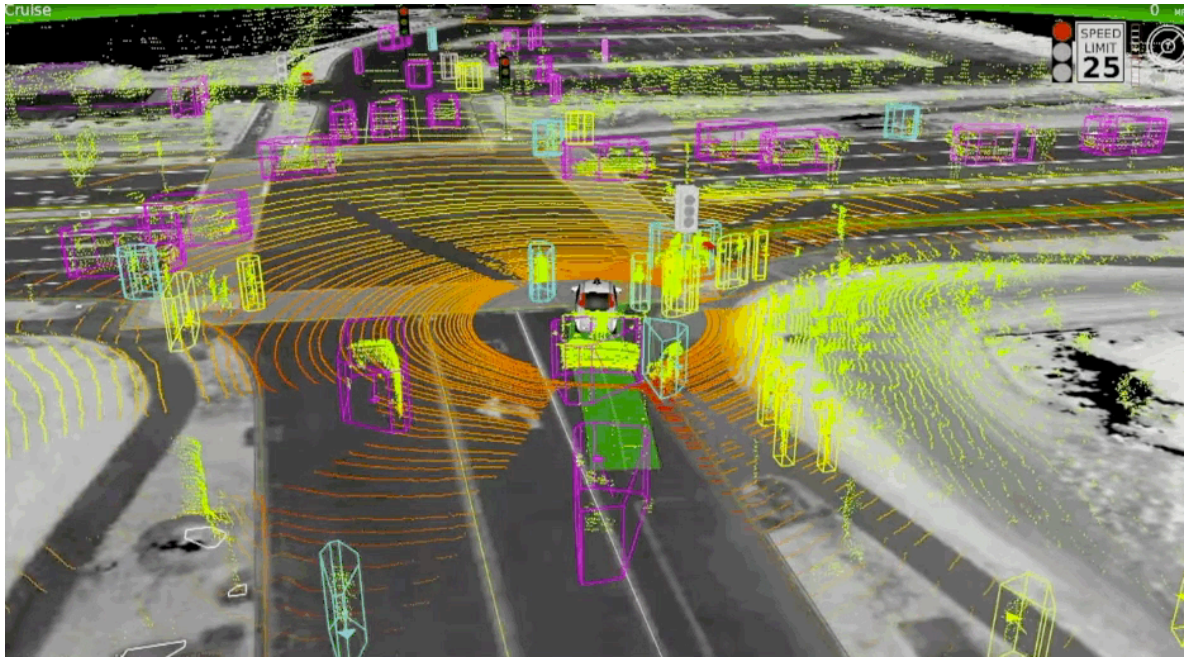
Autonomous Cars need to do 3 things

Perception

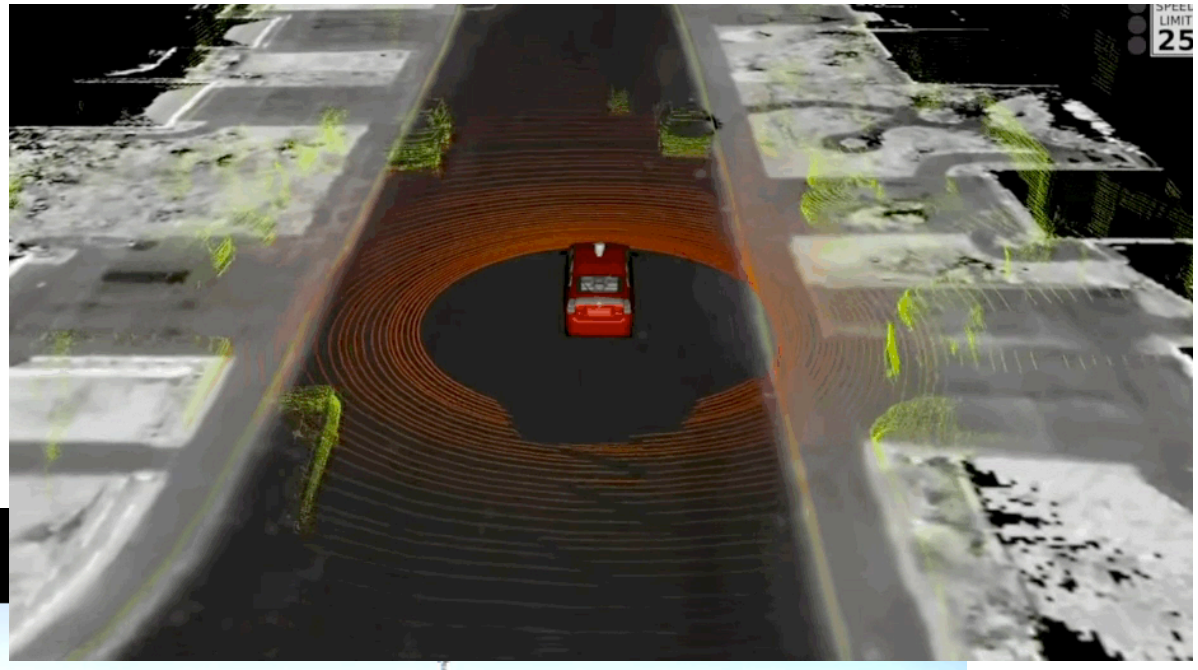

LIDAR UNIT
CAMERAS
MAIN COMPUTER IN TRUNK
RADAR SENSORS
ADDITIONAL LIDAR UNITS

Decision





Action



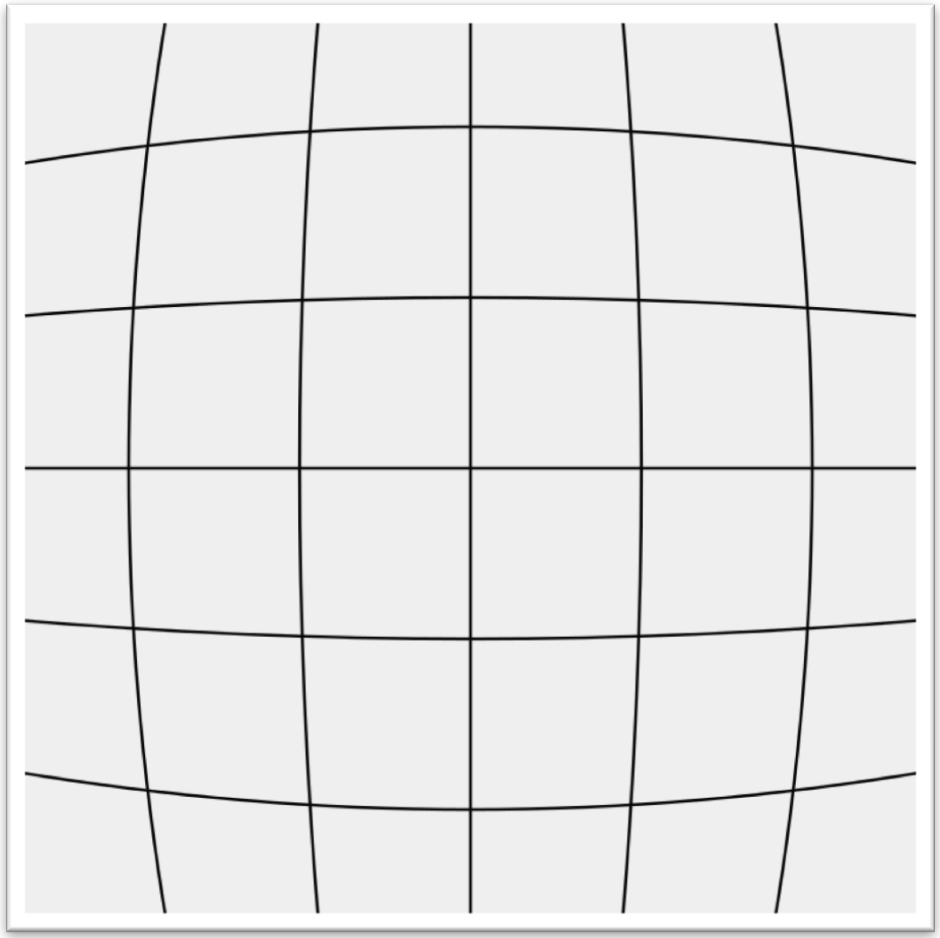
Finding lane lines is perception and decision

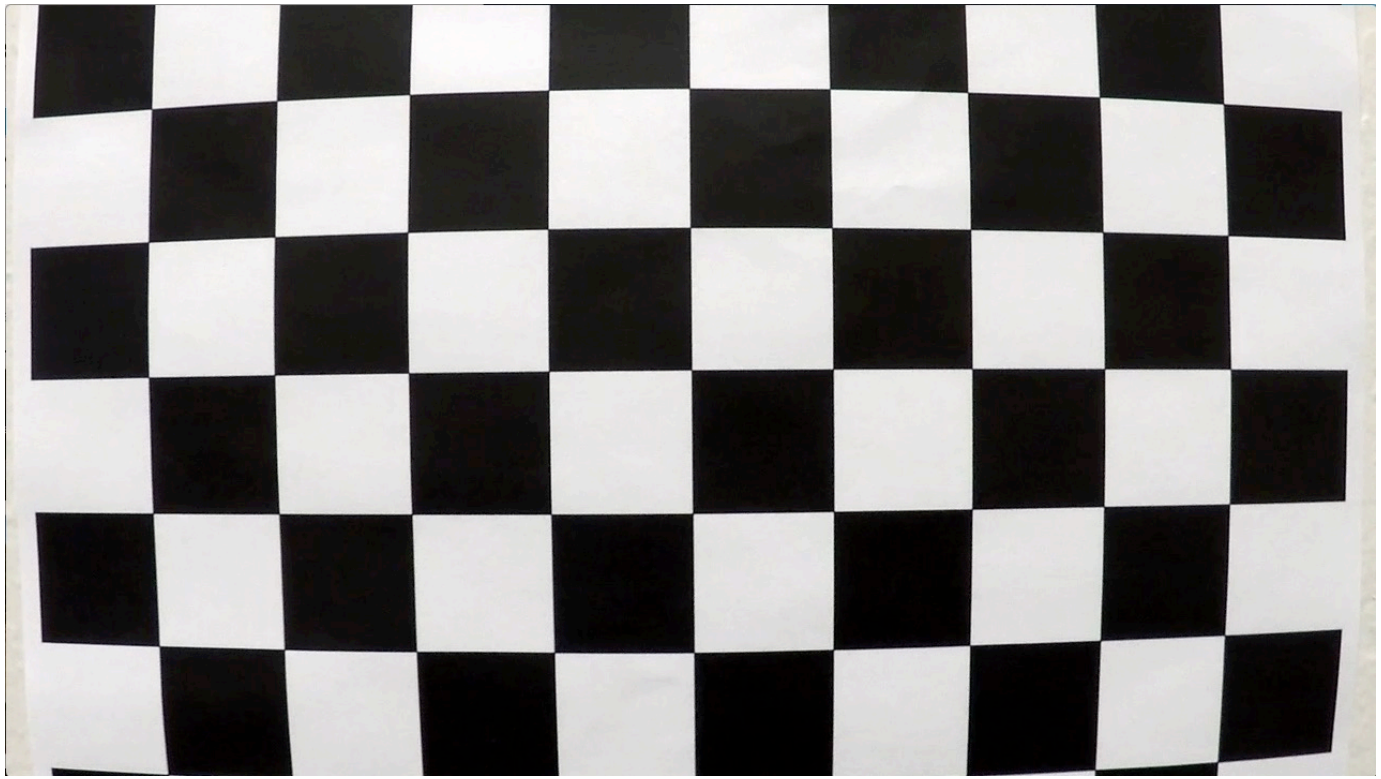
What are we building?

1. Undistort
2. Warp
3. Isolate Lanes
4. Curve Fit
5. Final Image

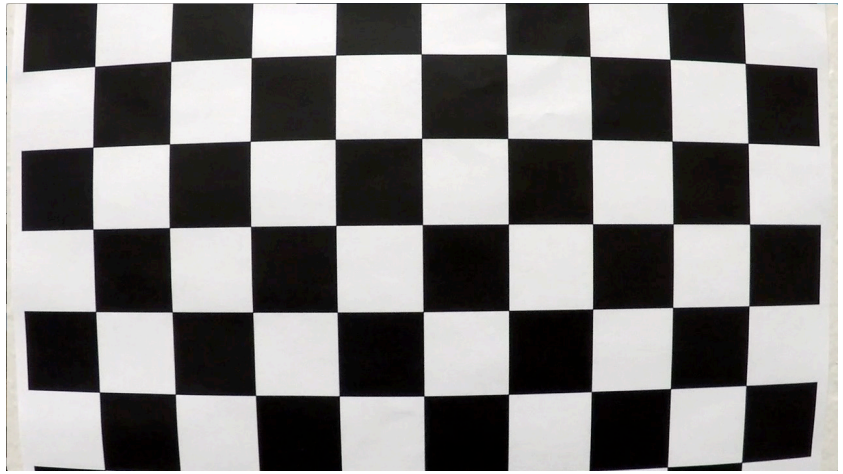
Removing distortion

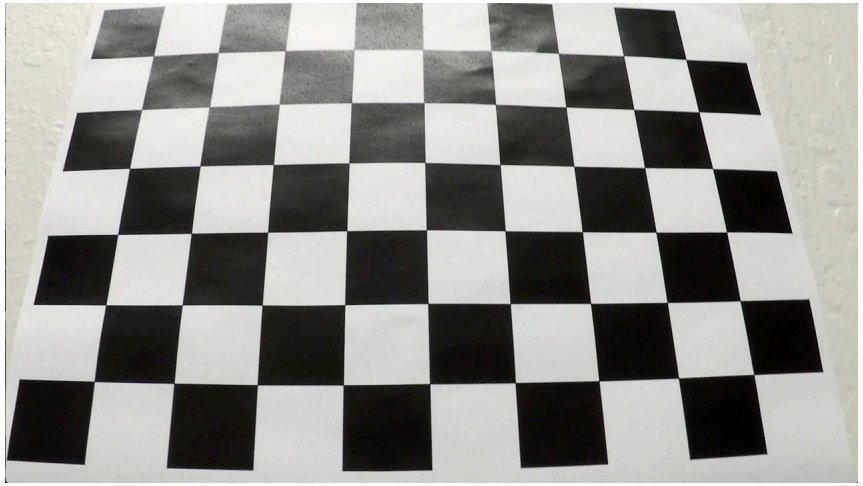
Camera Lens Distortion

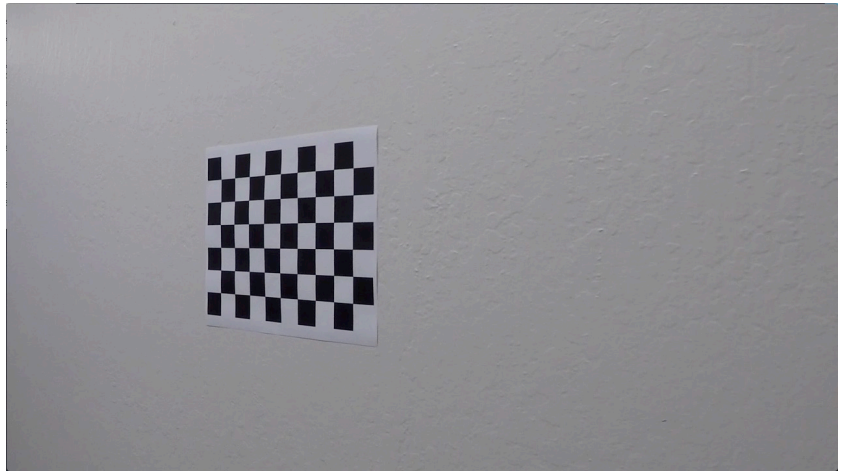


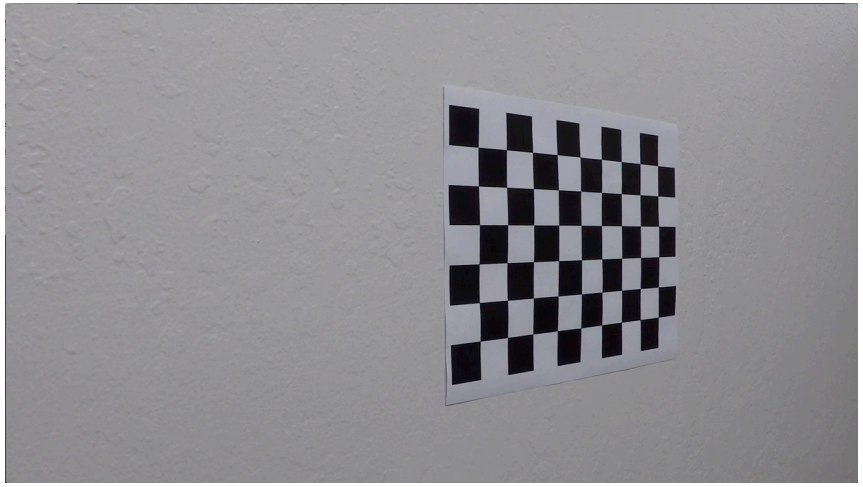


OpenCV helps us correct for these distortions

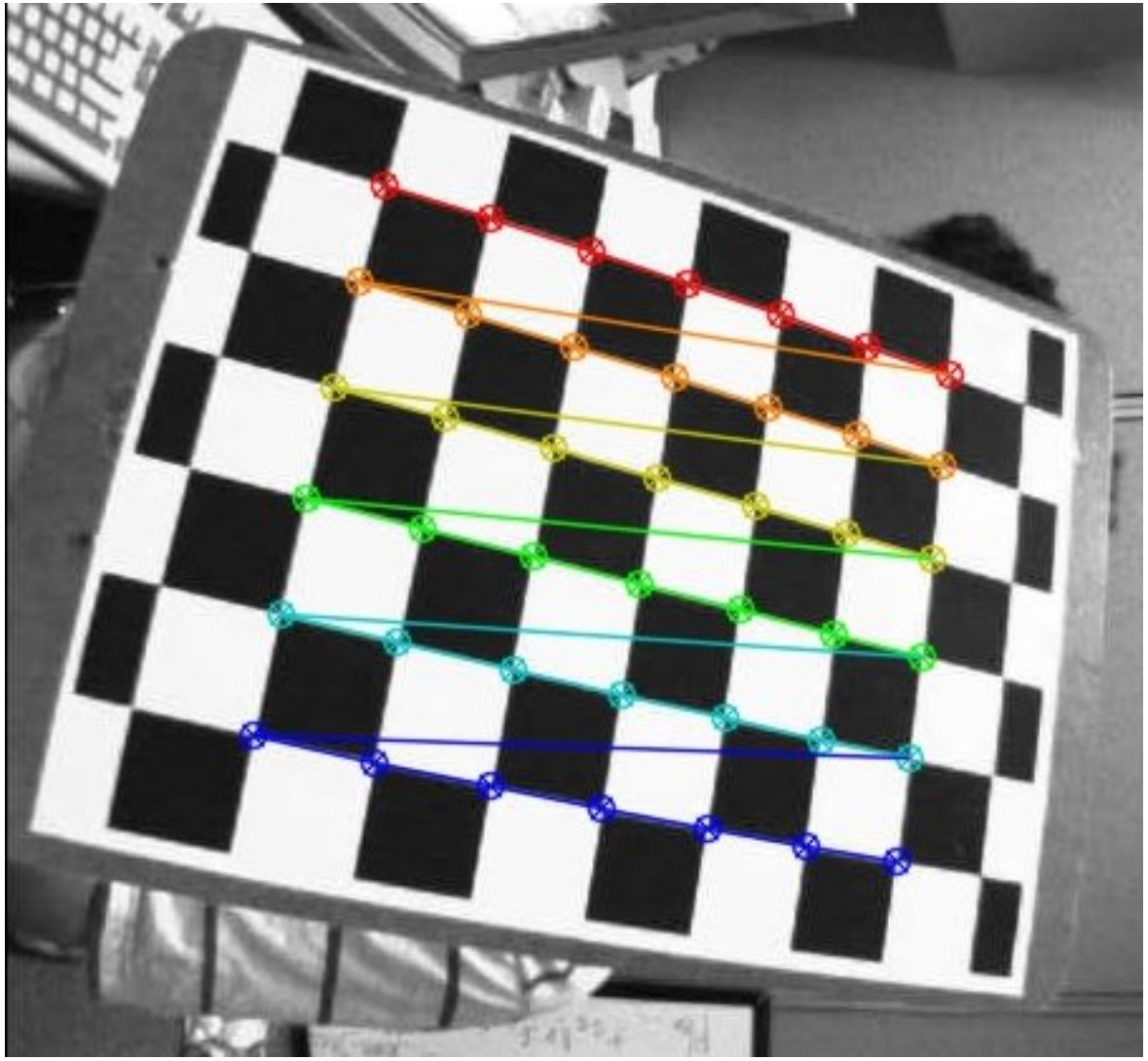






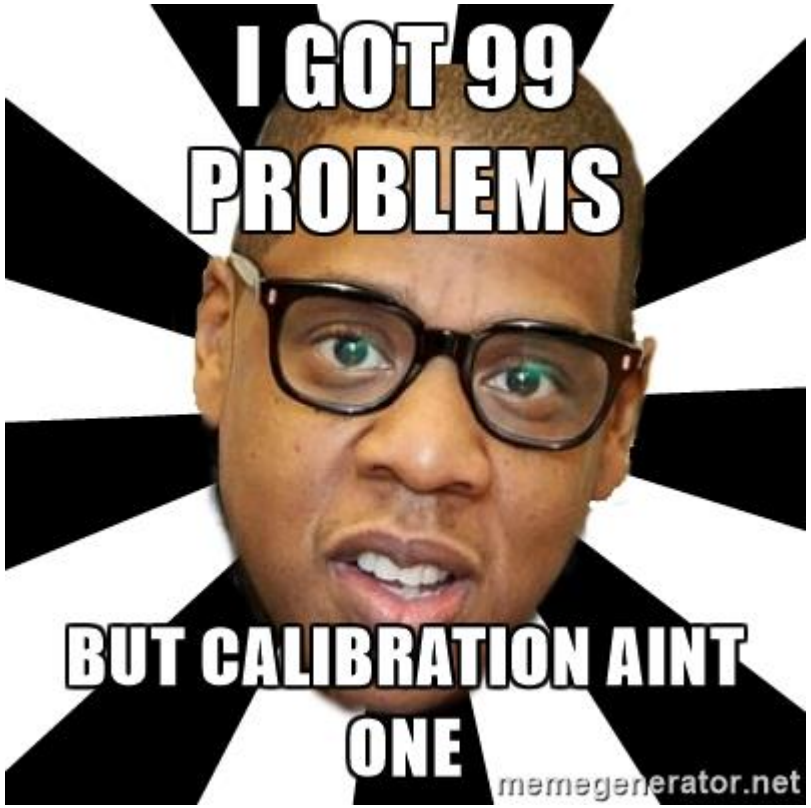


```
ret, corners = cv2.findChessboardCorners(gray, (9,6), None)
```



Calibrate the camera

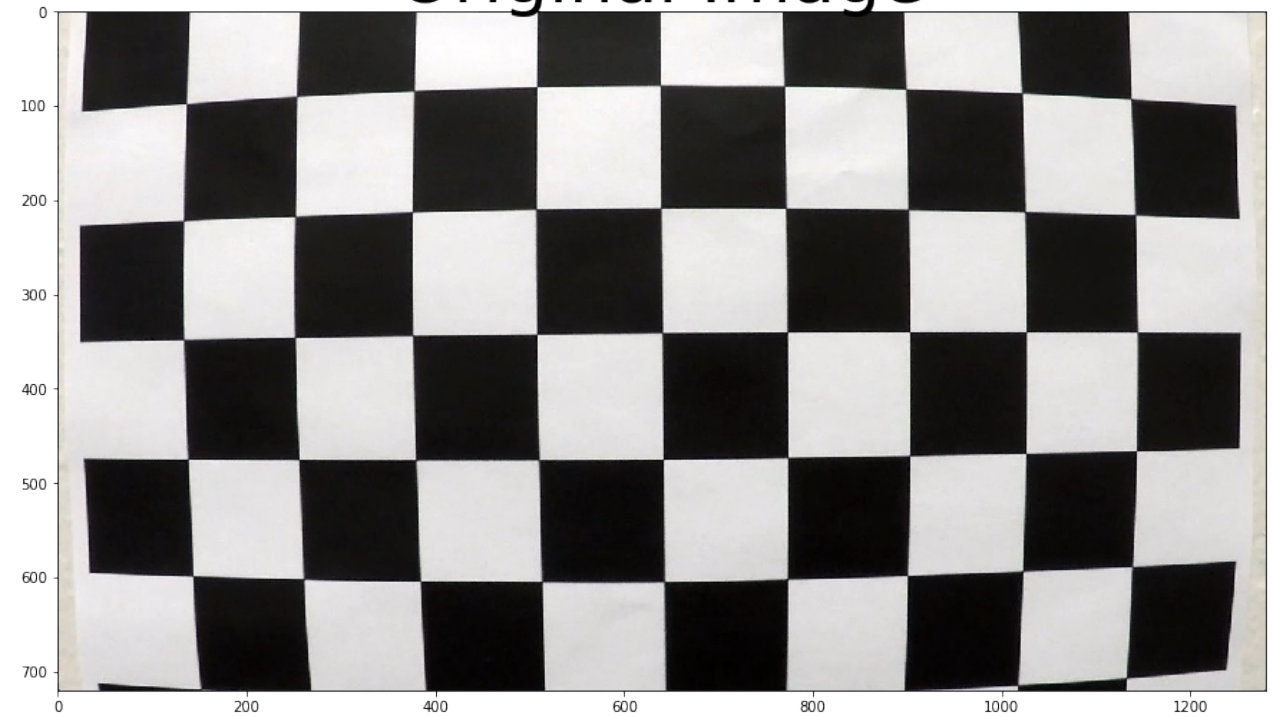
```
ret, mtx, dist, rvecs, tvecs =
cv2.calibrateCamera(
      objpoints,
      imgpoints,
      gray.shape[::-1],
      None,
      None
)
```



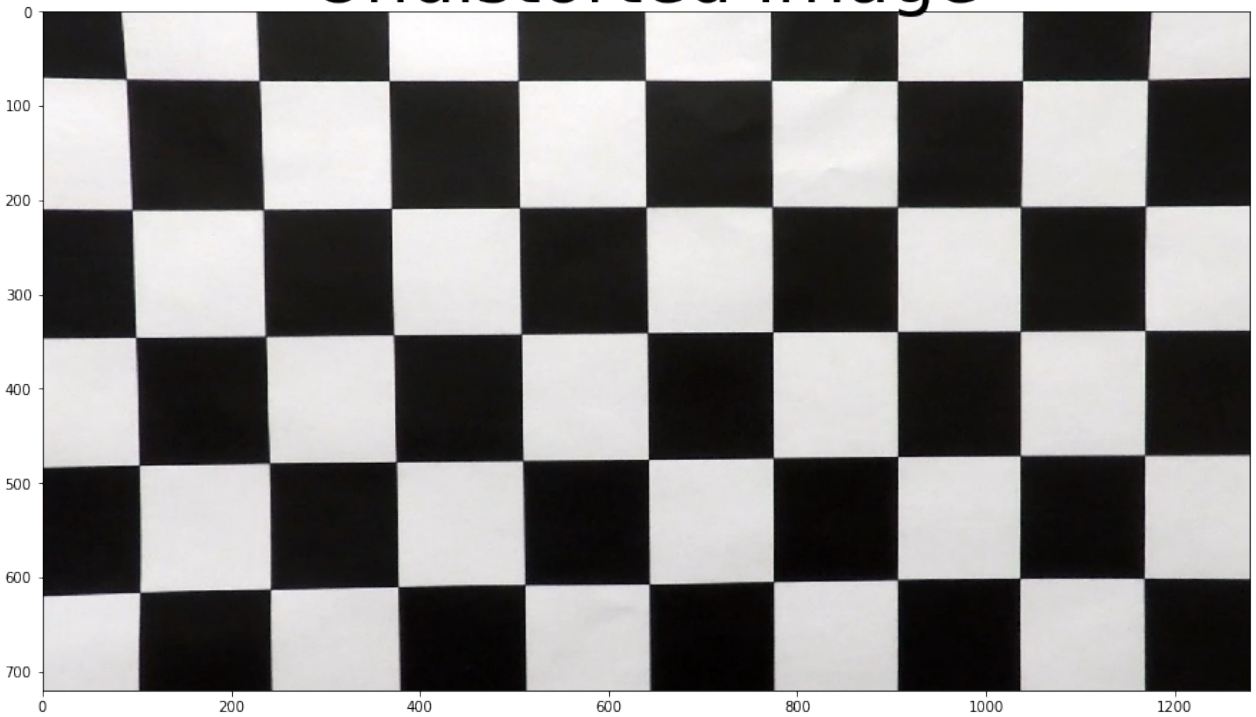
Use the camera calibration to undistort images

```
undist = cv2.undistort(img, mtx, dist, None, mtx)
```

Original Image

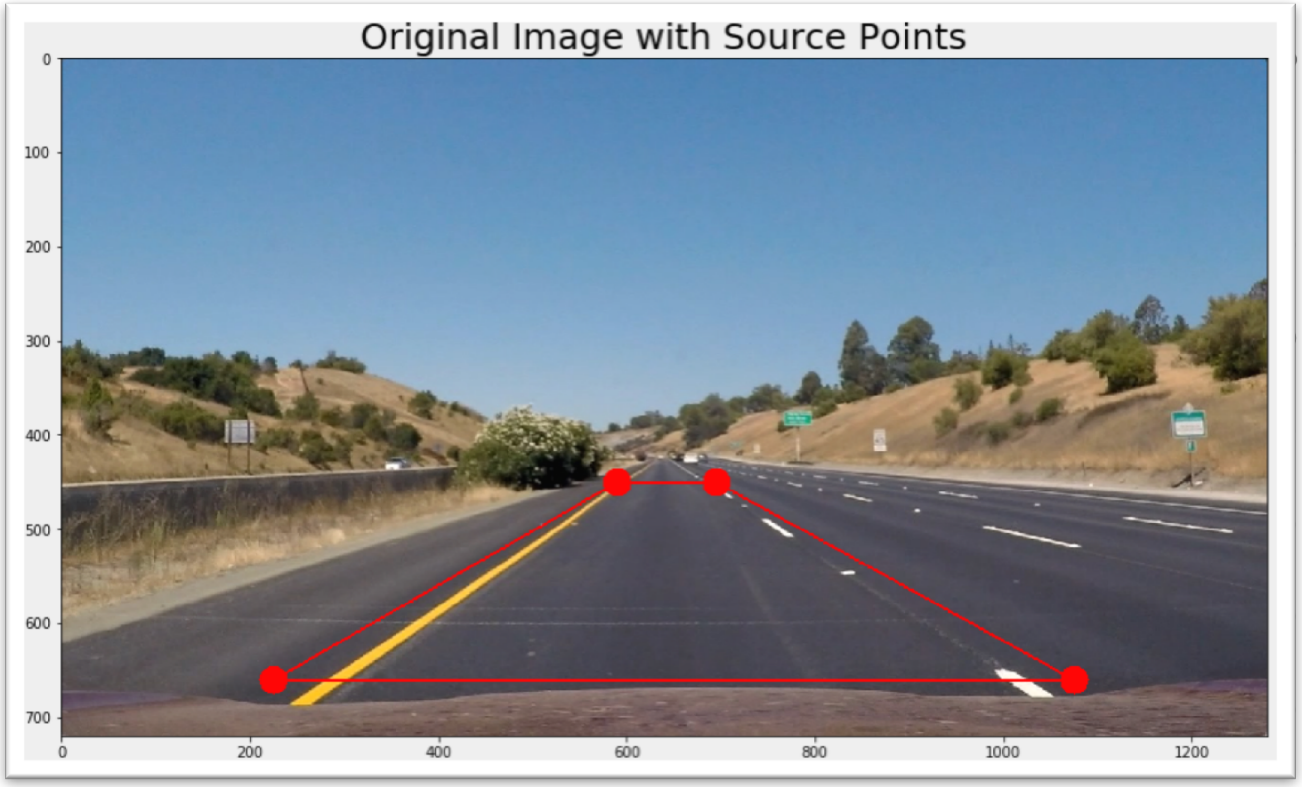


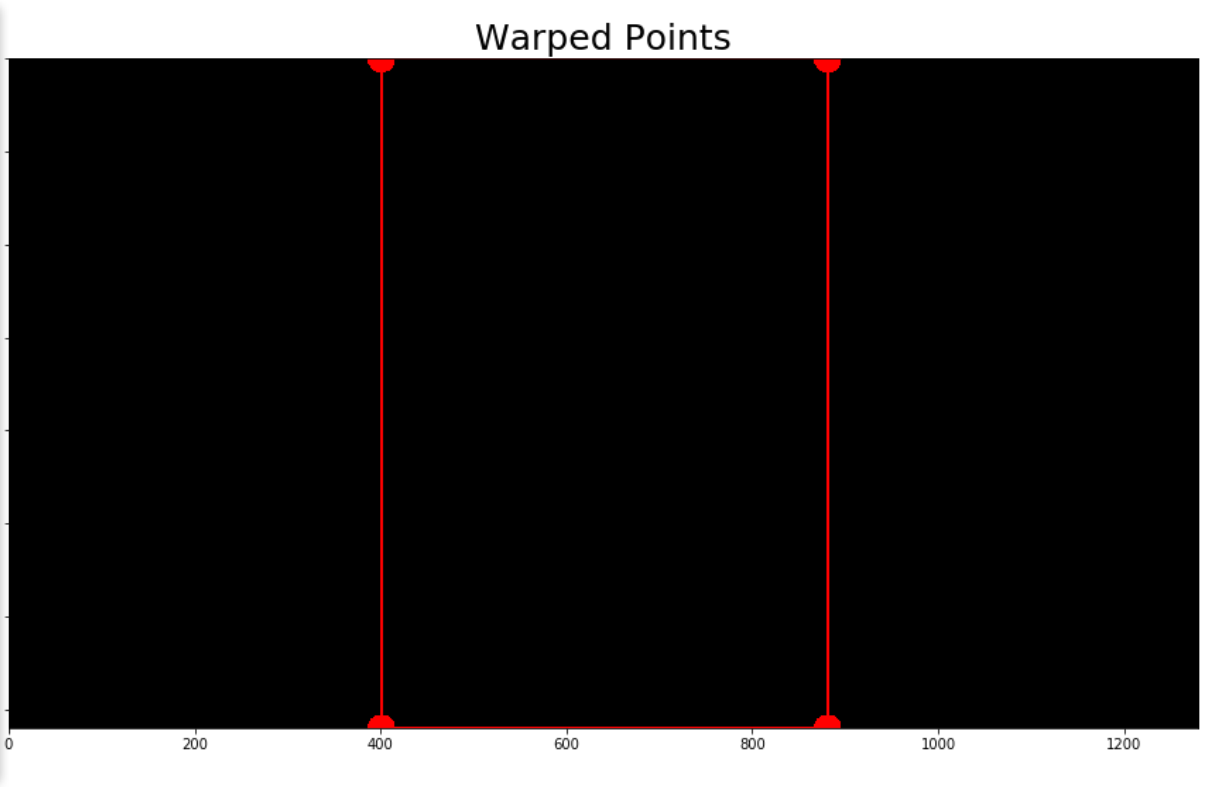
Undistorted Image



Warping images

Need a “birds eye view” for curve fitting



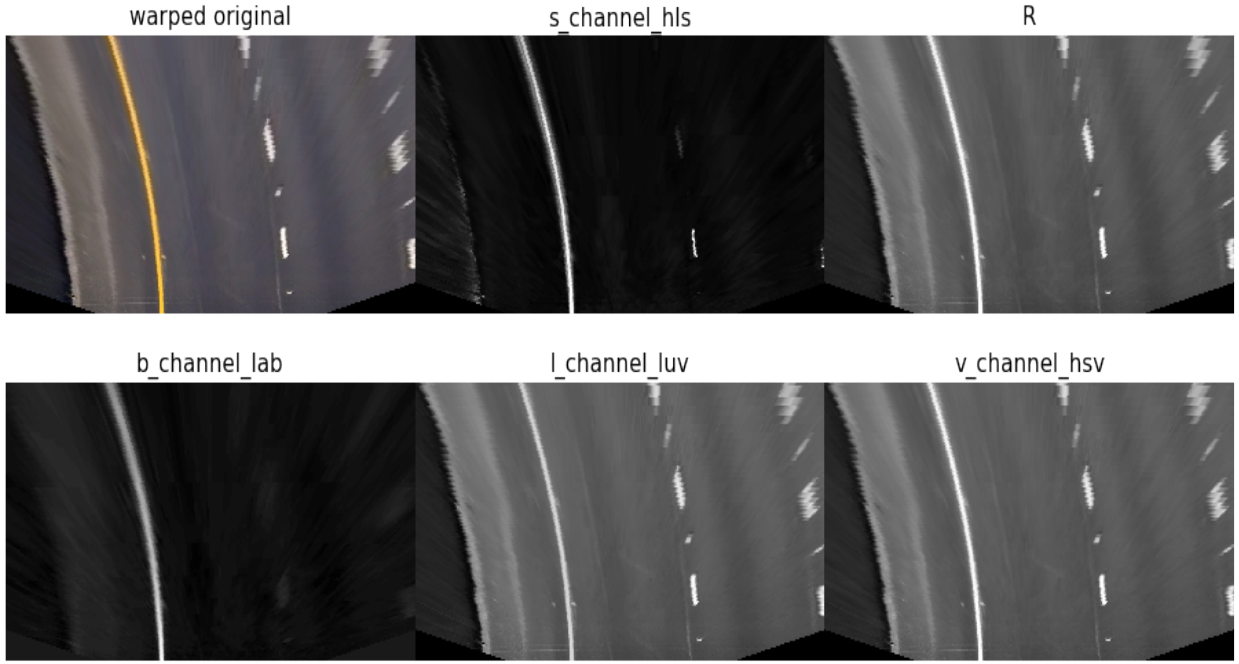



```
# create a transformation matrix
M = cv2.getPerspectiveTransform(src, dst)
```

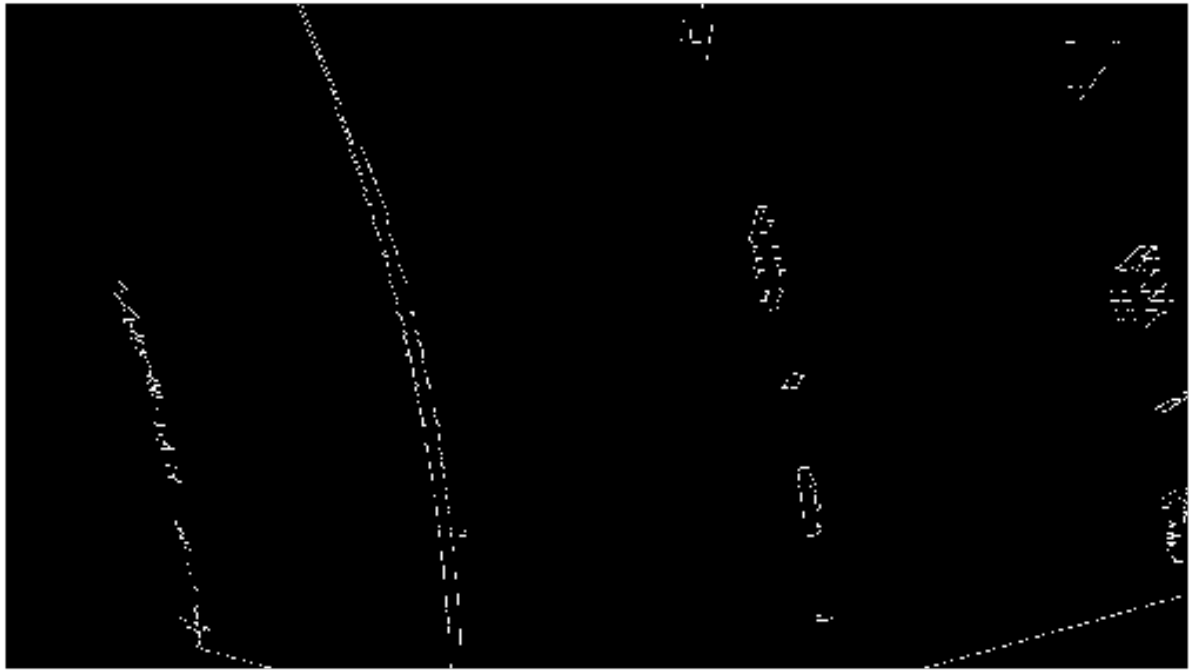
```
# apply the transform to the original image
warped = cv2.warpPerspective(img, M, img_size)
```

Finding the lane lines

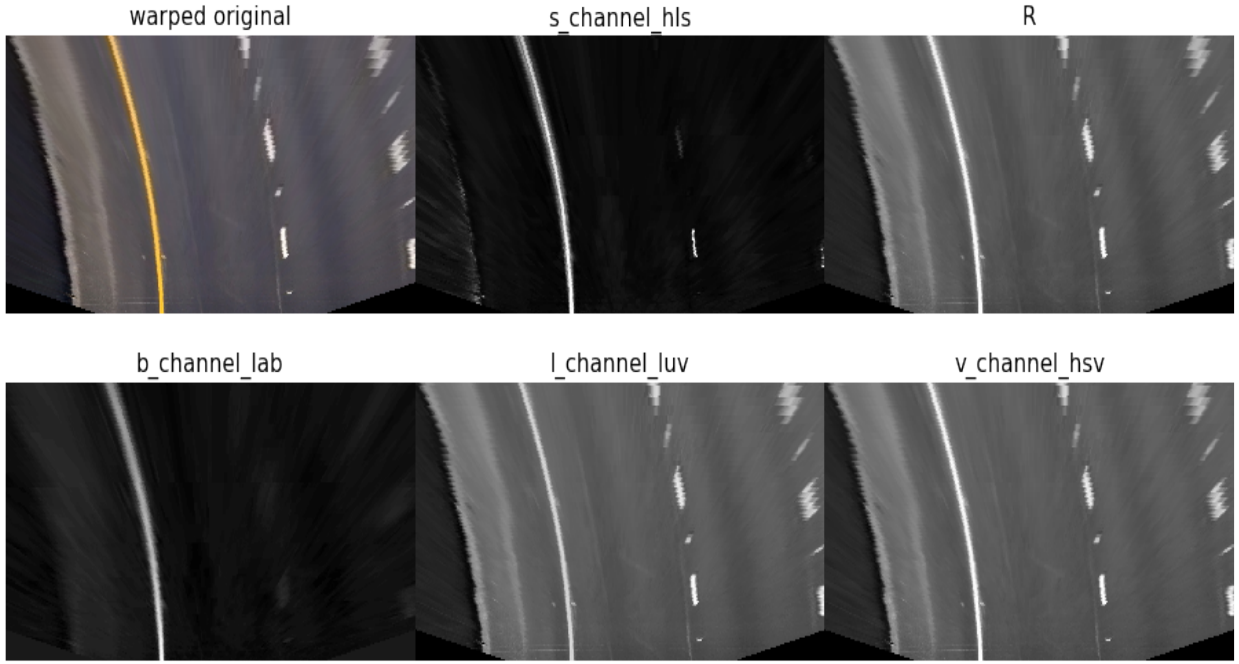
Color Selection



Edge Detection



Color Selection



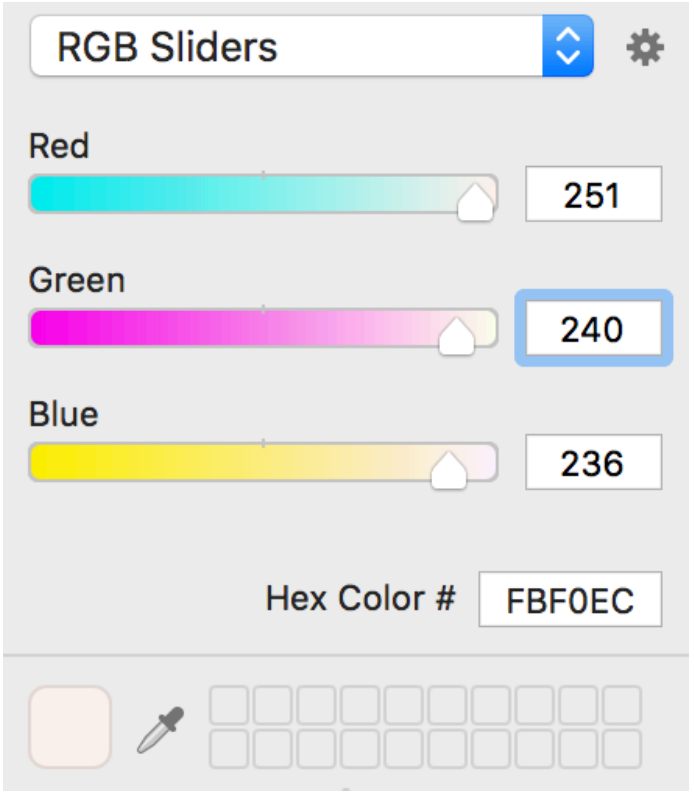
Edge Detection

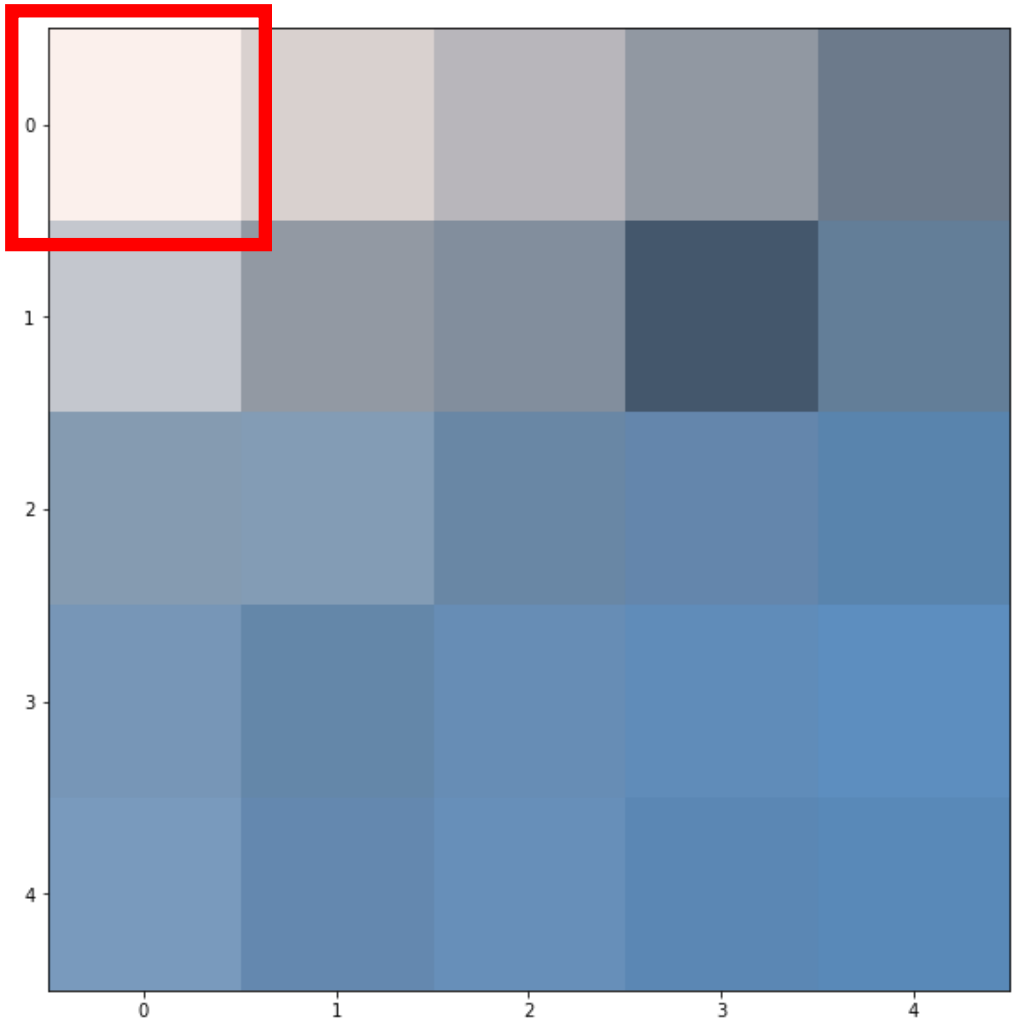
Anatomy of an image

```
img[0:10, 0:10, :]
```

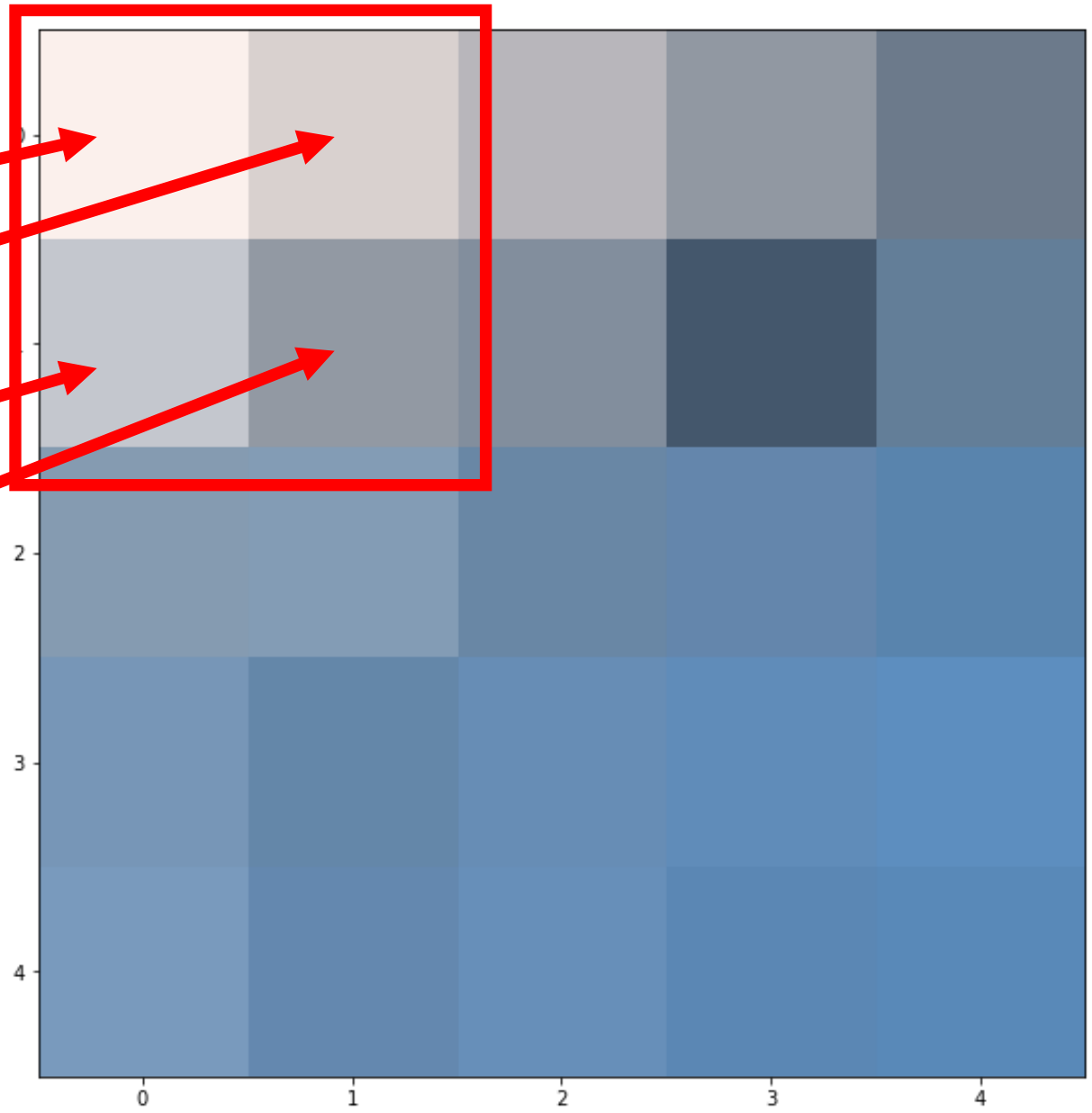
```
> img[0,0,:] # first pixel
array([251, 240, 236])
```

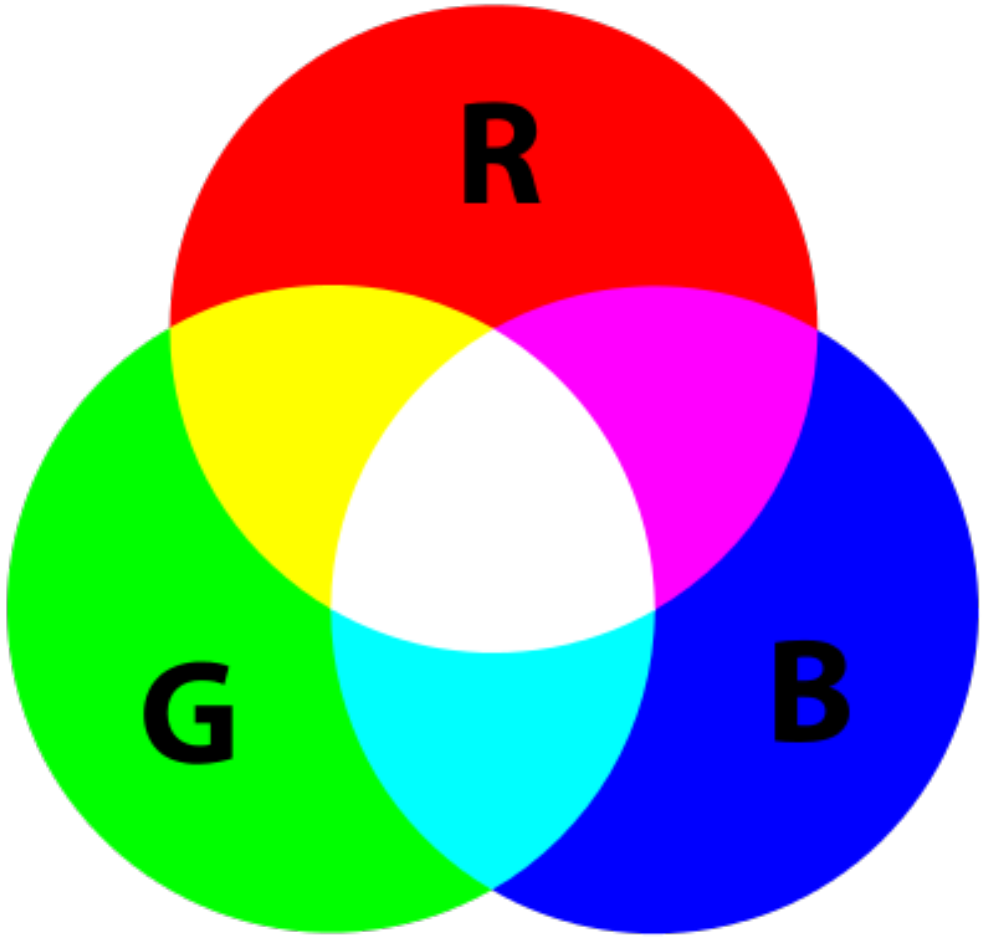
Red Green Blue

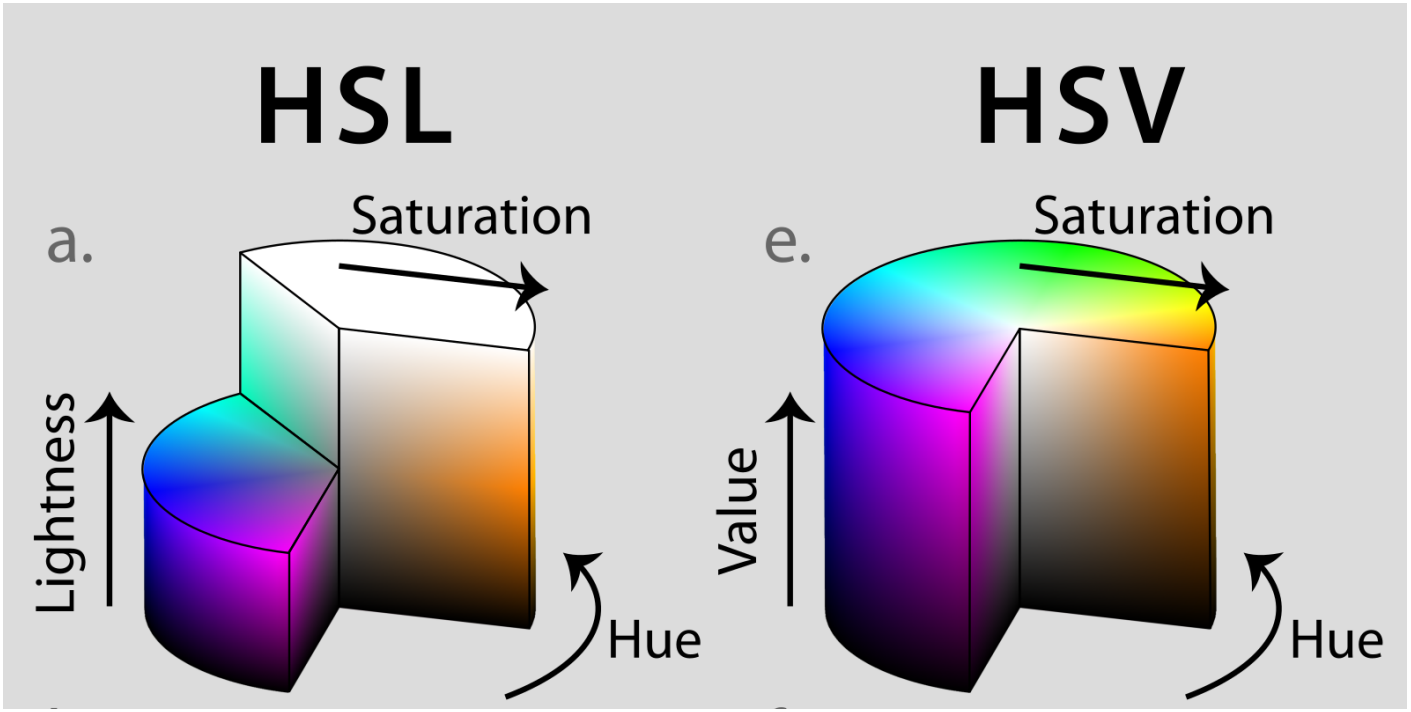


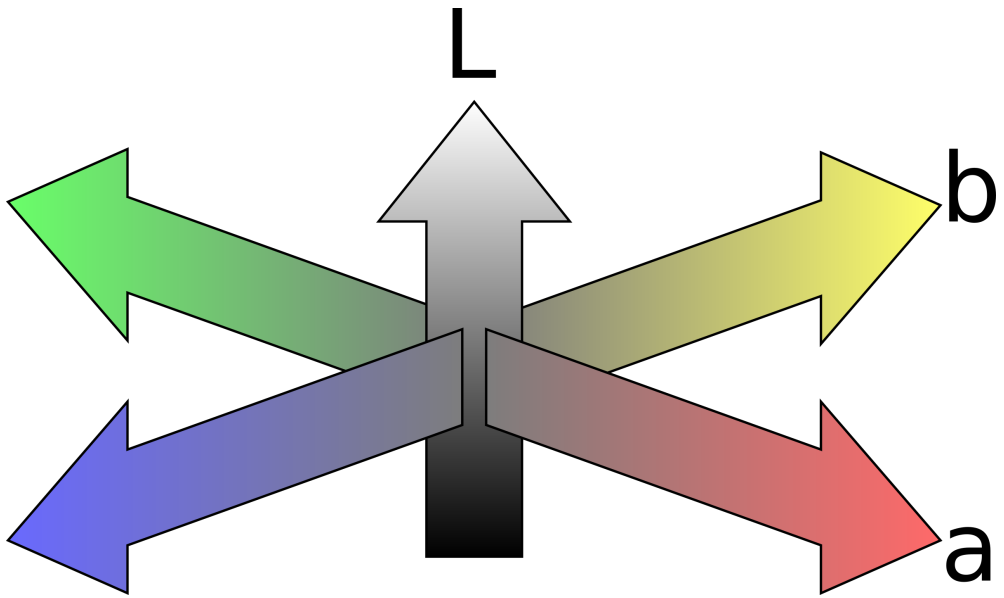


```
> img[0:2,0:2,:]

array([[[251, 240, 236],
        [217, 209, 207]],

       [[196, 199, 206],
        [146, 153, 163]]],
)
```




R
G
B

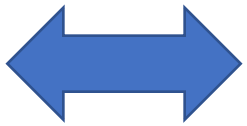

HSL
a.
Saturation
Lightness
Hue
HSV
e.
Saturation
Value
Hue


L
b
a

OpenCV makes changing color space easy

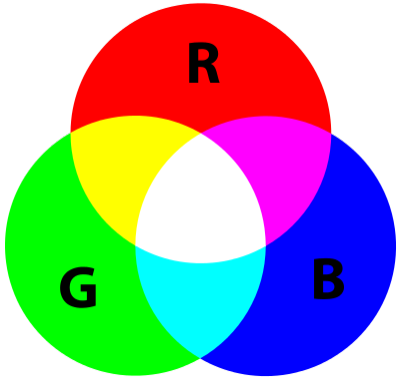
```
# convert RGB image to Hue Light Saturation (HLS)
HLS = cv2.cvtColor(RGB, cv2.COLOR_RGB2HLS)
```

```
> HLS[0,0,:]
array([ 8, 244, 166])
```



```
> RGB[0,0,:]
array([251, 240, 236])
```

Isolate each color channel



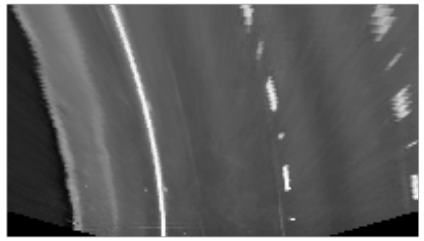

```
red   = img[:, :, 0]
green = img[:, :, 1]
blue  = img[:, :, 2]
```

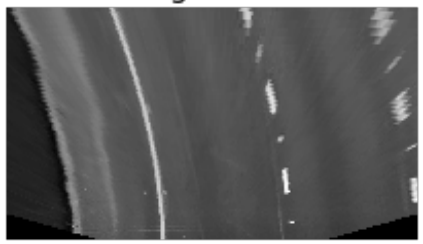
Red Channel

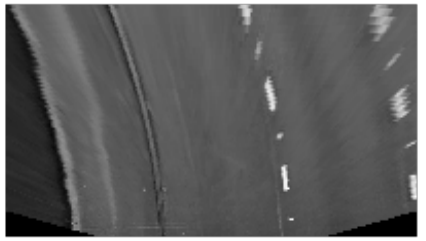
Green Channel

Blue Channel

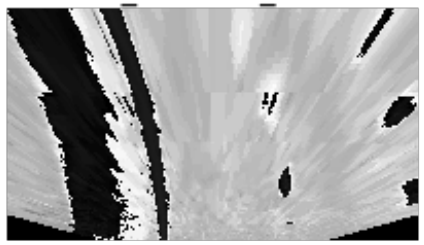
RGB

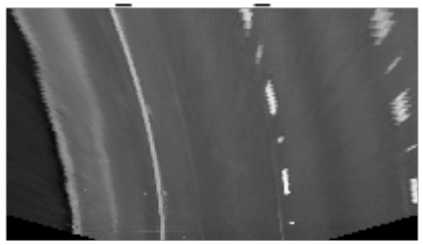

red

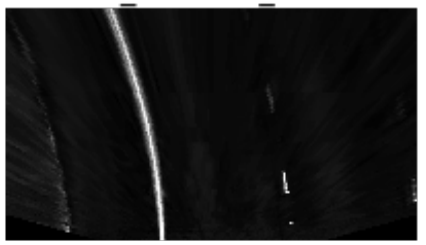

green


blue

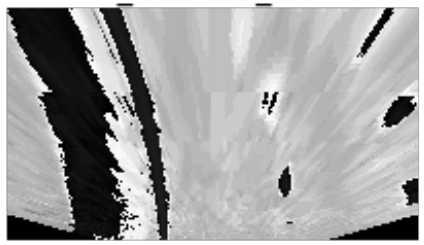
HLS

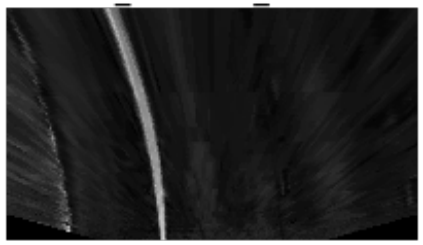

h_channel_hls

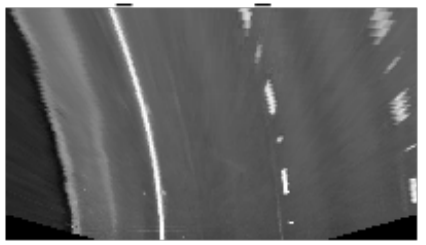

l_channel_hls


s_channel_hls

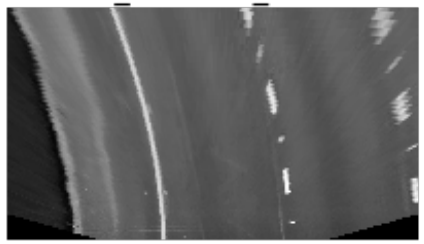
HSV

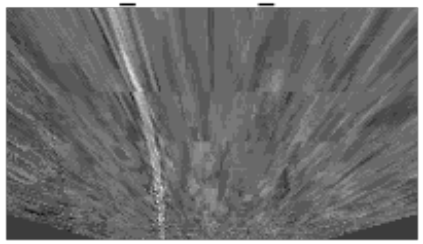

h_channel_hsv

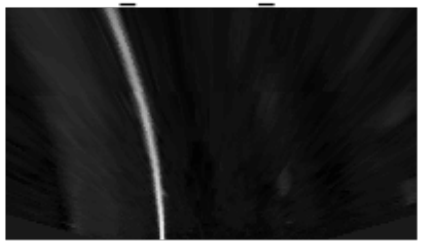

s_channel_hsv


v_channel_hsv

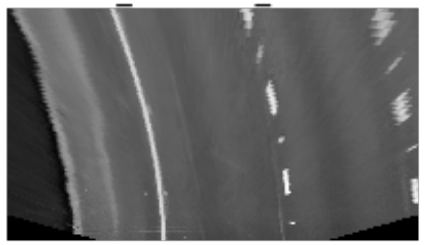
LAB

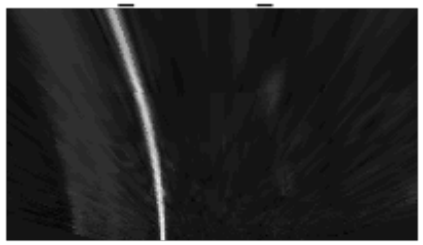

l_channel_lab

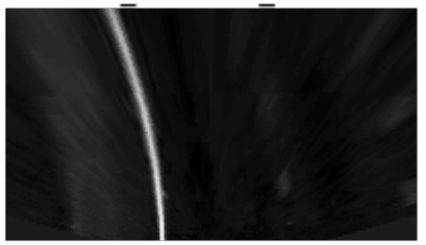

a_channel_lab


b_channel_lab

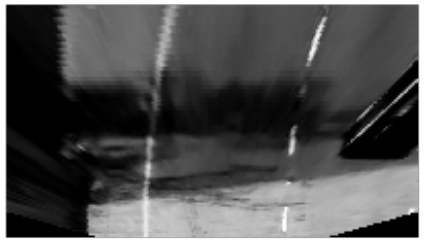
LUV

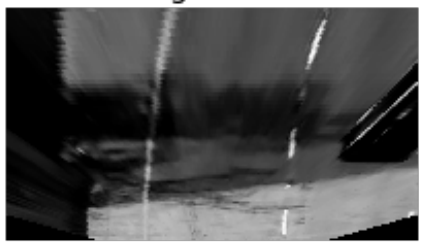

l_channel_luv

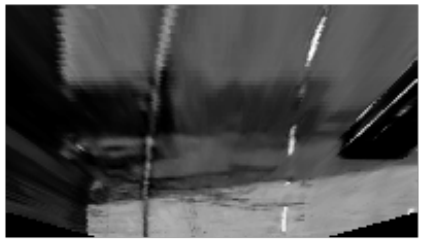

u_channel_luv


v_channel_luv

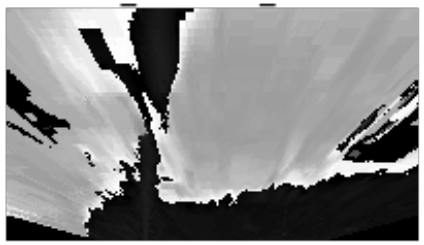
RGB

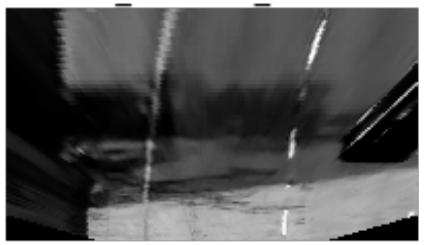

red

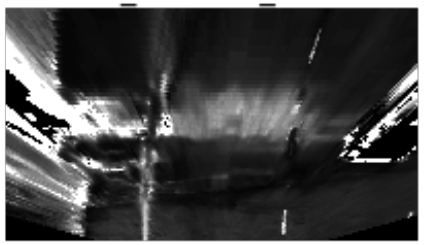

green


blue

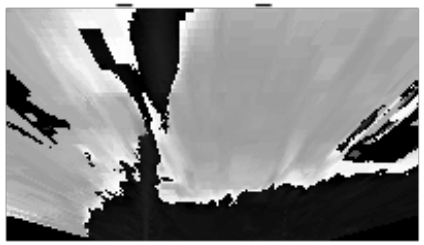
HLS

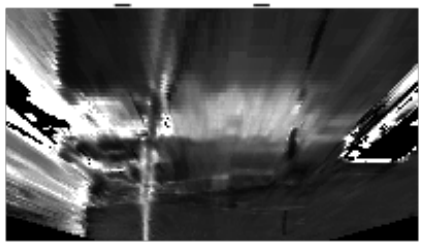

h_channel_hls

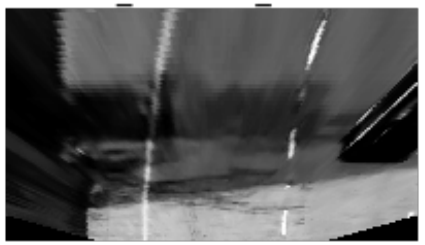

l_channel_hls


s_channel_hls

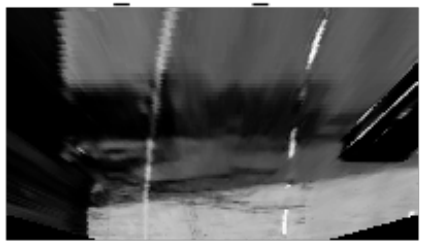
HSV

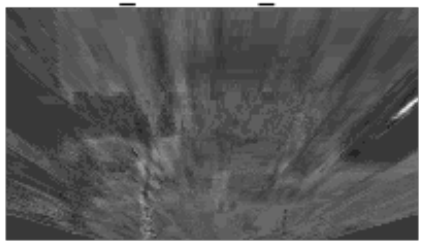

h_channel_hsv

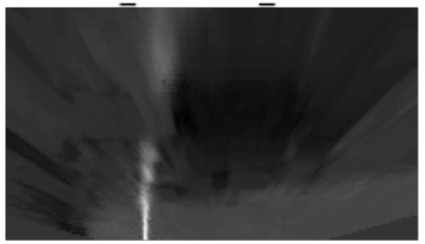

s_channel_hsv


v_channel_hsv

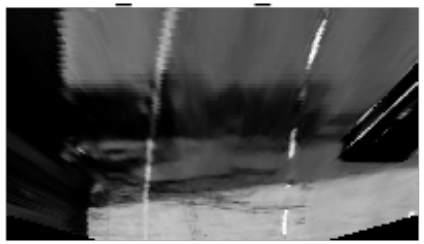
LAB

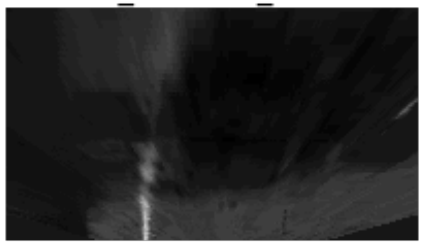

l_channel_lab

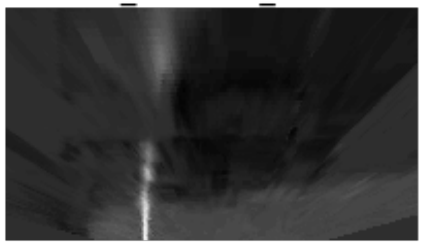

a_channel_lab


b_channel_lab

LUV

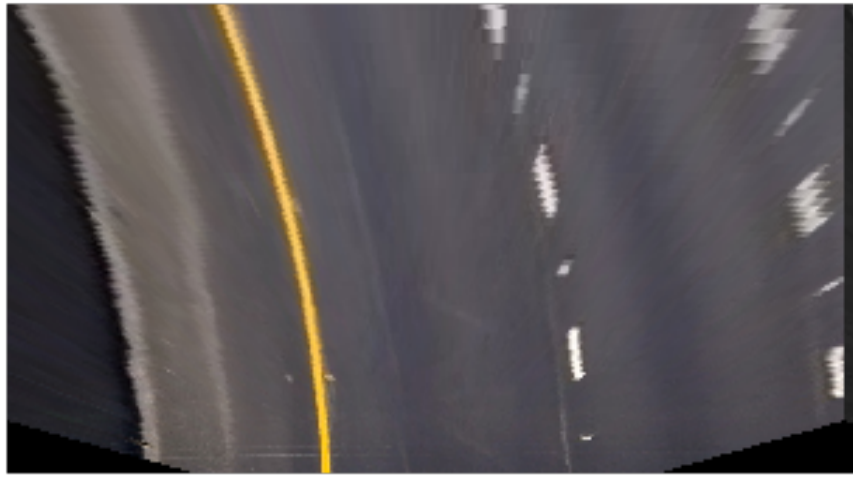

l_channel_luv


u_channel_luv

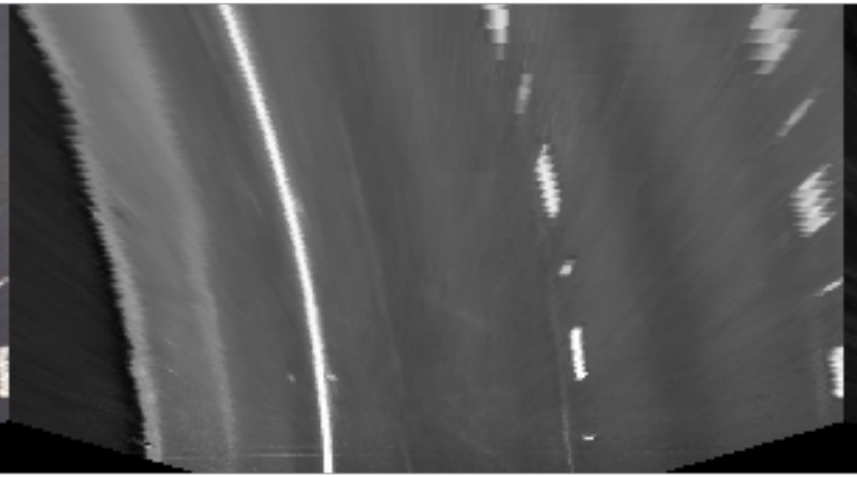

v_channel_luv

The best ones…

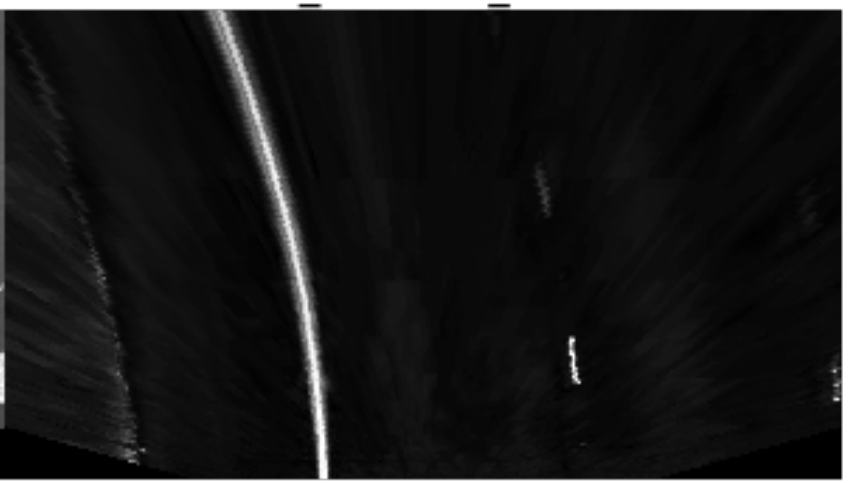
warped original



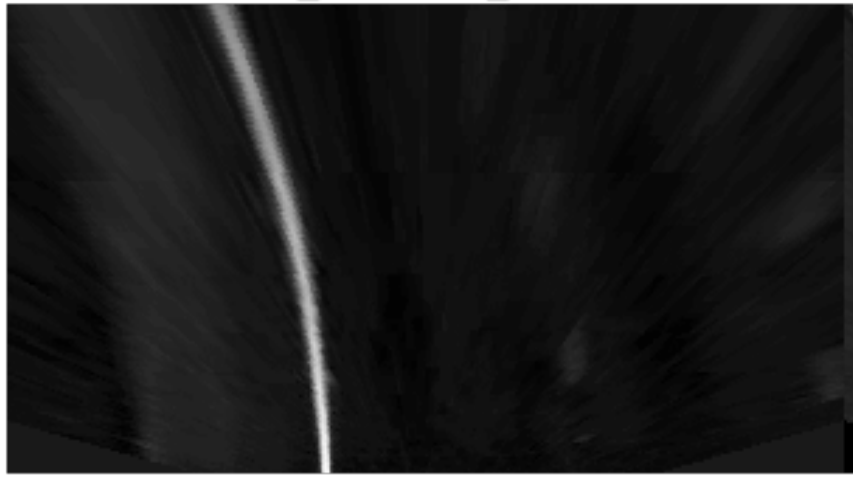
red



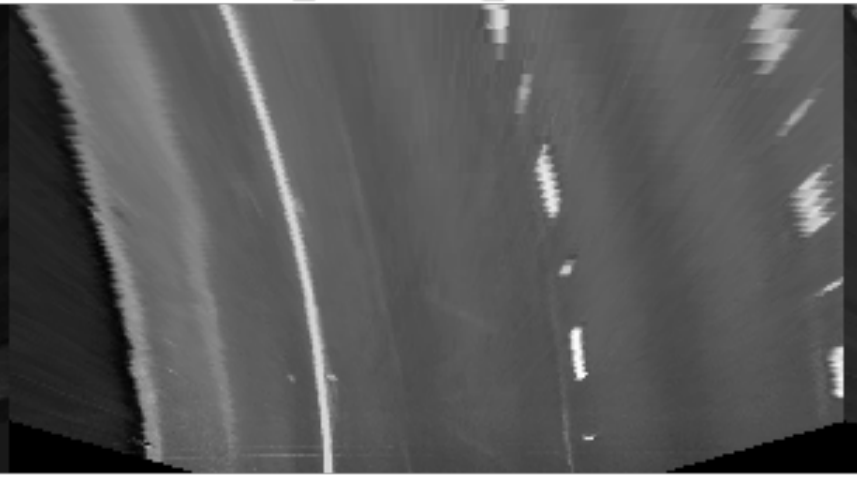
s_channel_hls



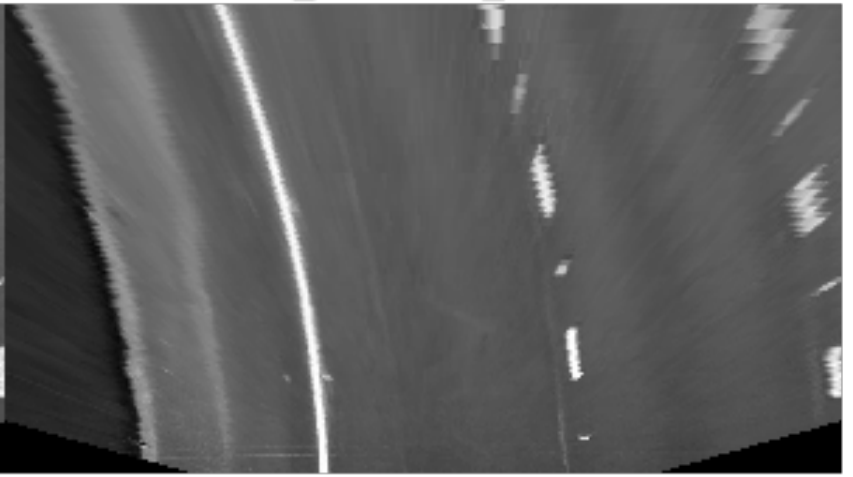
b_channel_lab



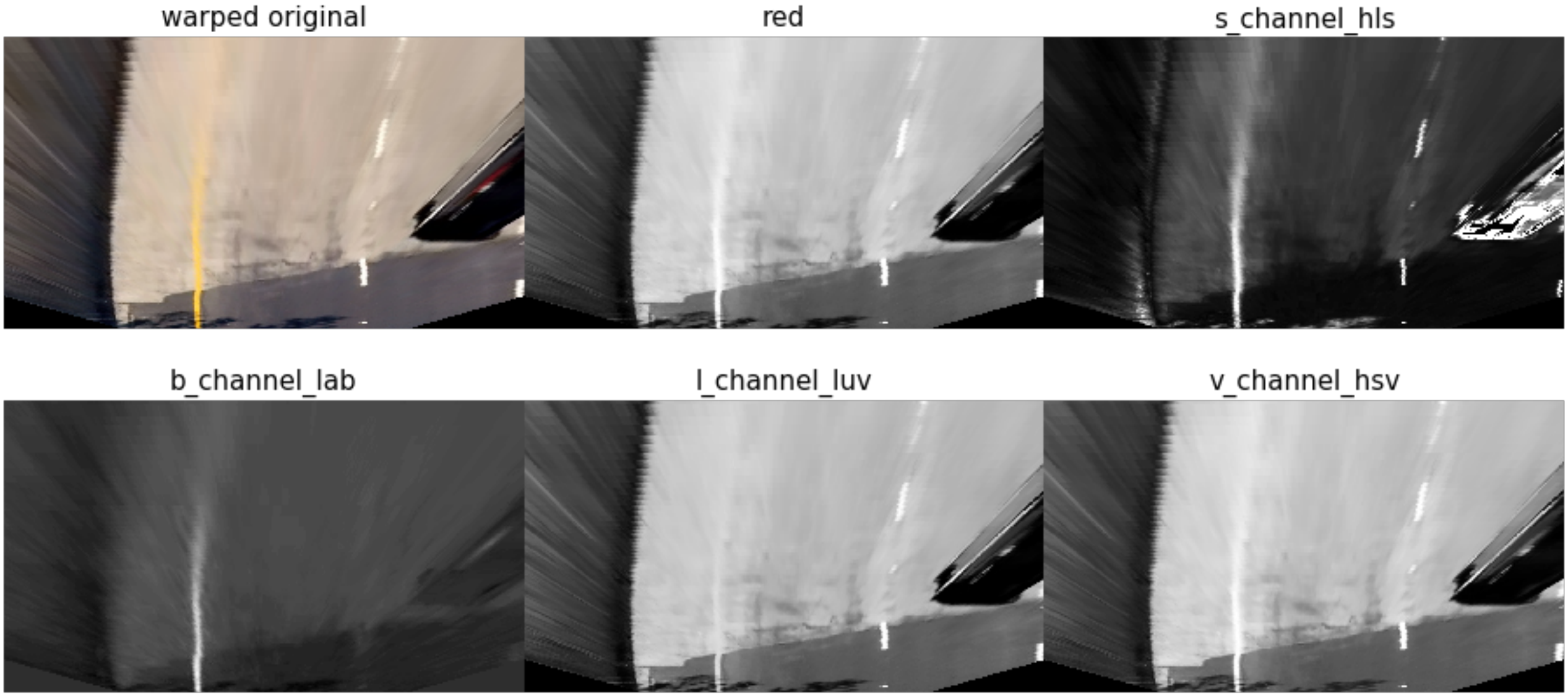
l_channel_luv



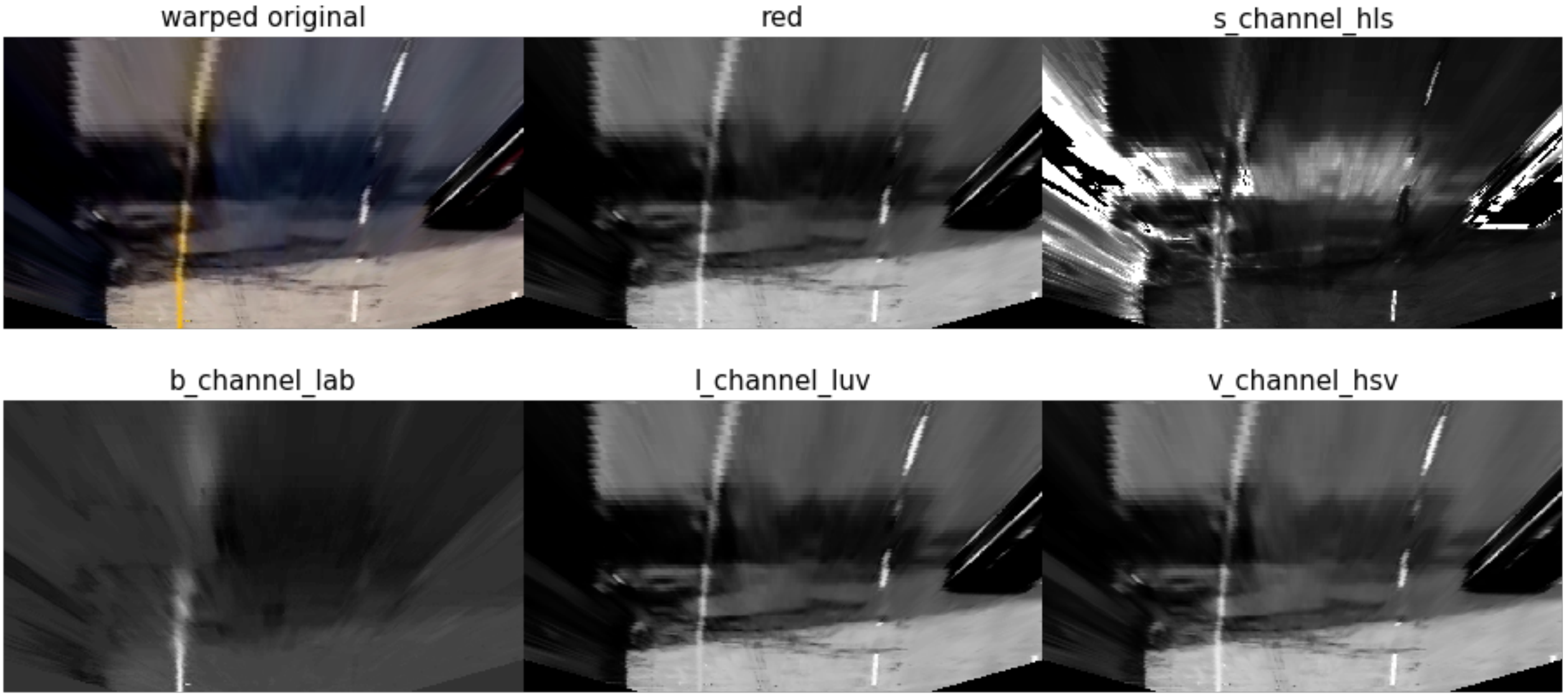
v_channel_hsv



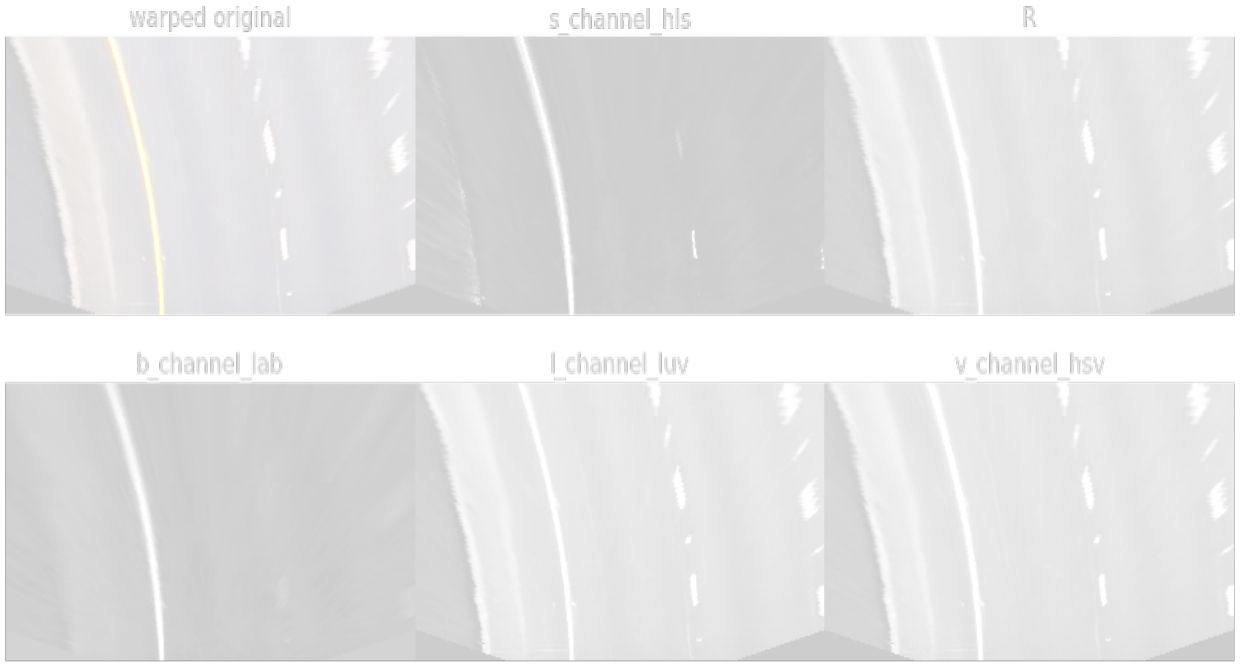
But some images are harder than others



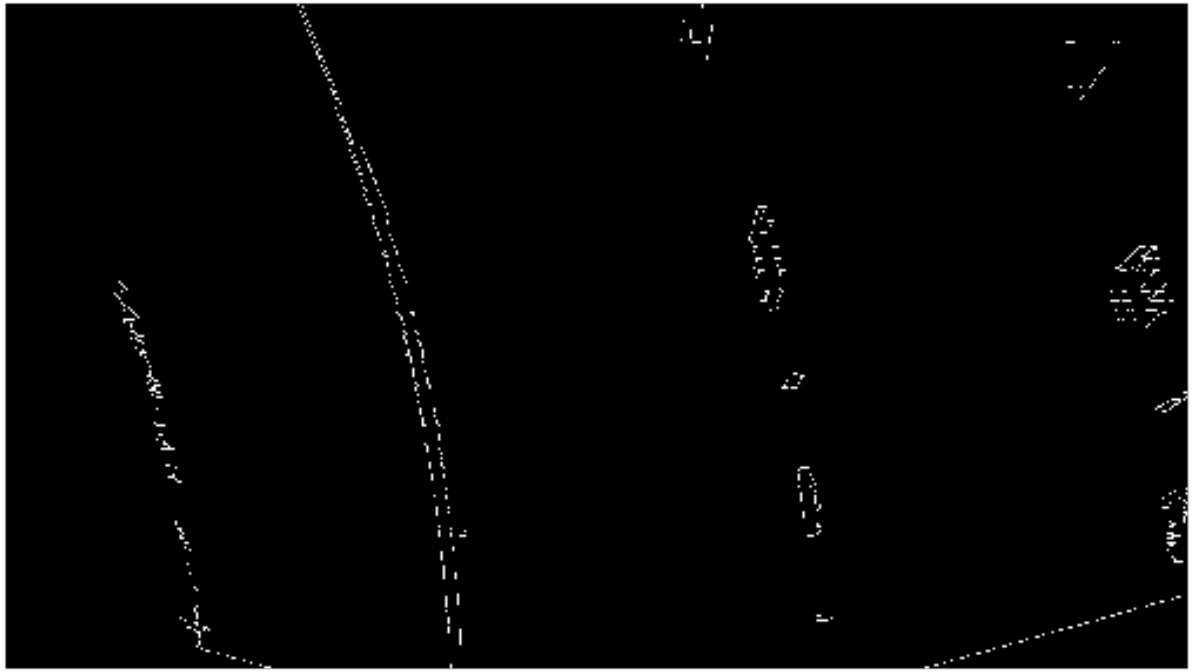
And some are really hard



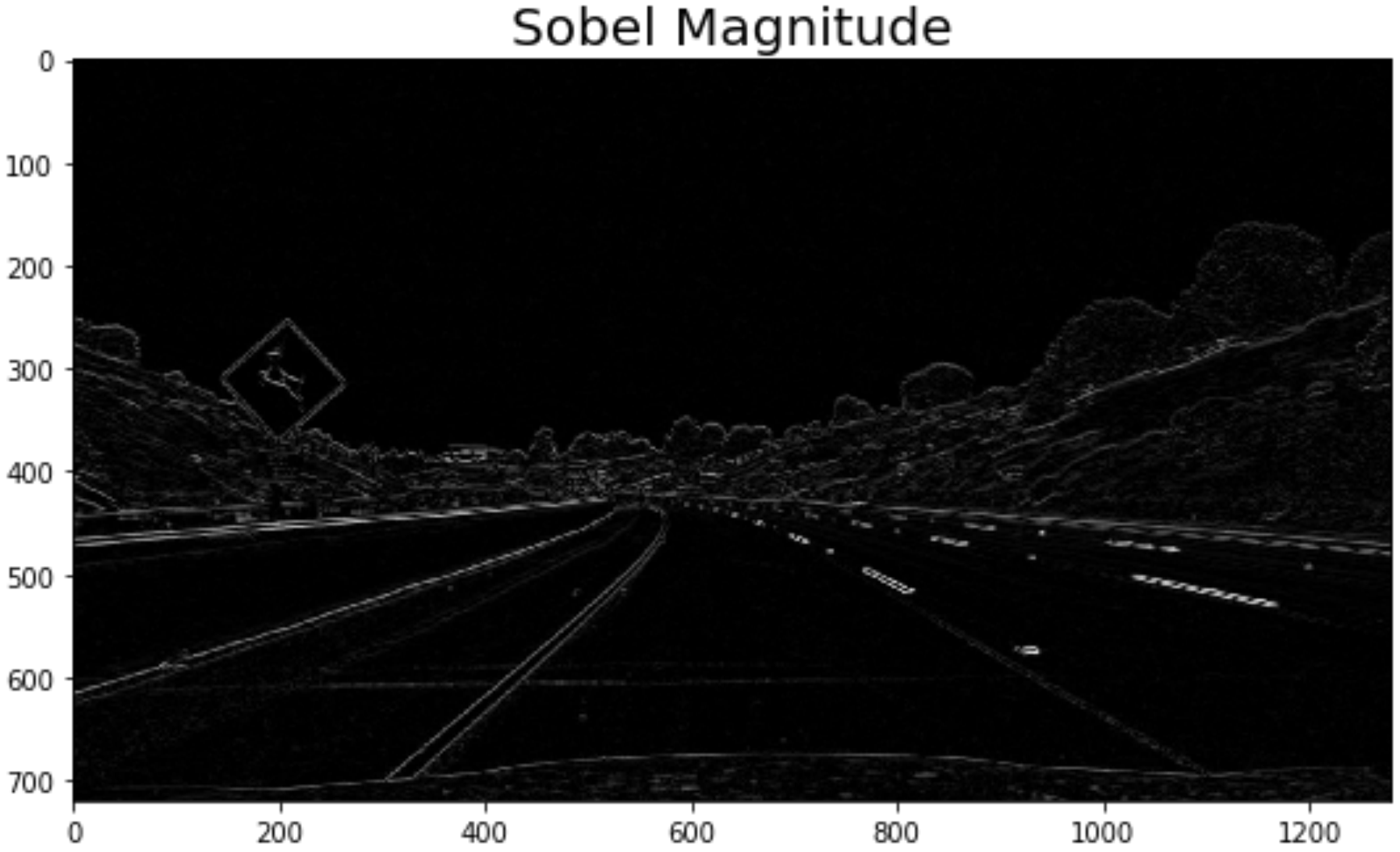
Color Selection



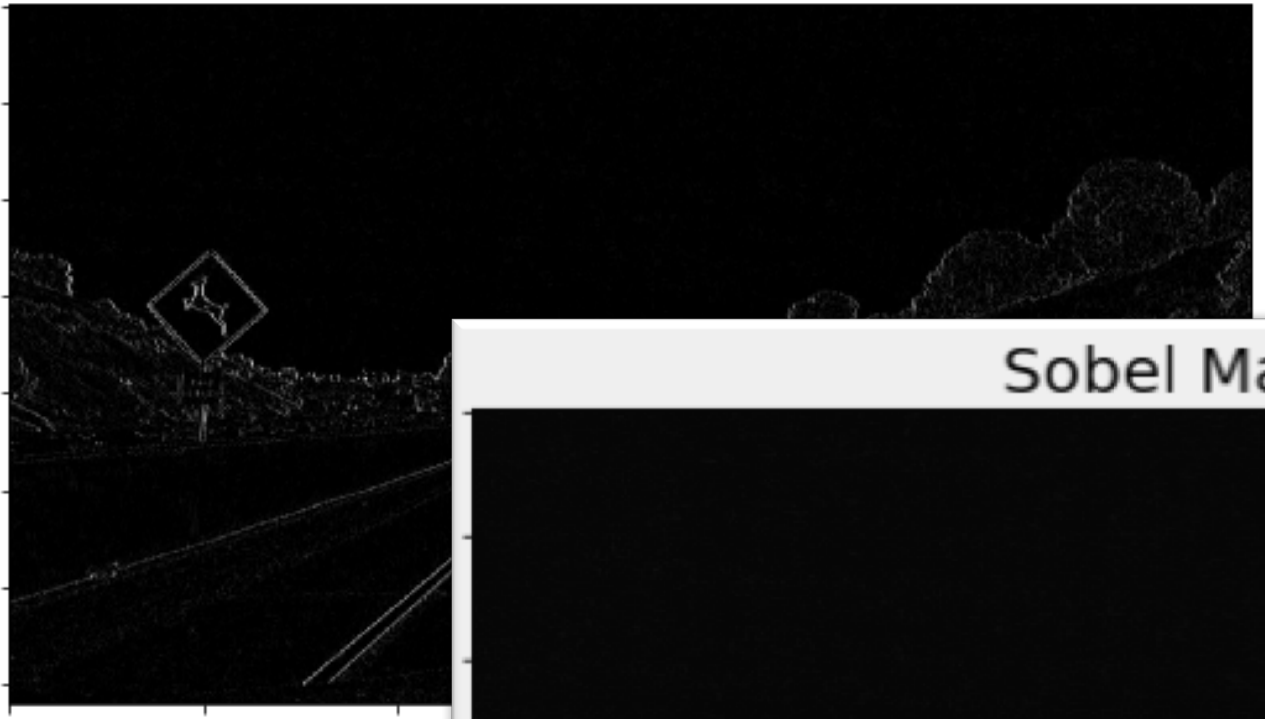
Edge Detection



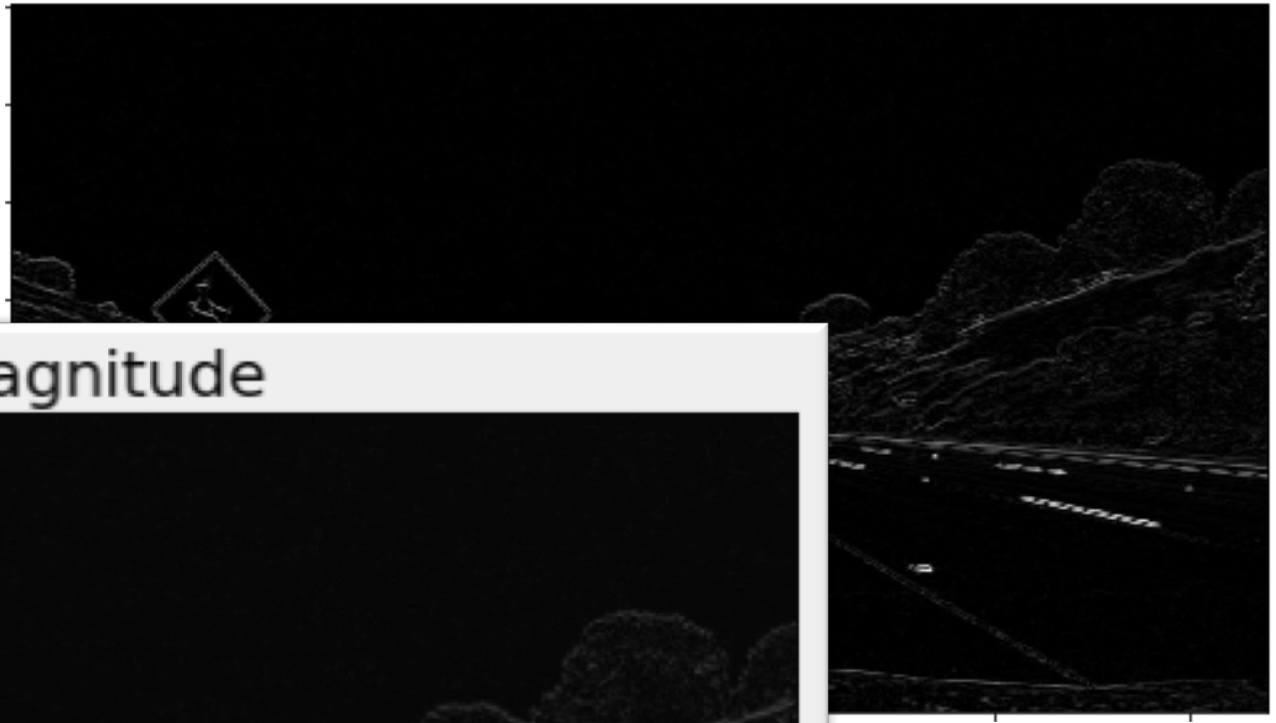
We can use built in OpenCV functions to find edges



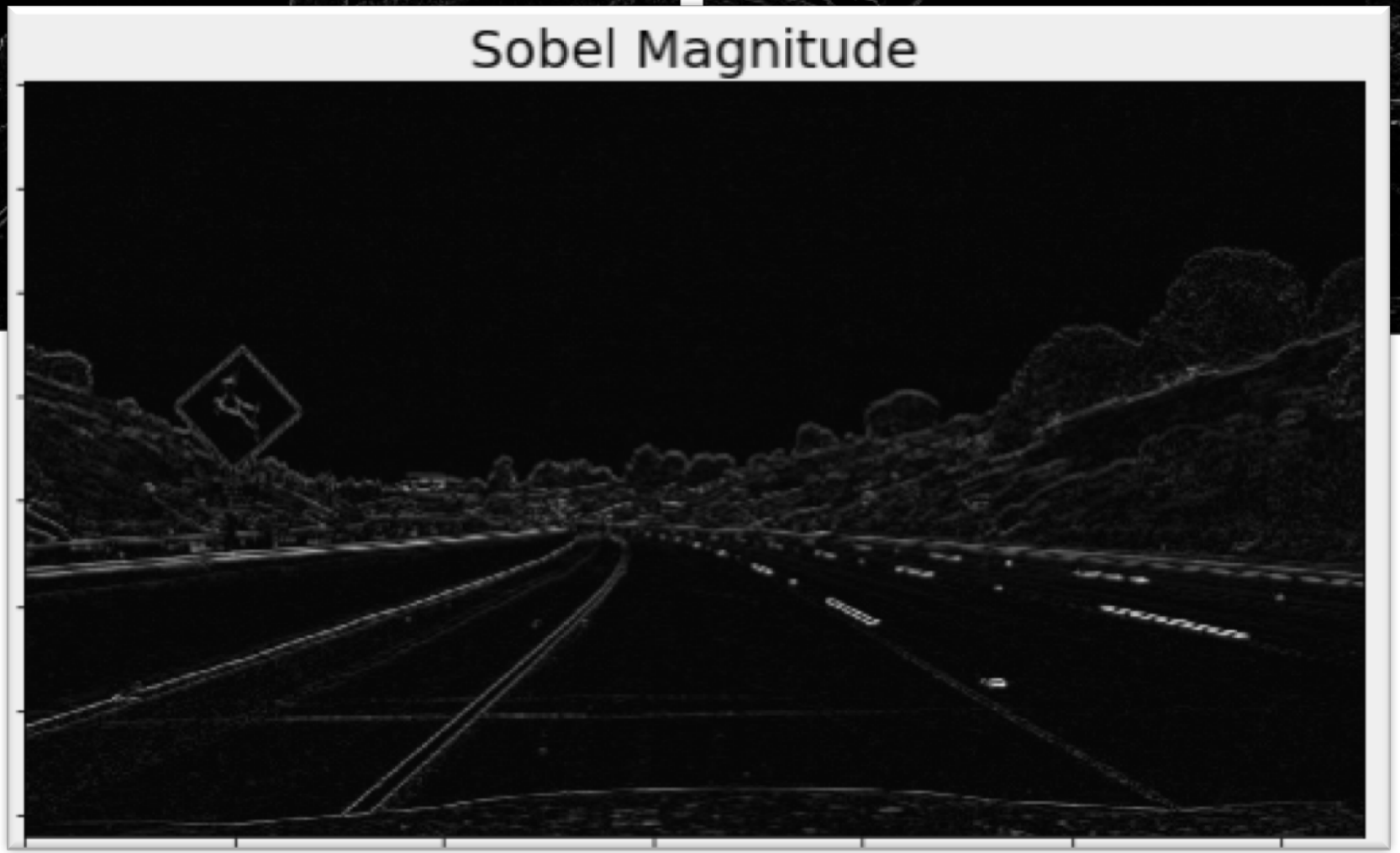
Sobel X



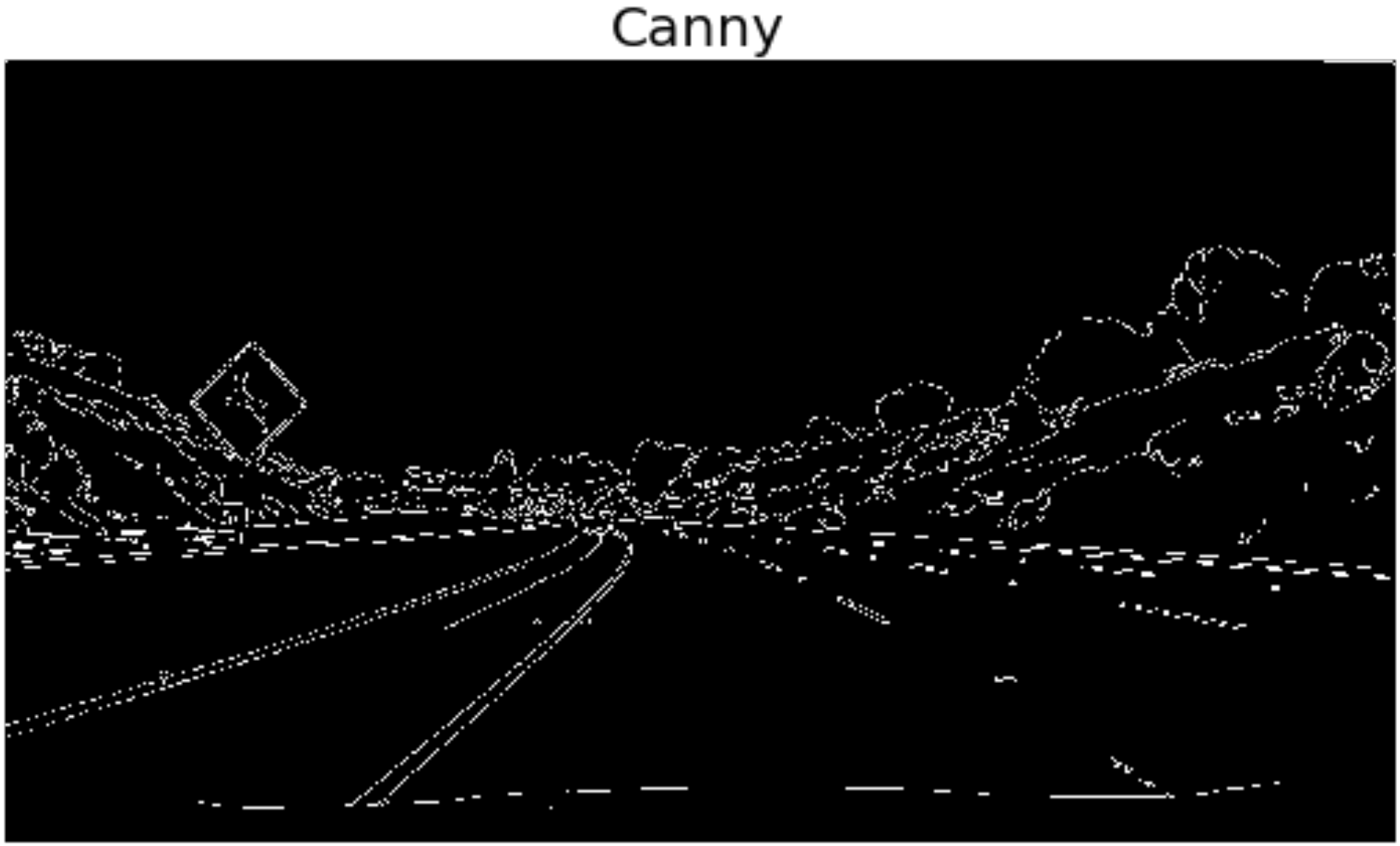
Sobel Y



Sobel Magnitude

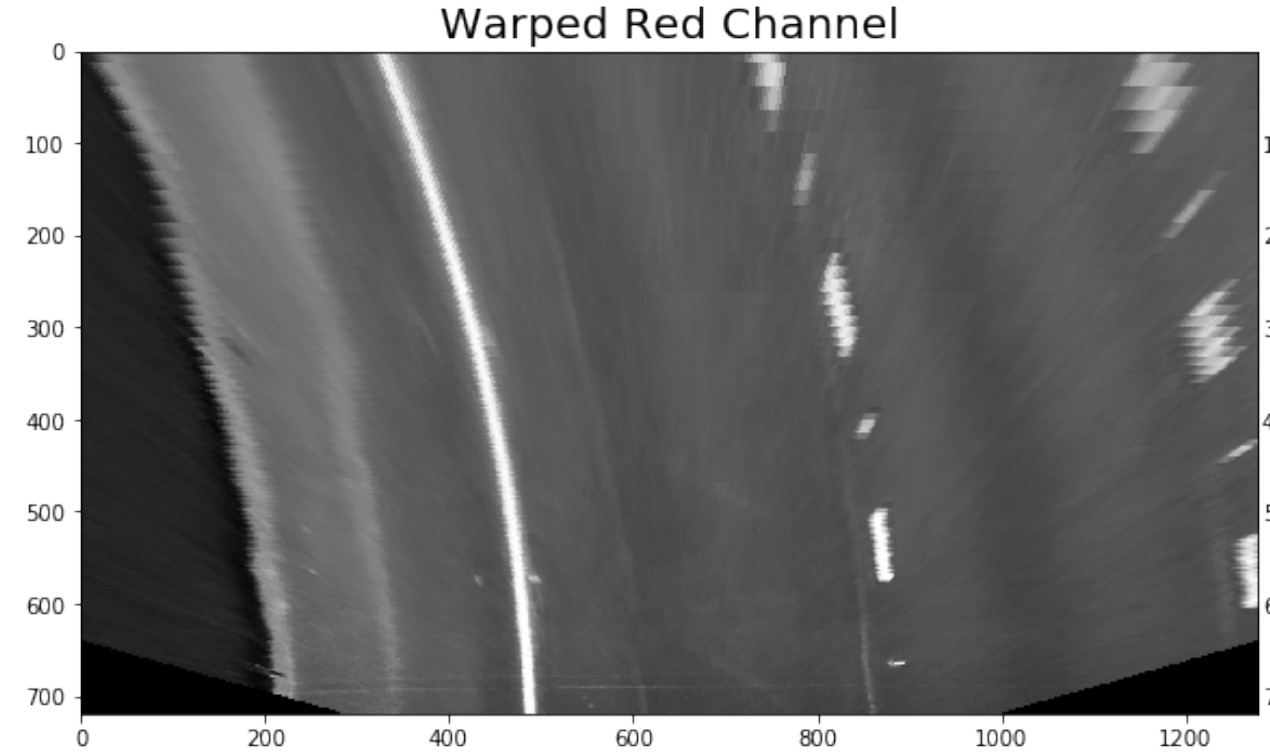


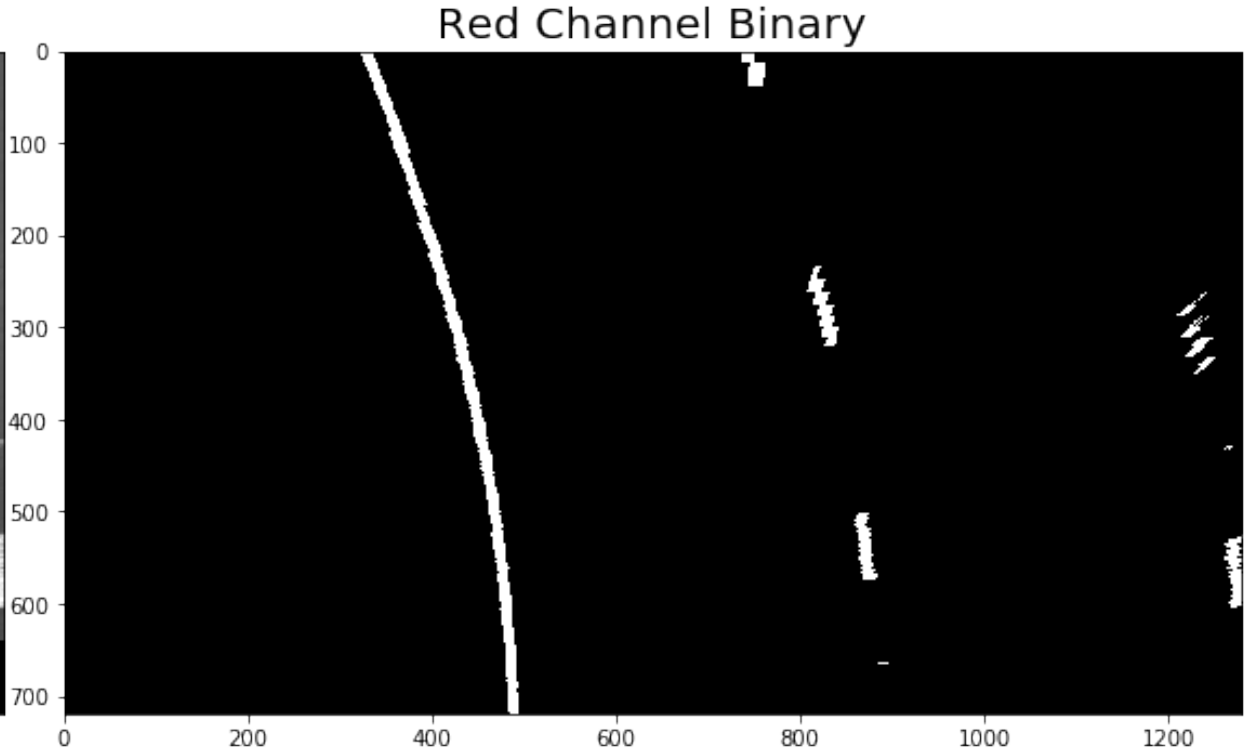
Canny edge detection



Use binary thresholding to isolate “hot” pixels

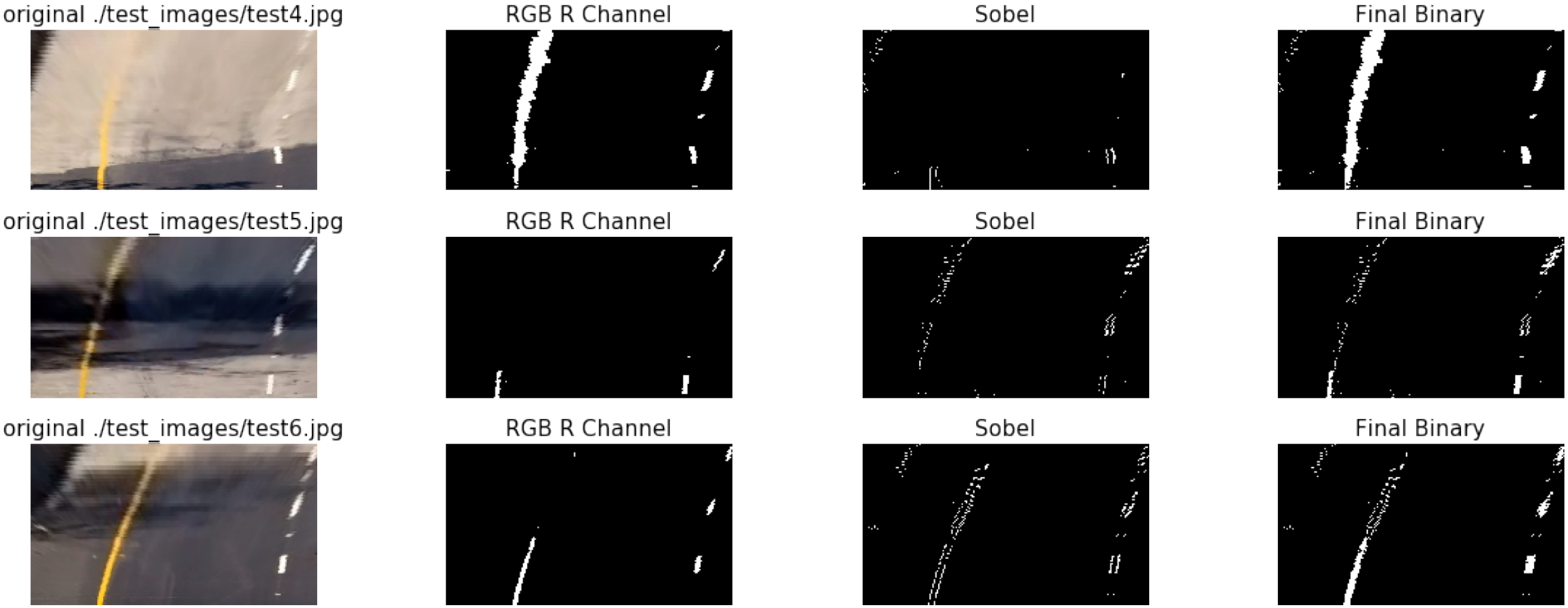
```
channel = warped[:,:,0]
thresh = (200,255)
output = np.zeros_like(channel)
output[(channel >= thresh[0]) & (channel <= thresh[1])] = 1
```



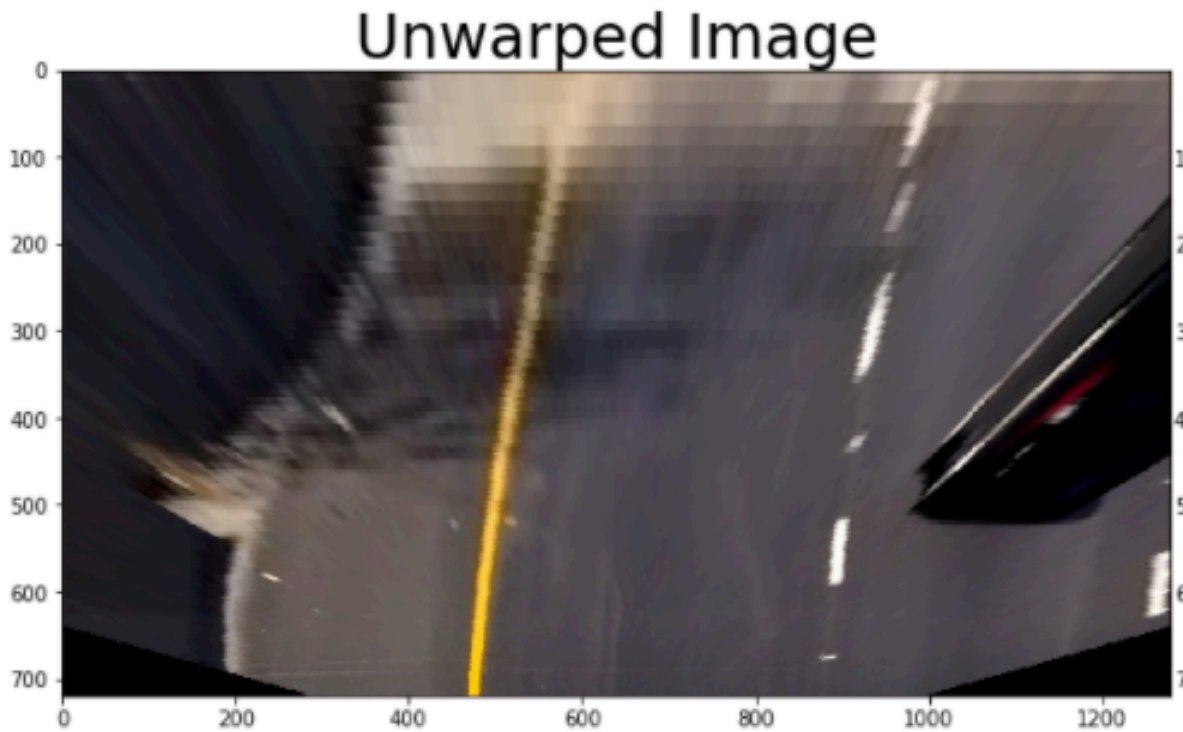


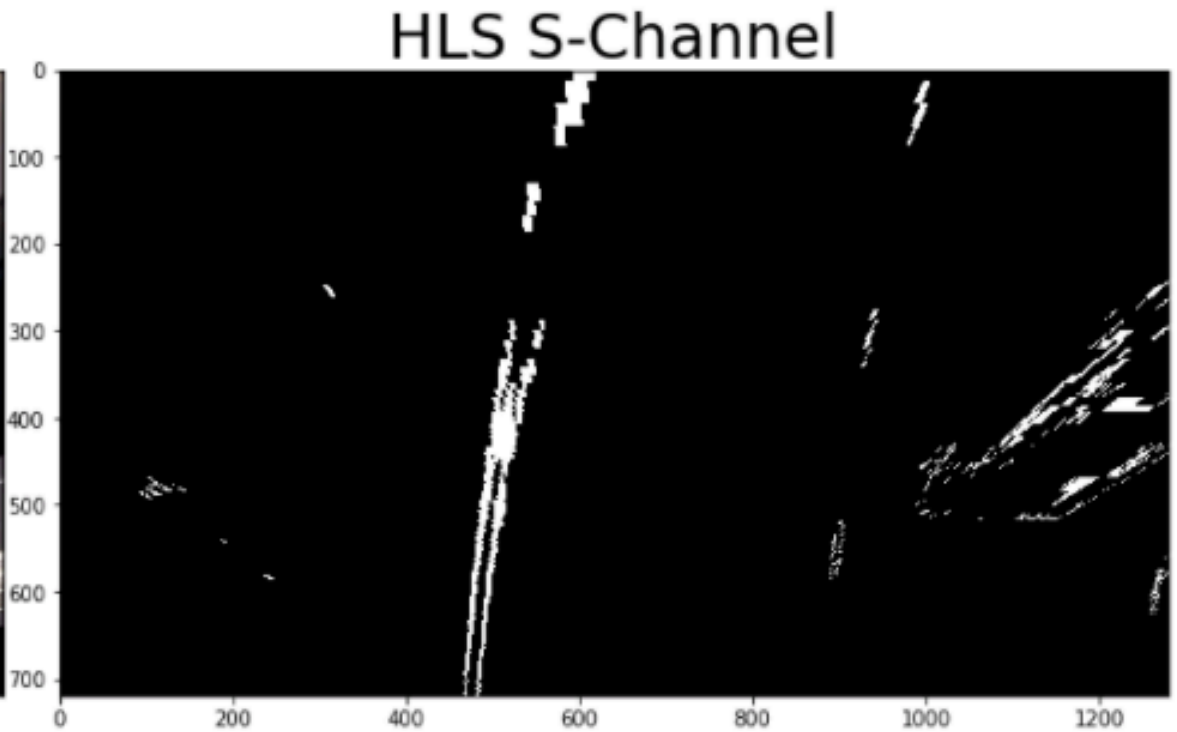
Combine binary threshold images

```
combined_binary = np.zeros_like(red)
combined_binary[ (red == 1) | (sobel == 1) ] = 1
```



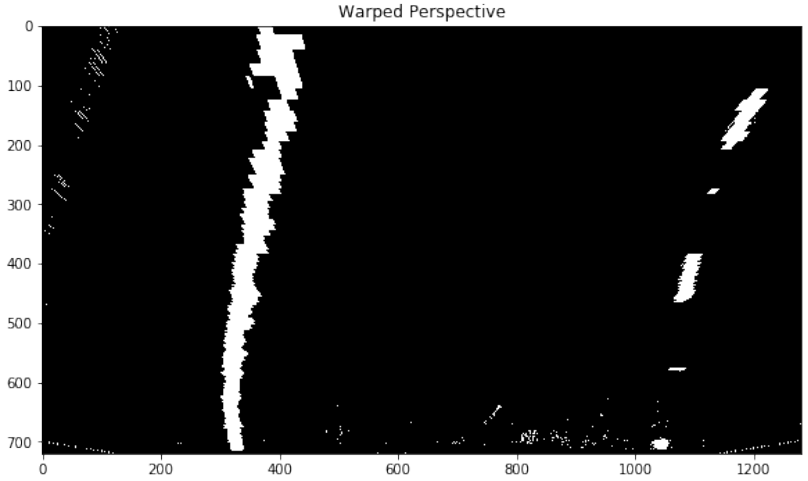
Create a set of sliders to update the thresholds

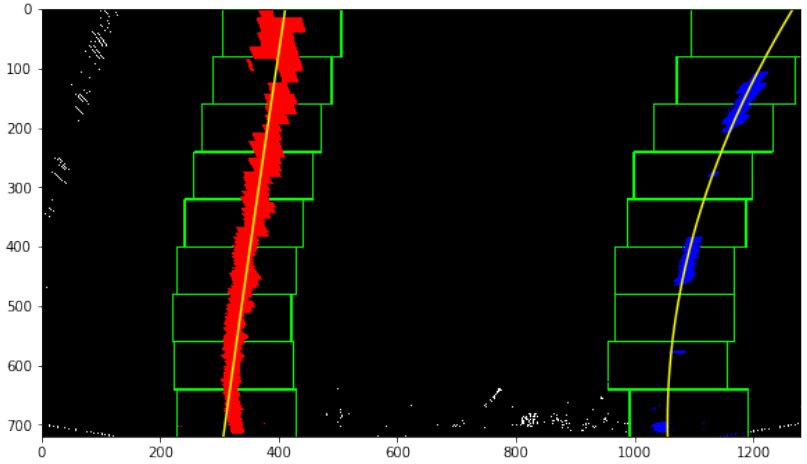




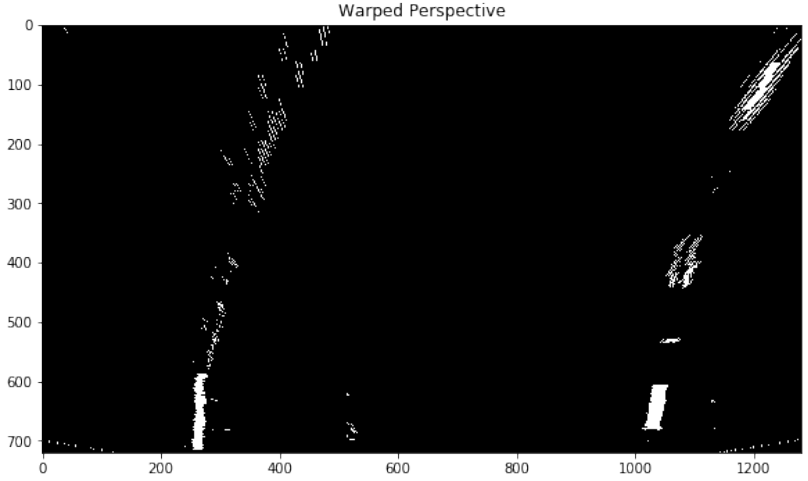
Curve Fitting

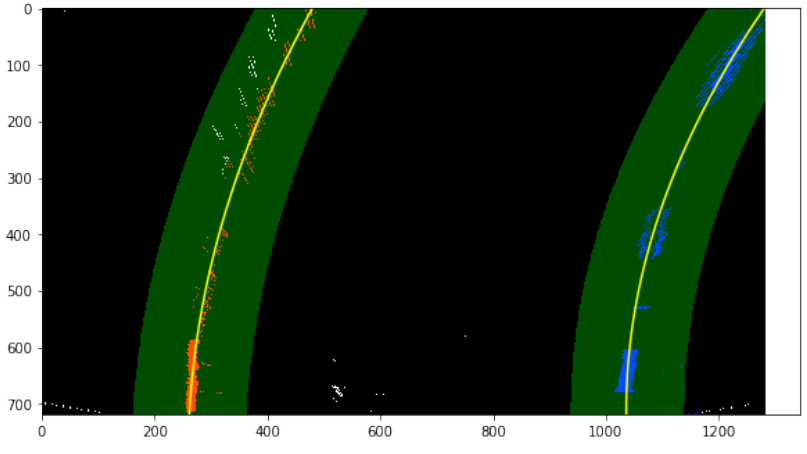
Method 1





Method 2

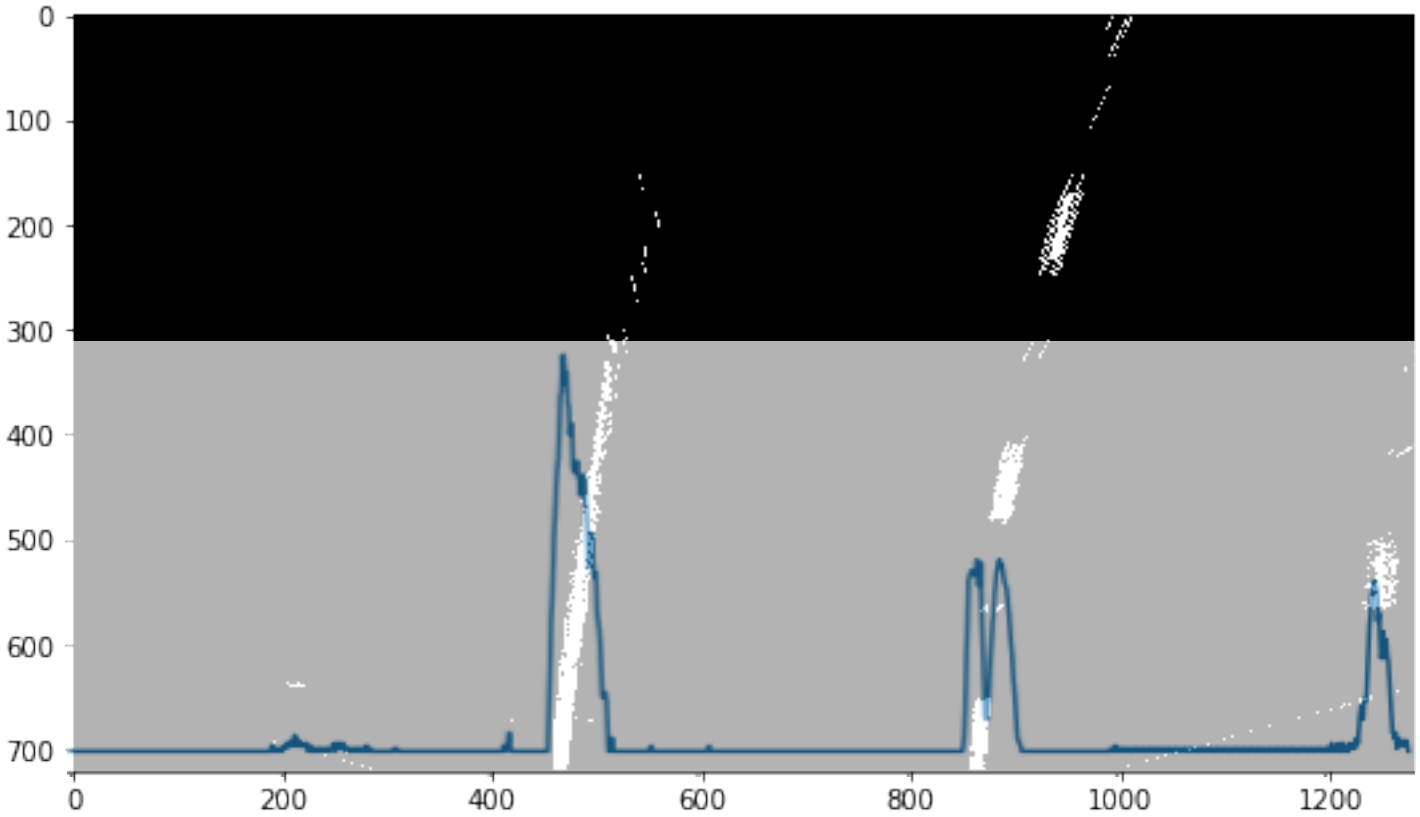




Step 1: Find the start of the line

```
histogram = np.sum(img[img.shape[0]//2:,:], axis=0)
```

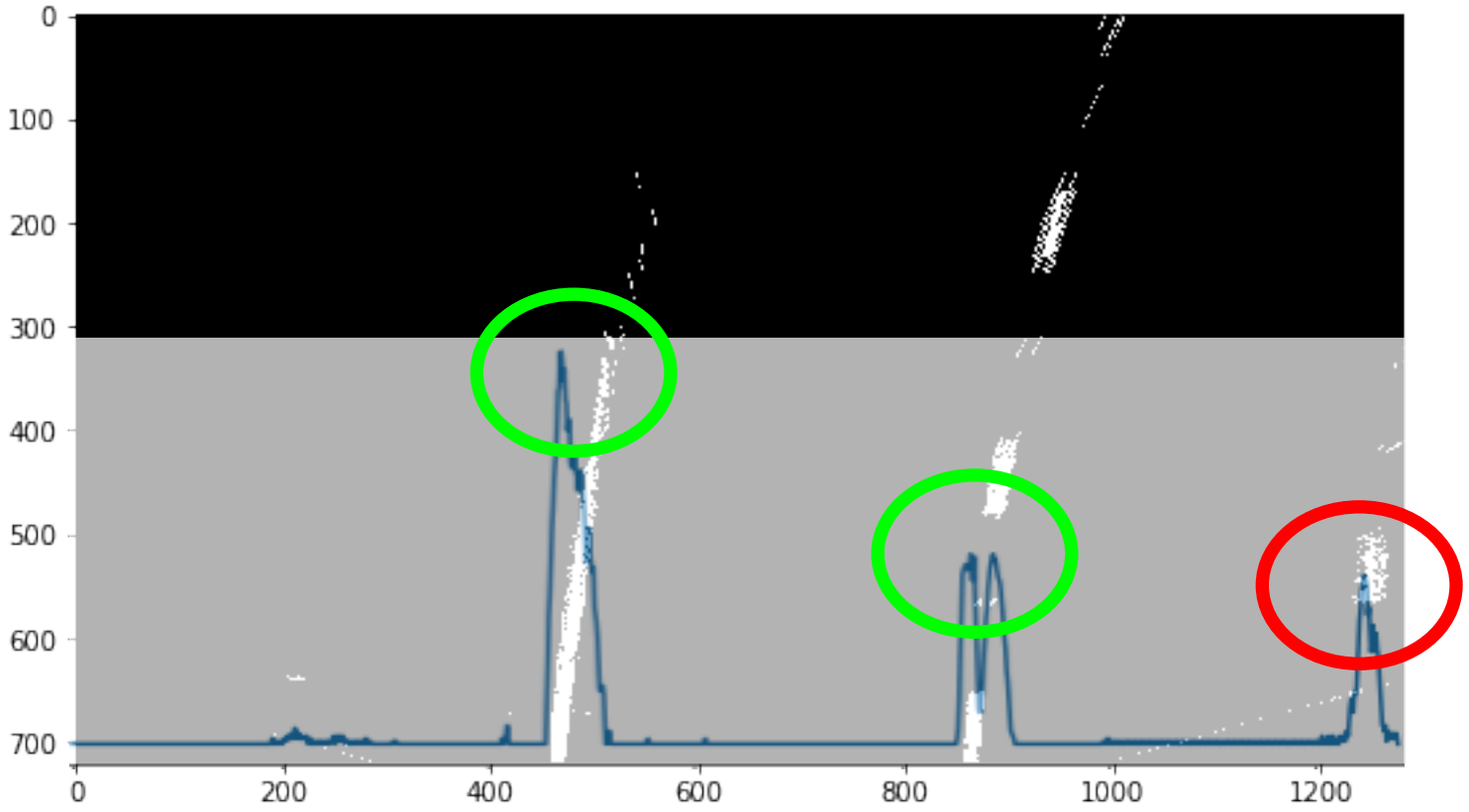
Sum white pixels at x location



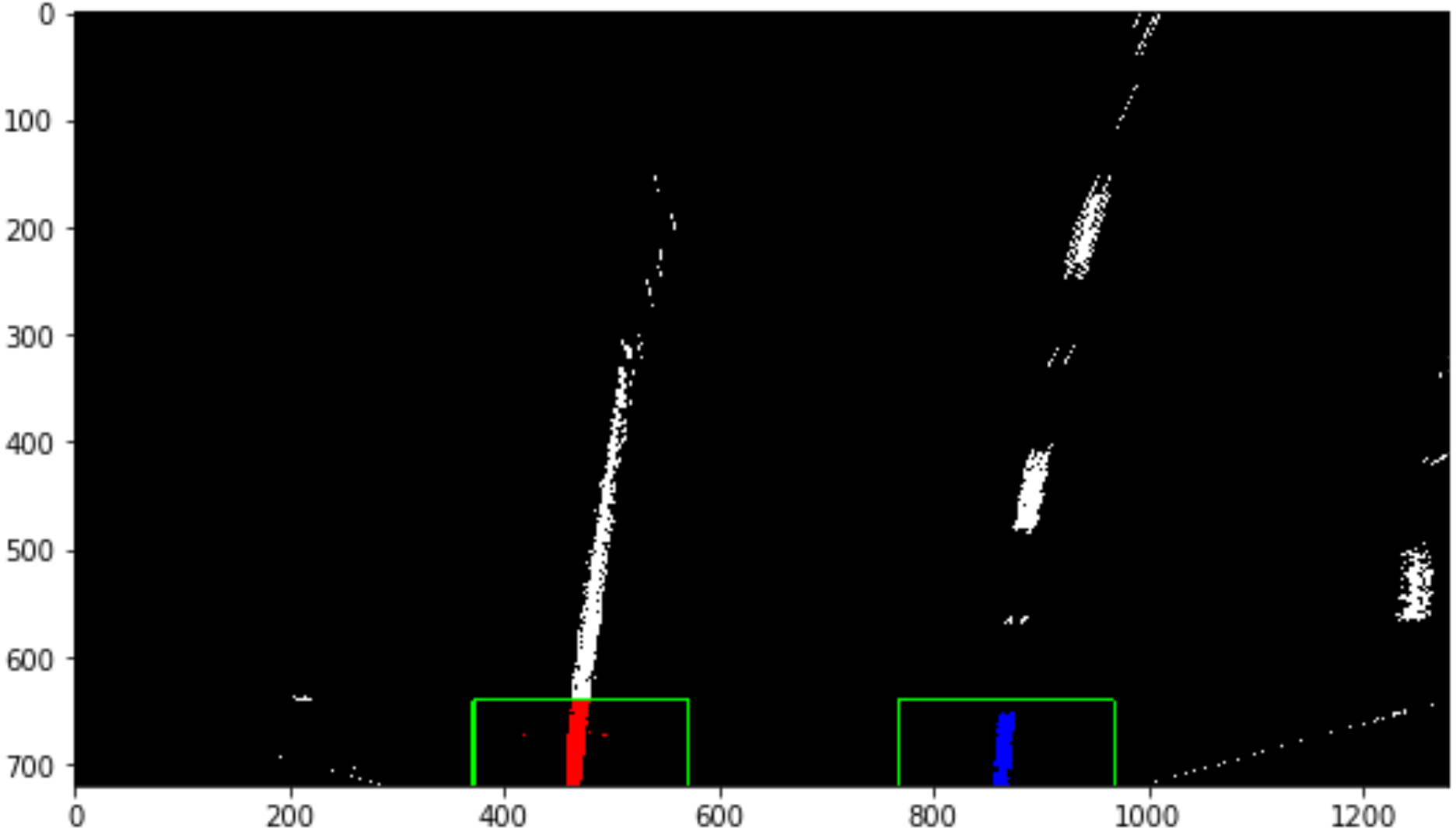
Pixel Position

Step 1: Find the start of the line

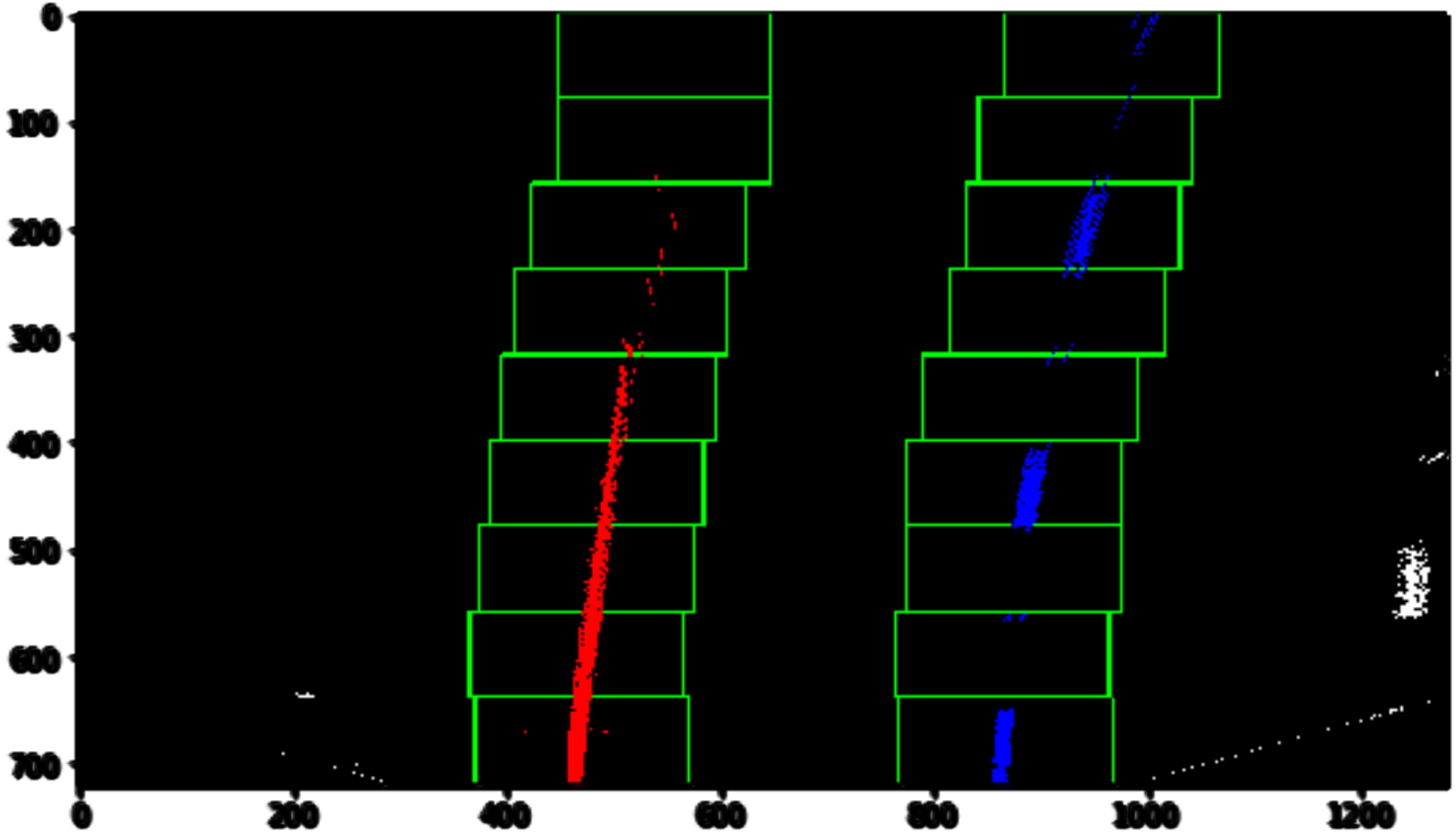
```
midpoint = np.int(histogram.shape[0]/2)
leftx_base = np.argmax(histogram[:midpoint])
rightx_base = np.argmax(histogram[midpoint:]) + midpoint
```



Step 2: Create windows around these maxima

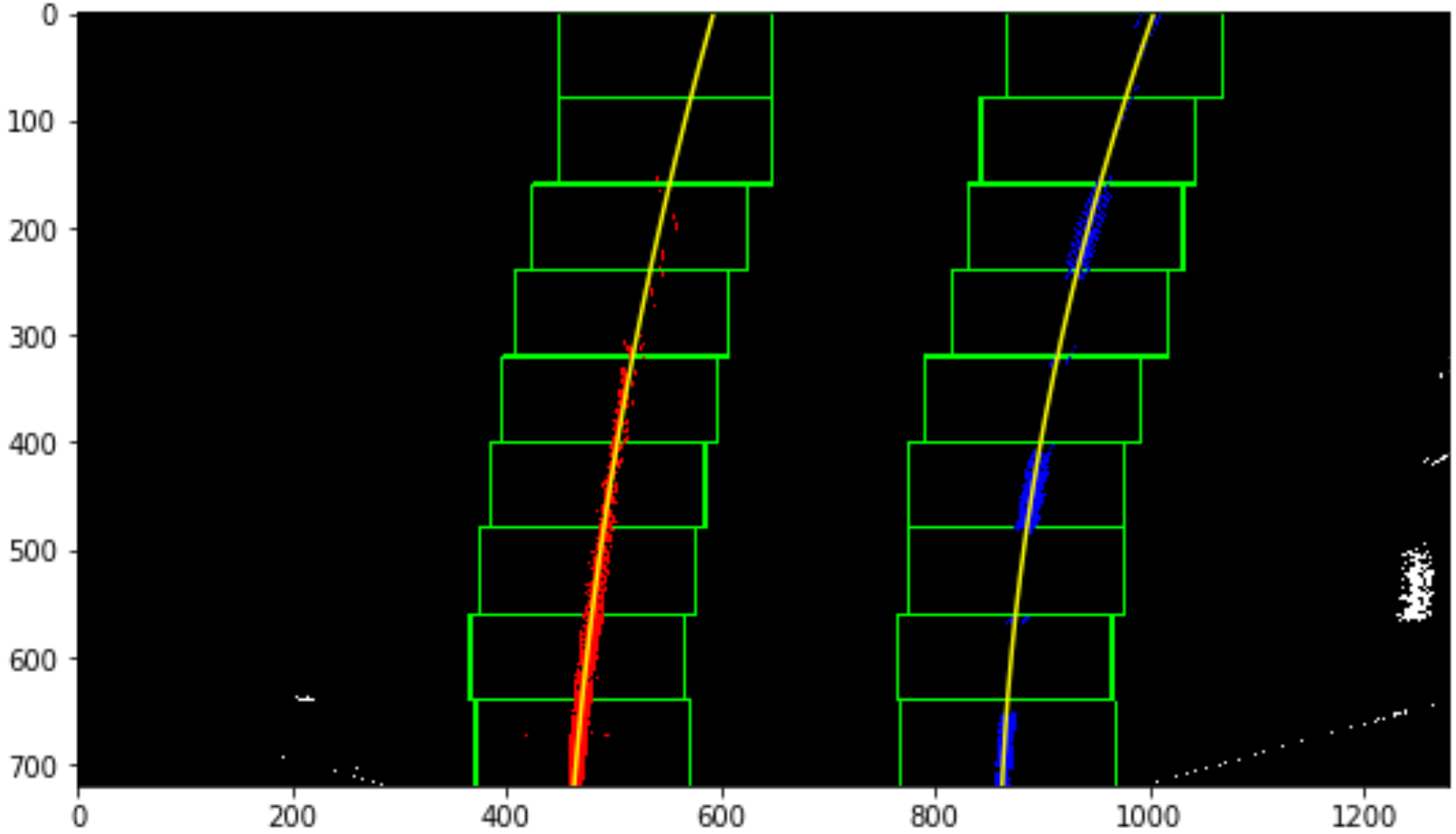


Step 3: Stack and move the windows

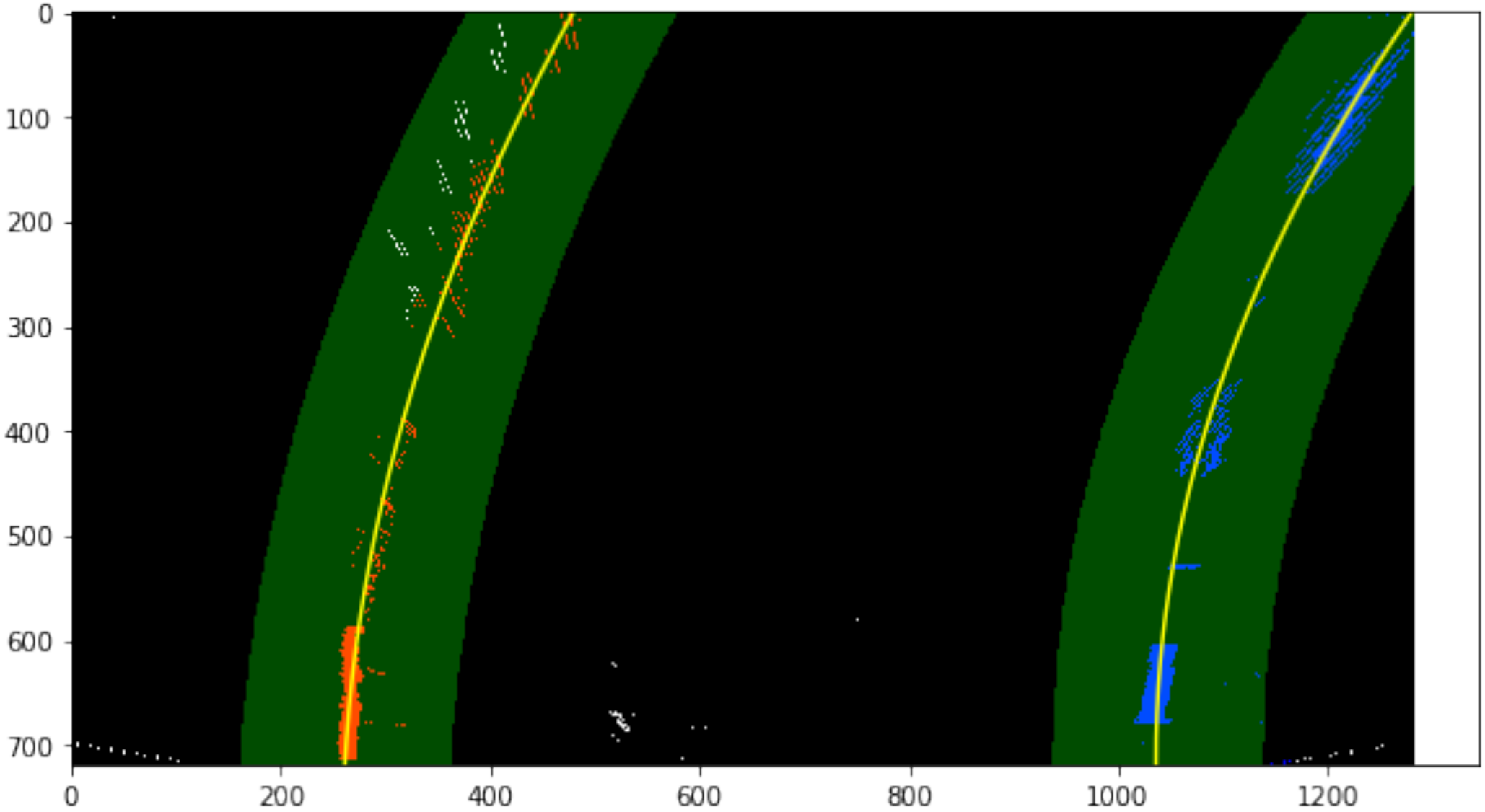


Step 4: Polyfit all the points from windows

```
left_fit = np.polyfit(lefty, leftx, 2)
right_fit = np.polyfit(righty, rightx, 2)
```

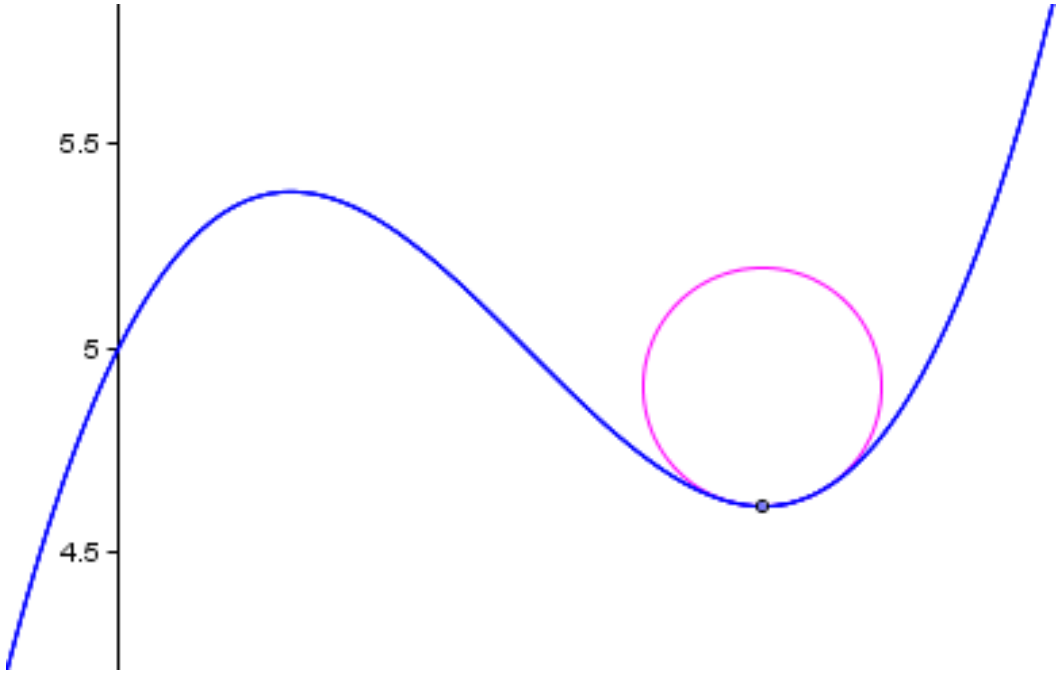


Method 2 uses an existing fit



Final Image

Calculating radius of curvature



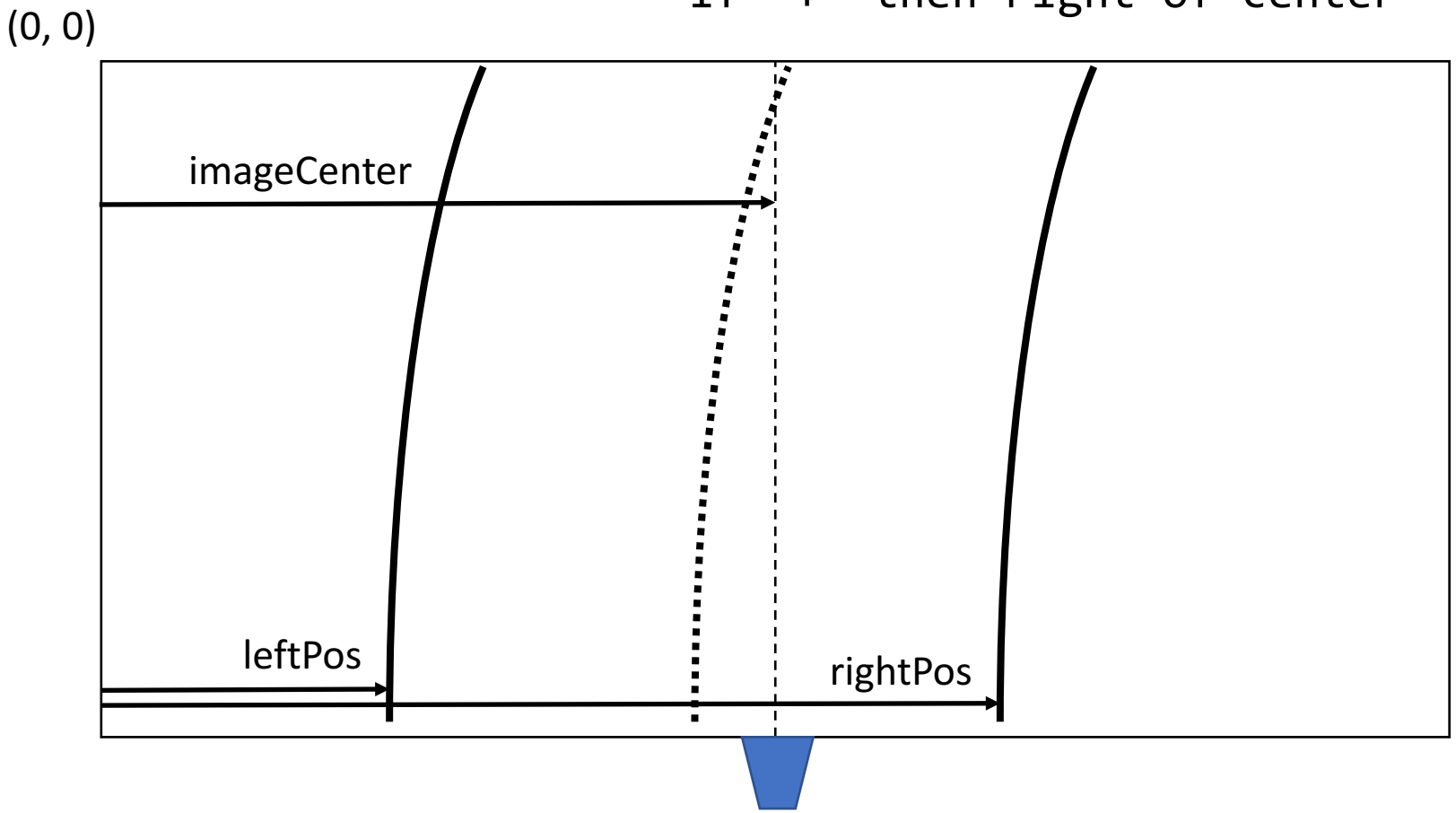
$$\text{Radius of curvature} = \frac{\left[1 + \left(\frac{dy}{dx}\right)^2\right]^{3/2}}{\left|\frac{d^2y}{dx^2}\right|}$$

Polyfit equation: $y = Ax^2 + Bx + C$

```
fit = [A, B, C]

curve_rad = ((1 + (2*fit[0]*y_eval + fit[1])**2)**1.5) /
np.absolute(2*fit[0])
```

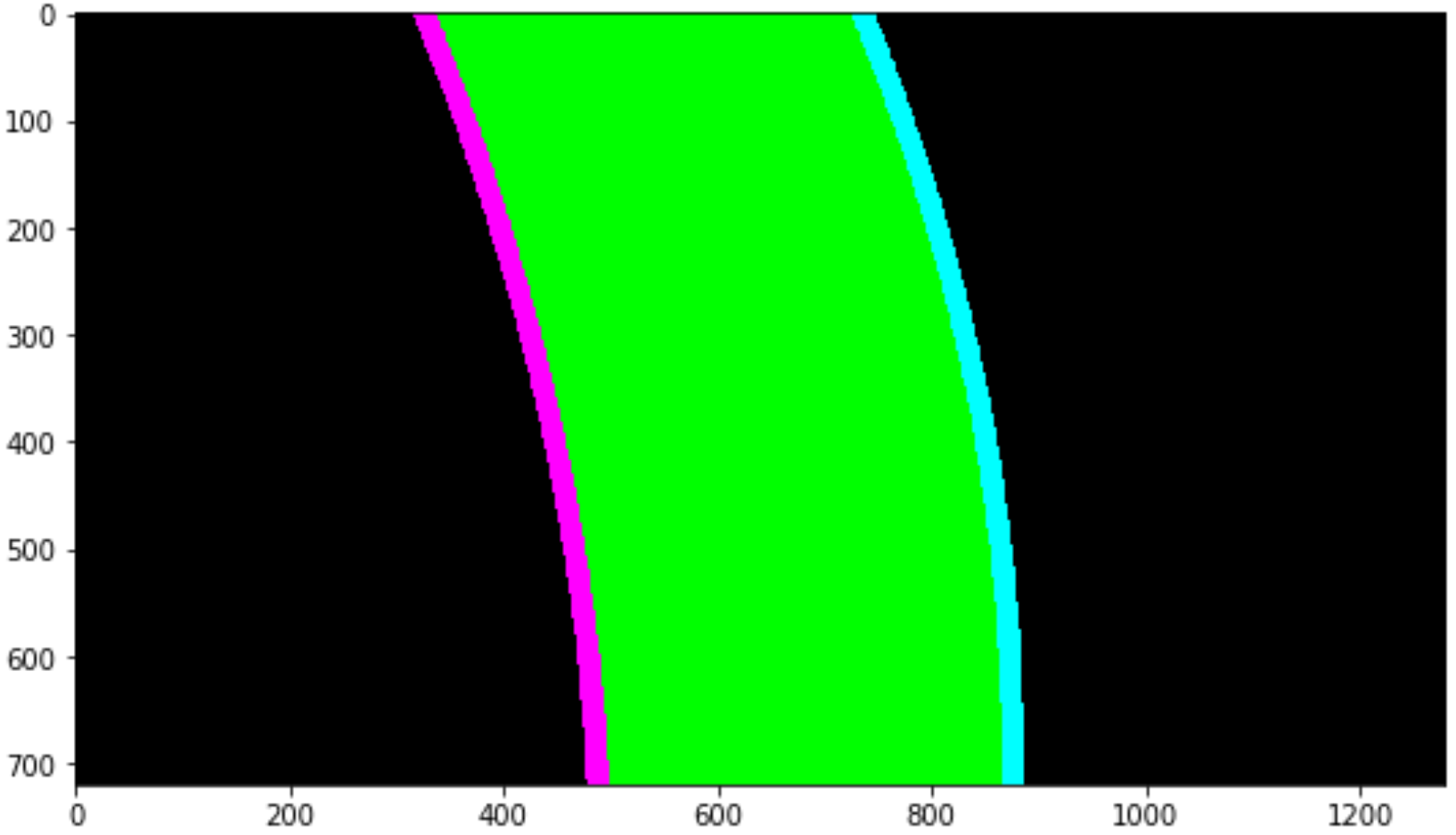
Distance to lane center

```
laneCenter = (rightPos - leftPos) / 2 + leftPos
distanceToCenter = laneCenter - imageCenter
If “+” then right of center
```



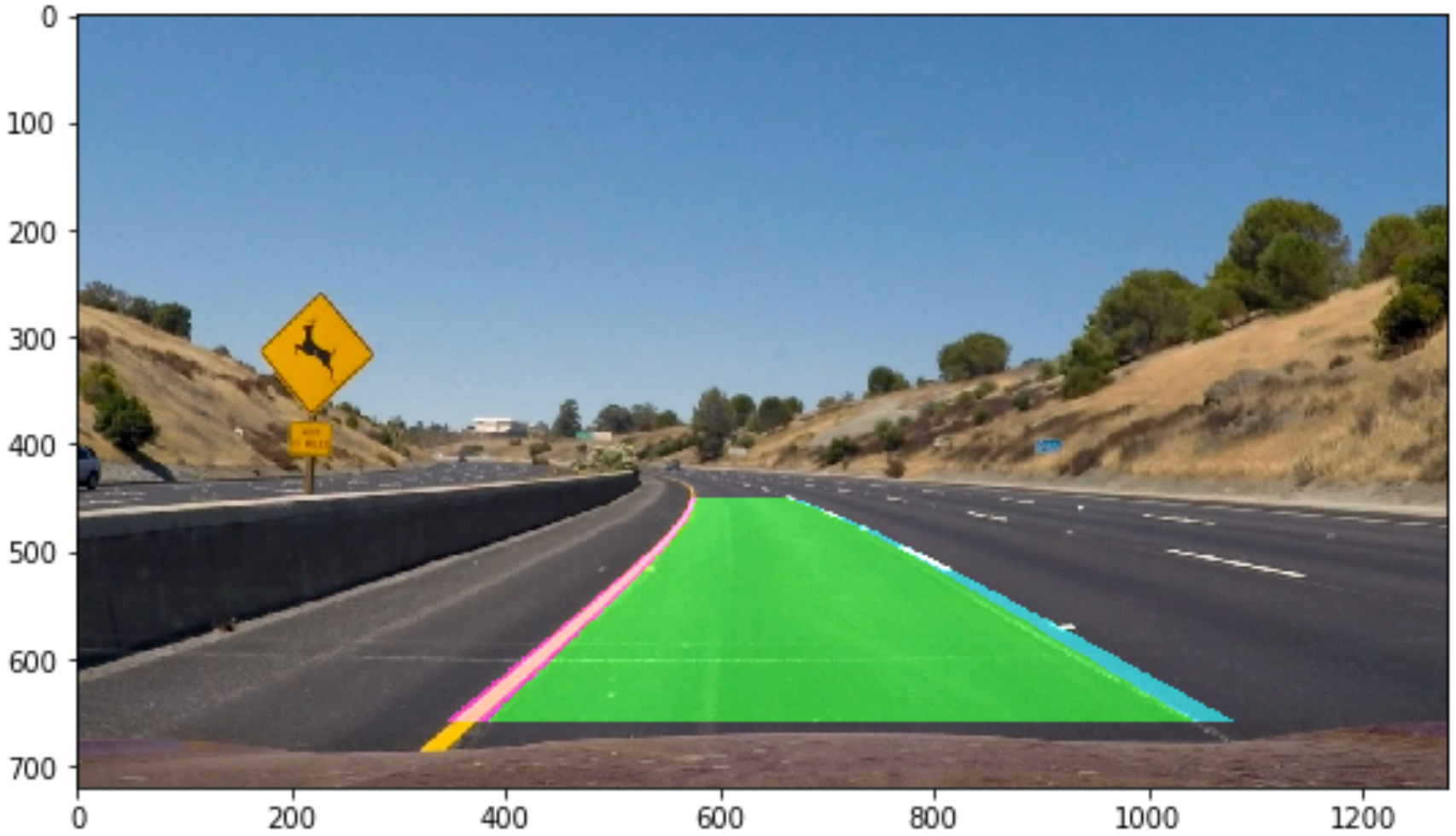
Plotting the lines and the drive area

```
cv2.fillPoly(color_warp, np.int_([pts]), (0,255, 0))
cv2.polylines(color_warp, np.int32([pts_left]), …)
```



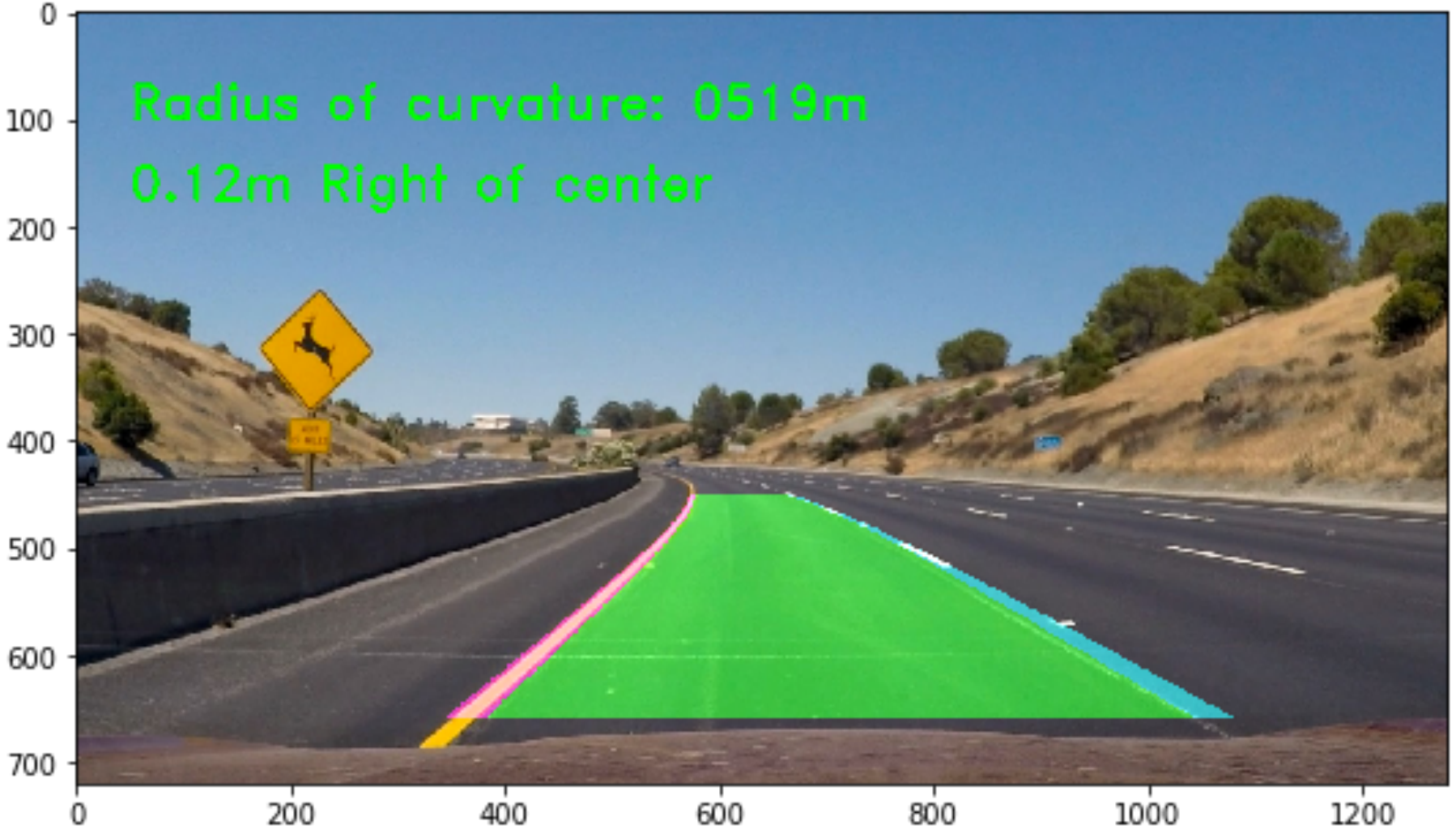
Unwarp the image and add to the original

```
result = cv2.addWeighted(img, 1, newwarp, 0.5, 0)
```



Add the radius and center distance

```
cv2.putText(img, text, (50,100), font, 1.5, (0,255, 0), 2, cv2.LINE_AA)
```



Building more

- Image warping
- Dynamic color channels
- Speed
- Smoothing

Questions?

github.com/rkipp1210/pydata-berlin-2017

Sources

- http://www.intmath.com/applications-differentiation/8-radius-curvature.php
- Test images and videos come from the udacity open source self-driving car repo: https://github.com/udacity/self-driving-car
- https://www.nytimes.com/interactive/2016/12/14/technology/how-self-driving-cars-work.html
- Gifs from Giphy