Advanced Lane Line Finding

1. Introduction

Workflow of advanced lane line finding can be roughly illustrated as following procedures:

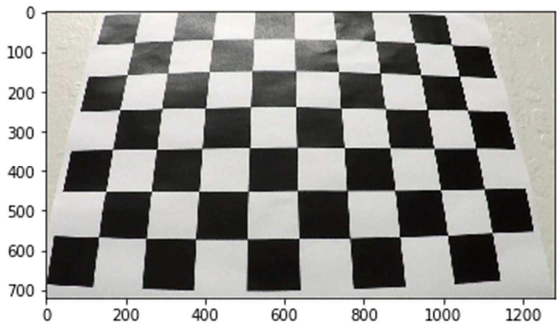
2. Image Pre-processing

In Pre-processing phase, practical detailed workflow is show as figure below:

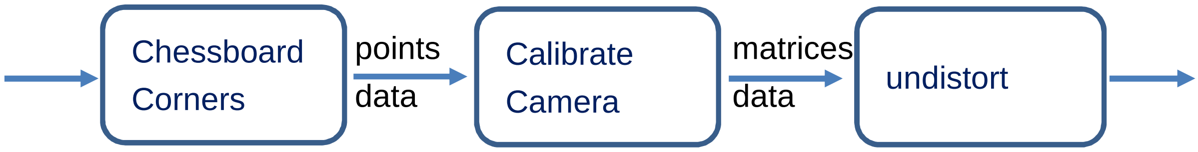
2.1. Camera Calibration

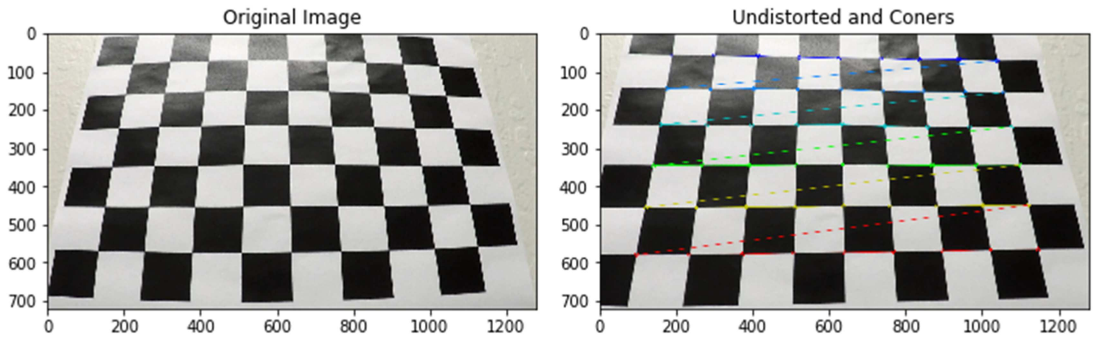
The purpose of camera calibration is to eliminate to image distortion caused by physical installation error of camera mounting position or by unparallel camera lens.

Chessboard is introduced here for performing calibration. By applying **cv2.findChessboardCorners**, precise **corner position** can be pinpointed. This function requires input of number of points in each row and column. For example, image below has 9 points each low and 6 points each column.



It is also essential to obtain destination point indices before calculating reverse-distortion matrix. Function **cv2.calibrateCamera** calculates matrices for undistortion. Last step is **cv2.undistort** to undistort raw image.





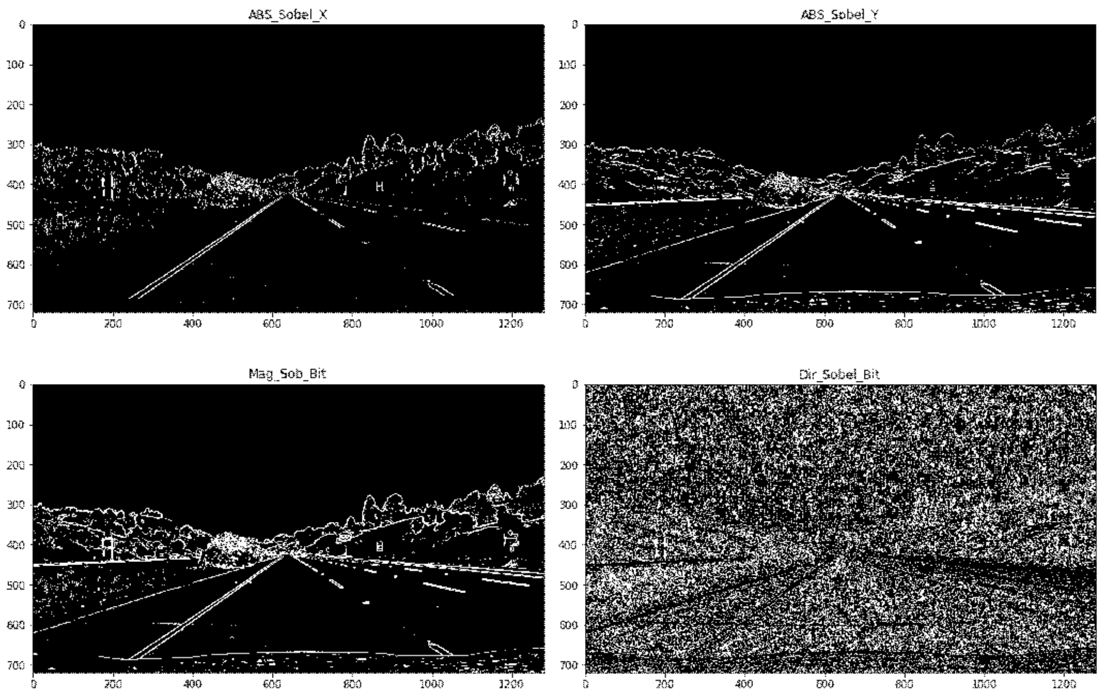
Above pictures show results of camera calibration.

2.2 Pixels Selection

Observe outputs from different methods and stack result together.

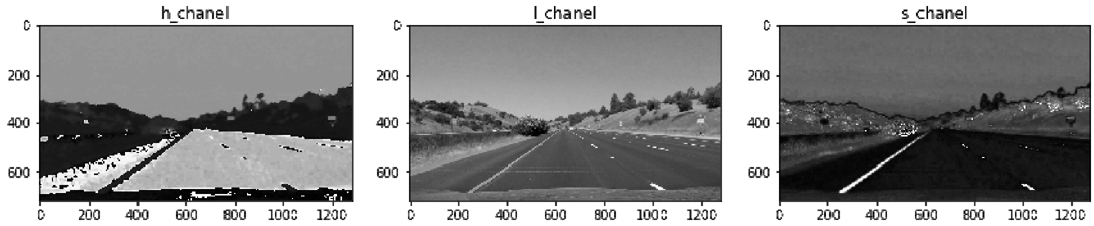
2.2.1 Sobel

Multiple methods are candidates for keeping image Pixels. Instead of general Canny edge detection, Sobel methods can provide gray scale derivative in specific situation.



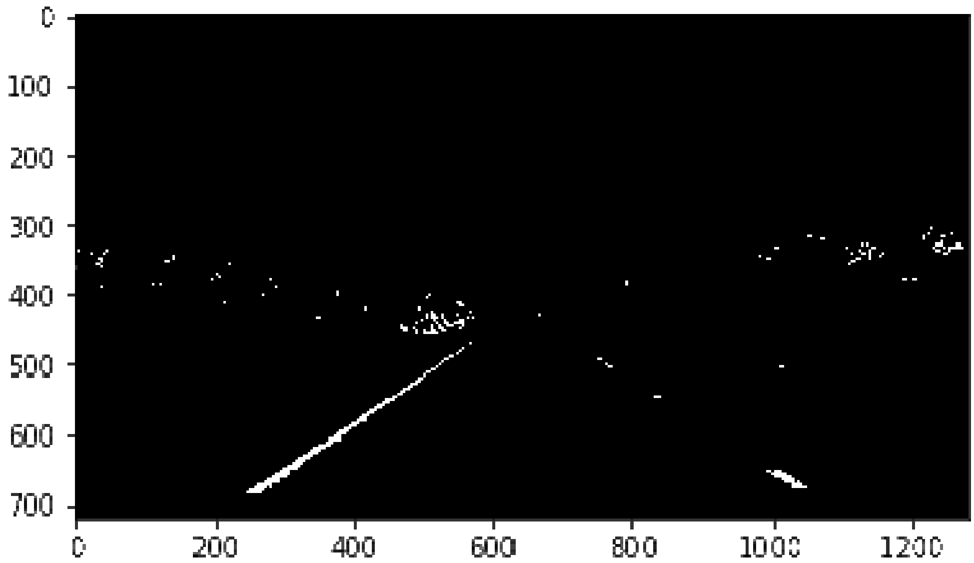
2.2.2 HLS Color Space

In addition to Sobel, HLS color space is also taking into consideration that it provide useful information regardless strength of lightness.



2.2.3 S channel and Sobel absolute x

After examining results multiple methods, binary images filtered from HLS s channel and from sobel absolute x can provide distinctive lane pixels. Final decision is to add up these images together for preserve maximum points data for polynomial calculation.

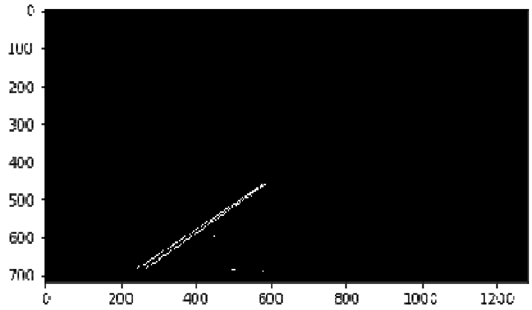


2.3 Perspective Transformation

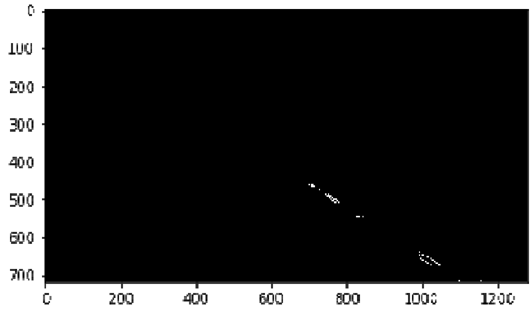
In order to perform transformation, source point and destination point are essential for function **cv2.getPerspectiveTransform(src, dst)** to retrieve transformation matrix. In order to determine these points, **HoughLinesP** can offer straight lines and end points position. To provide noise free data for **HoughLinesP,** manually select region of interest.

Input data used here is absolute sobel x, whose capability of providing lane contour can create decisive straight line.

2.3.1 Left and Right side ROI



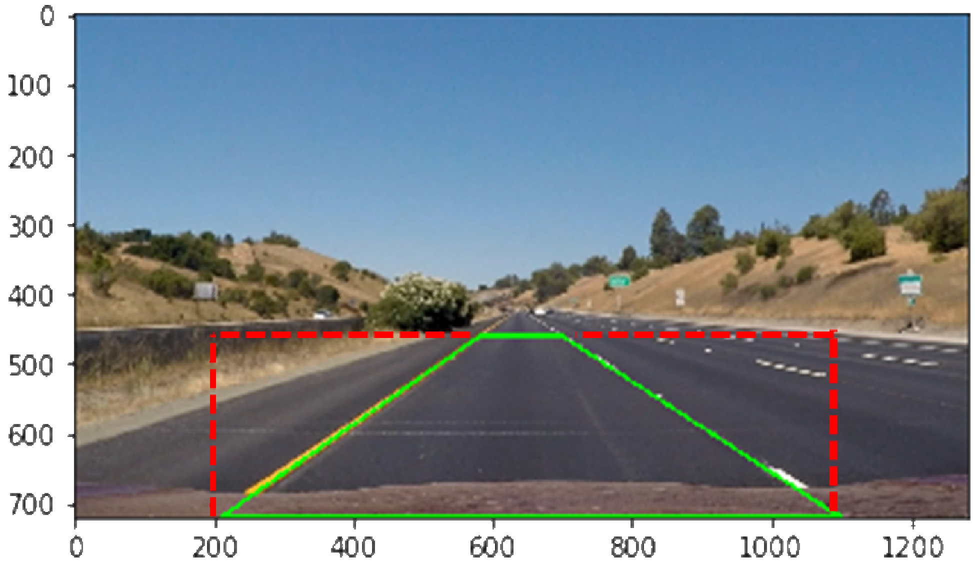
Left ROI



Right ROI

Right and left region of interest are separately picked to keep the function's line number as small as possible. Function **Get_Source_Points(Binary_image, mask_points, top_y_coornate)** performs **HoughLinesP** averaging line and extrapolate line to calculate end points.

2.3.2 DST Points Selection



In image above green polygon shows four source points at four corners. Easiest way is to use red intersections as upper part destination points. Perspective transformation result is shown in next page.

2.3.3 Perspective Transformation

Now src and dst data are available, transformation matrix can be access by:
M = cv2.getPerspectiveTransform(src, dst) , switch src and dst, inverse transformation matrix is also calculated.
Inv_M = cv2.getPerspectiveTransform(dst, src)
To warp an image, use following function:
output = cv2.warpPerspective(img, M, (width , height))

2.3.3.1 Transformation result

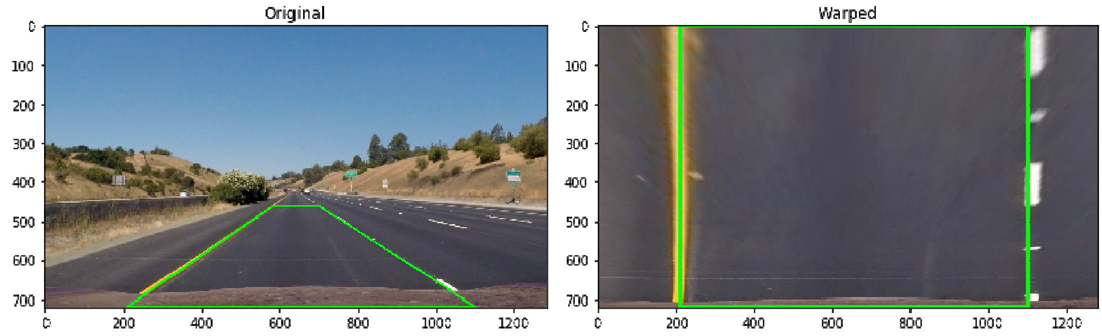
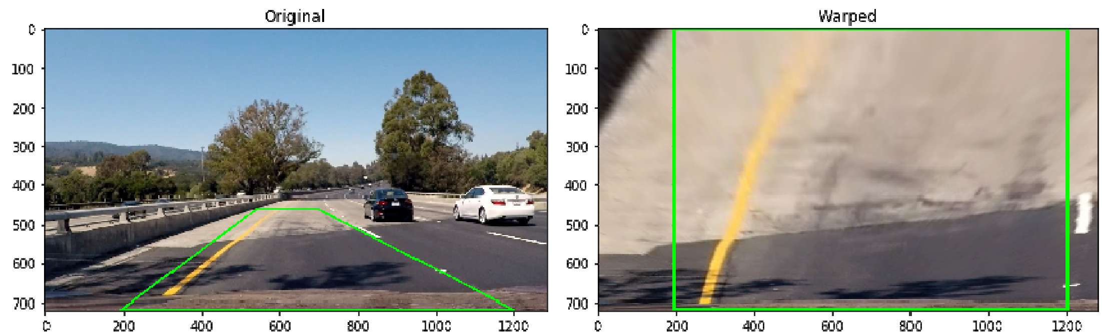


Figure above shows transformation result on straight lane, both left and right lane lines are shown clearly in the picture. However, when testing this on curve, as shown in picture below, a large portion of right hand side lane is not included. This will lead to problems while collecting pixels.

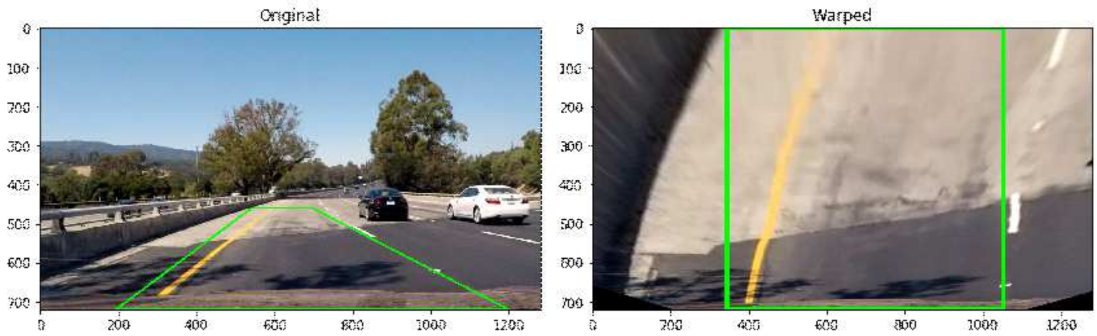


A little tweak on dst points can successfully address this issue. Below are original and modified code.

```
src = np.float32([ left_up, right_up, right_down, left_down, ])
dst = np.float32([ [left_down [0]              ,0 ],
                   [right_down[0]             ,0],
                   [right_down[0]              , right_down[1]],
                   [left_down[0]              , left_down[1]] ])
```

```
offset = 150
src = np.float32([ left_up, right_up, right_down, left_down, ])
dst = np.float32([ [left_down [0] + offset   ,0 ],
                   [right_down[0] - offset   ,0 ],
                   [right_down[0] - offset   , right_down[1]],
                   [left_down [0] + offset   , left_down[1]] ])
```

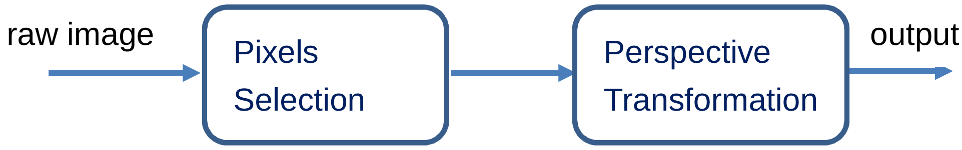
Warp image with offset dst points is show in the next page. Right lane line which is previous excluded is now inside image.



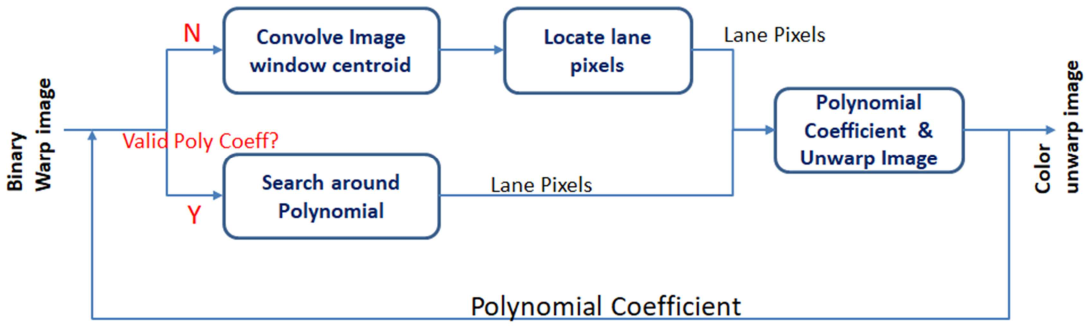
2.4 Image Pre-processing Conclusion

For later lane detection processing, camera calibration is not used since there is no evidence between camera calibration test images and lane detection images and videos.

In this project, actual image pre-processing work flow is shown below:



3. Lane Detection



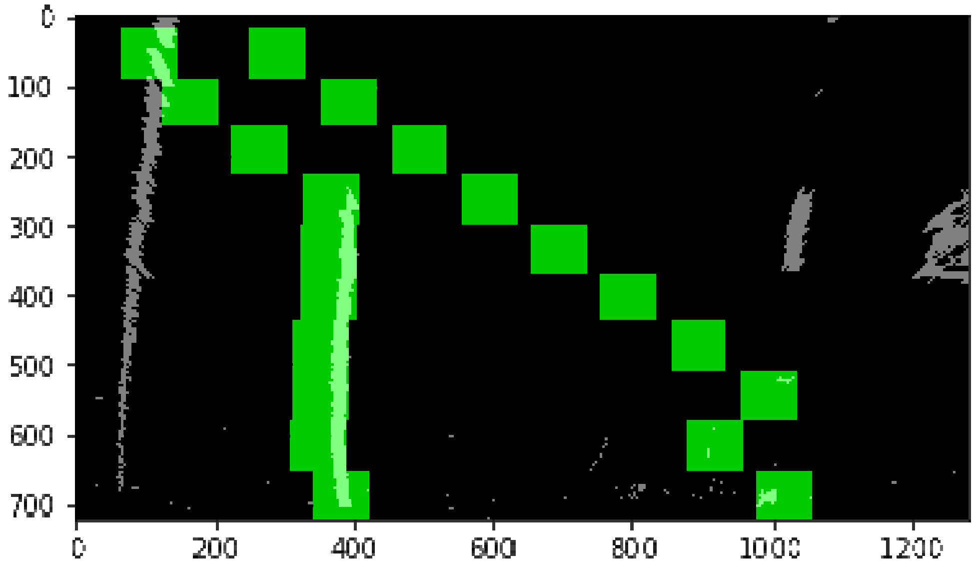
3.1 Convolve Image

As show in the chart above, if a new image goes through lane detection algorithm, this image will be convolved and then the peak is where the most likely position for the lane marker

First version of convolve algorithm is like introduced in lesson as shown below:

```
l_center =
np.argmax(conv_signal[l_min_index:l_max_index])+l_min_index-offset
```

Visualized output is shown in next page.

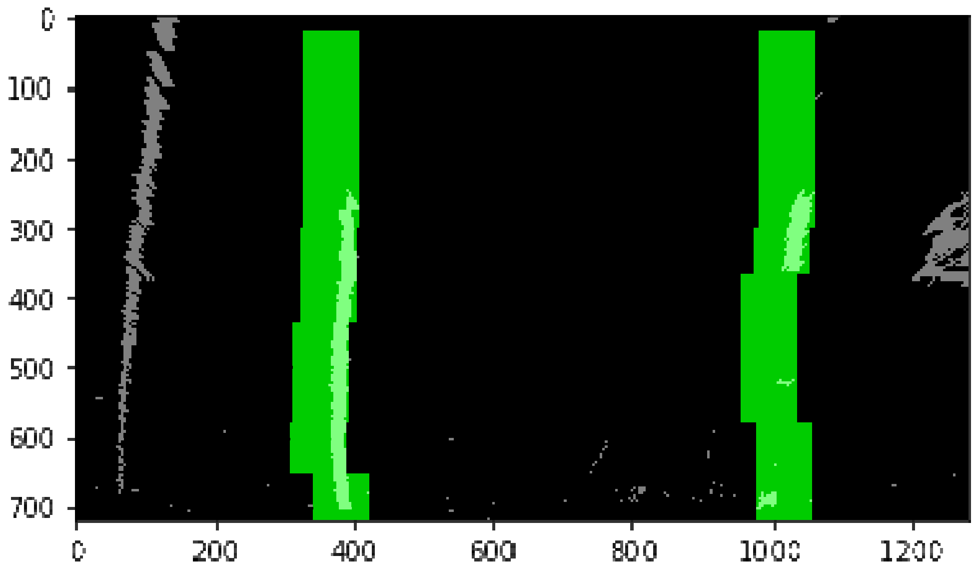


While zero points are undergone convolve, next center output subtract offset nevertheless. It's more reasonable to presume the next center x location remains the same since most lane line is continuous.

There, a threshold and condition are added to code.

```
if conv_signal[np.argmax(conv_signal[l_min_index:l_max_index])+l_min_index]
<= thresh:
    l_center = l_center
else:
    l_center =
    np.argmax(conv_signal[l_min_index:l_max_index])+l_min_index-offset
```

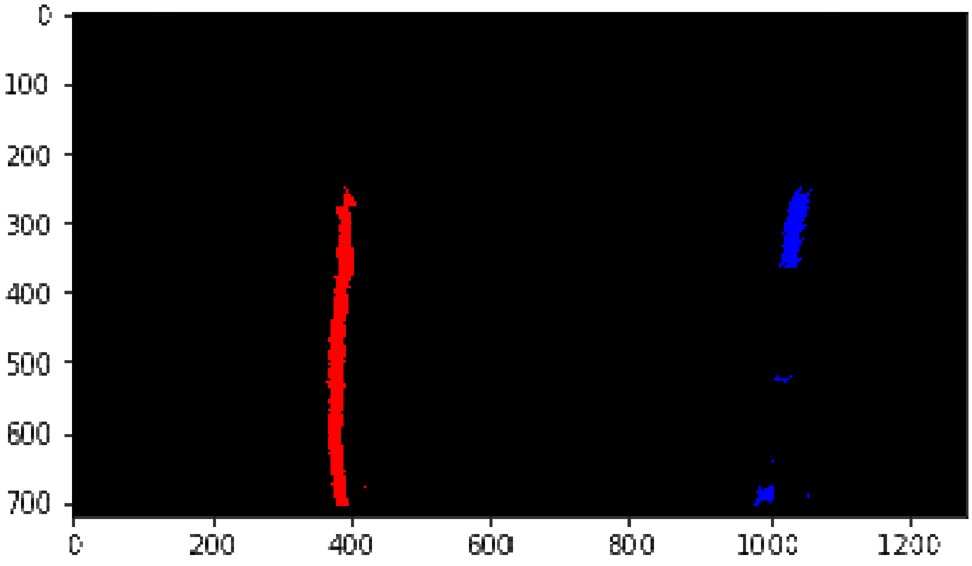
Visualized output is shown below.



3.2 Locate Line Pixels

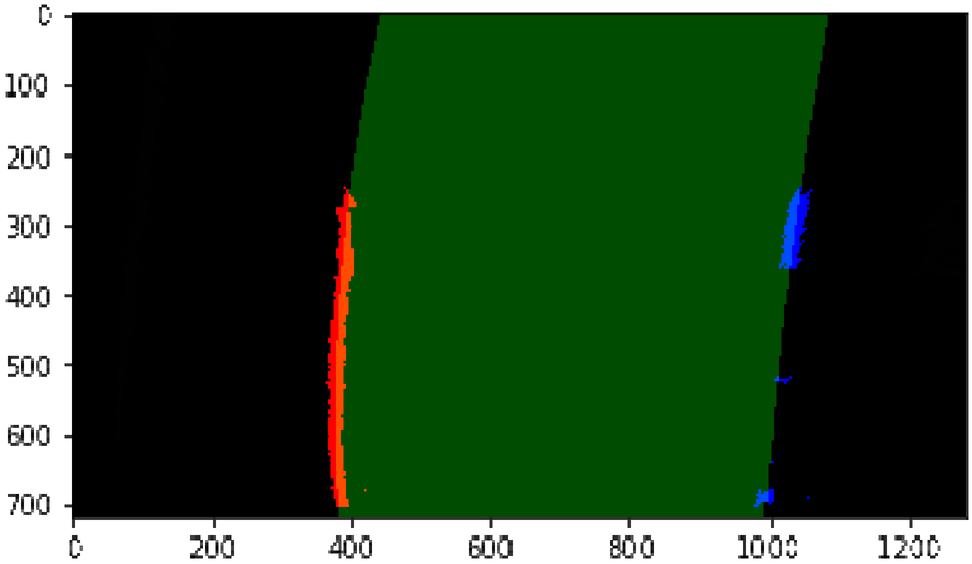
In this part, pixels in windows as shown in previous picture are select and colored.

This algorithm is performed in function:
Color_and_Locate_Lane_Pixels



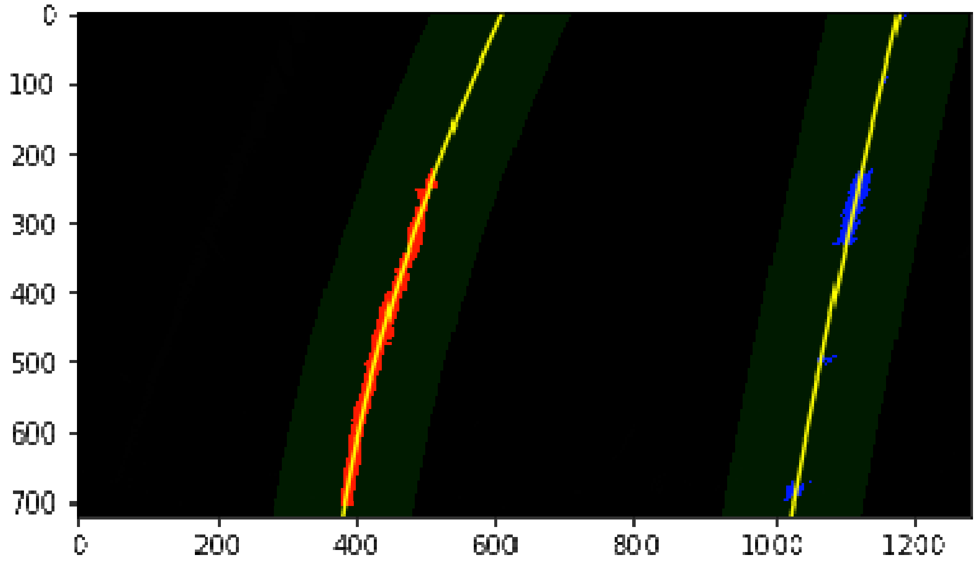
3.3 Polynomial coefficient, Radius, Center

When left and right lane line pixels are separately isolated, these data are used to calculated polynomial coefficient. Once coefficients are available, curvature rate and road center can be computed.



3.4 Search around Polynomial

Once polynomial coefficients are calculated, search for lane pixels can be more efficient by offset left lane line and focuses on pixels fall in the region. This is useful while processing videos.



4. Image Post-processing

Last step is to reverse the warped image and add visualized lane data along with curvature rate and vehicle center position on raw image input.