<u>Dear Reviewer(s):</u>

I struggled with this project for much longer than it should have taken me. Based on my mentor's suggestion, I submitted my project about 24 hours ago even knowing that it will not pass. This was to get feedbacks and those feedbacks were extremely valuable. I feel like I have a decent submission now. I really appreciate the help. Thank you!

Advanced Lane Finding Project

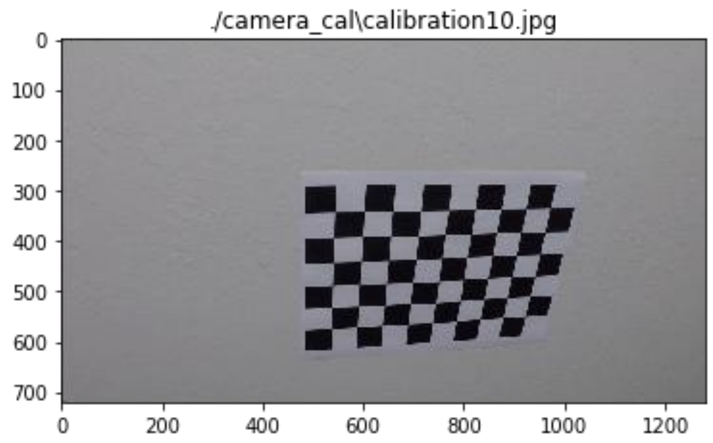
The goals / steps of this project are the following:

- 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.

Camera Calibration

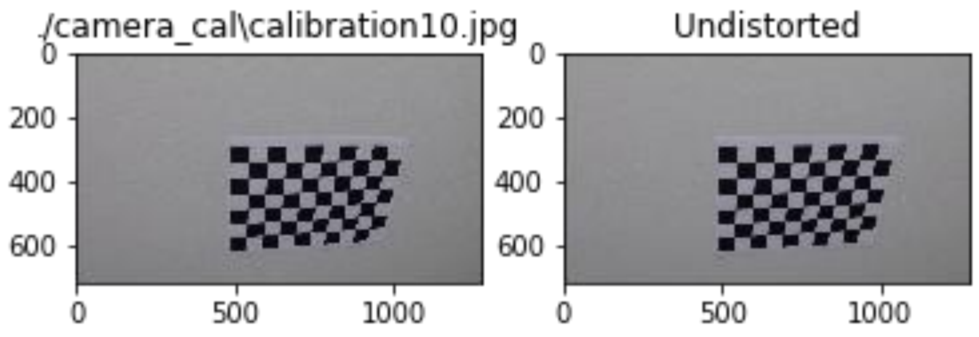
For camera calibration, I used the chessboard images provided by the course. Eighteen of twenty had a shape of 720 by 1280, while the other two had a shape of 721 by 1281. Chessboards are of various sizes are located in places of the image. Here is an example of a chessboard image.

Figure 1: Chessboard image



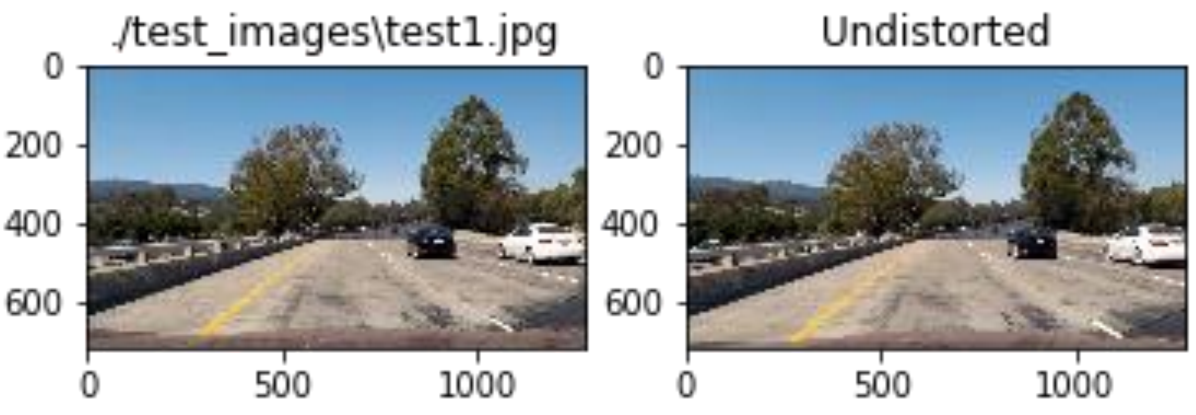
To calibrate the camera, I used the cv2.dfrawChessboardCorners, which uses corners of chessboards. There were 9 points across columns and 6 points up and down rows. Three of the images (images 1, 4, and 5) had at least one chessboard corners that were outside the images, thus corners were not drawn for these images. Figure 2 shows the calibrated chessboard images.

Figure 2: Calibrated chessboard images



I used the same calibration in six test images of the road. Figure 3 shows original and undistorted images of the one test image.

Figure 3: Original and undistorted image of a road



Gradient and color transforms

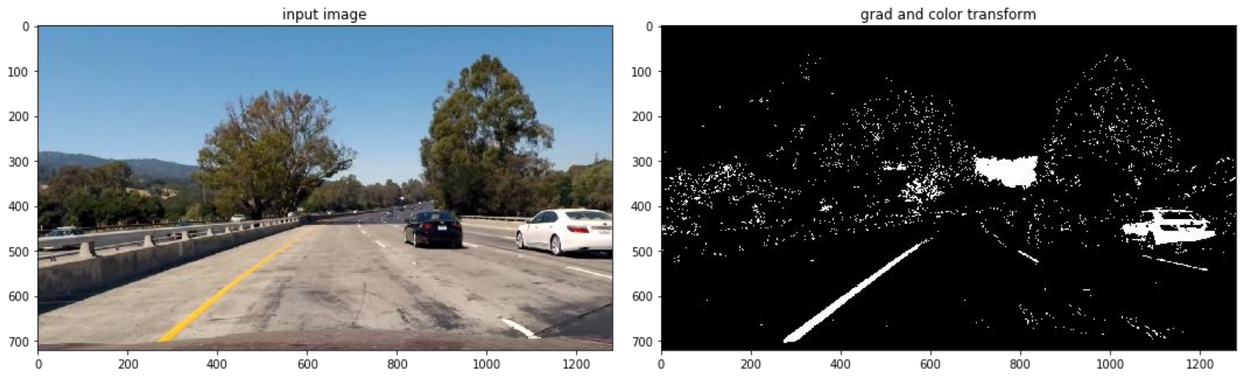
To better capture the lanes from images, I applied gradient and color transforms on the undistorted images.
I had several transformation functions that I tried out using different threshold parameters including following:

- Sobel transformation along x or y axis
- Magnitude of sobel x and y

- Direction of the gradient on sobel x and y
- Transformation on RGB colors
- Transformation on HLS color channel

After iterating through many different combinations, I decided to use the HLS transformation to detect yellow and white lanes and comebine with sobel gradient transformation in X direction and direction gradient transformations. Figure 4 shows the image before and after the transformation.

Figure 4: Image before and after transformation



Perspective transform

To better detect lanes, I then applied perspective transformation into bird-eye view. I used the following source and destination points.

Source	Destination
590, 450	200, 50
720, 450	1080, 50
1150, 720	200, 720
250, 720	1080, 720

Figure 5 shows the images before and after perspective transformation.

Figure 5: Image before and after perspective transformation

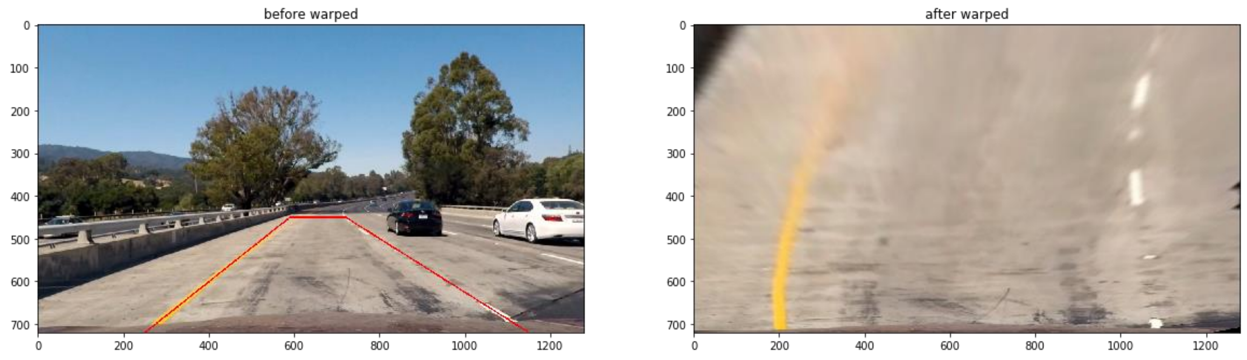
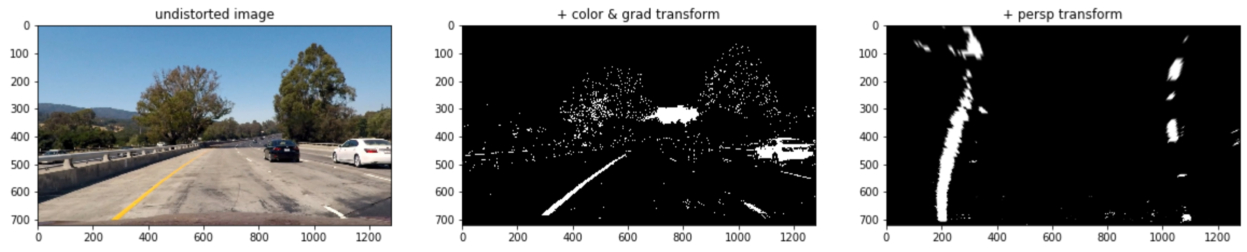


Figure 6 shows an undistorted image after color and gradient transformation followed by a perspective transformation.

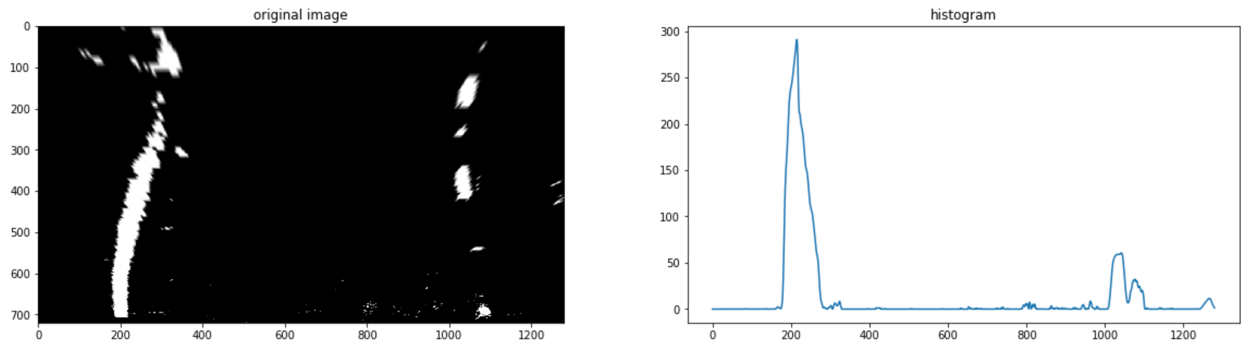
Figure 6: Combined transformation



Finding lanes from the image

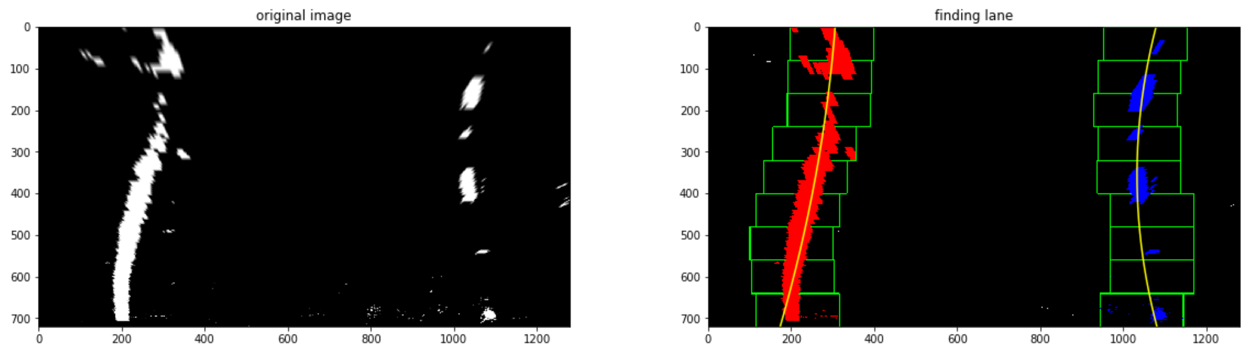
At this point, left and right lanes will be identified from the transformed images. First, we will use the histogram along the columns in the lower half of the image to identify where the lane might be. Figure 7 shows how histogram can be used shows where the lines are.

Figure 7: Histogram to identify lane location



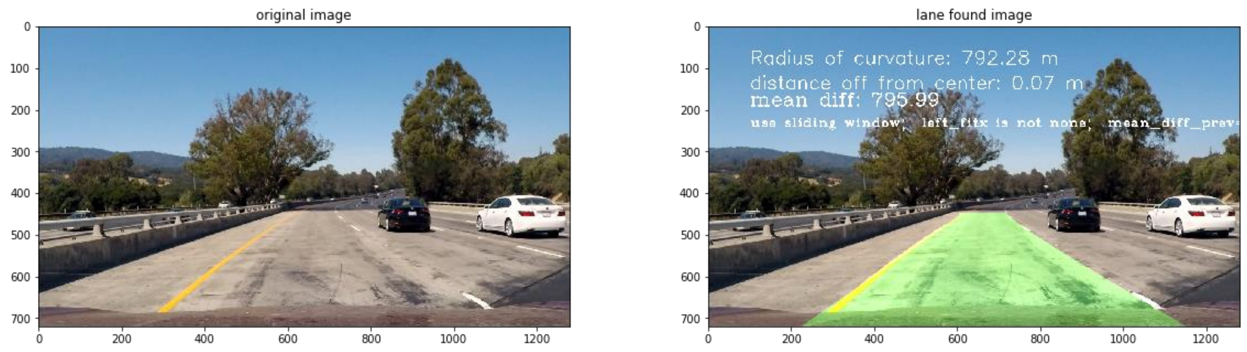
Next we will add sliding windows to lane locations derived from histogram and fit a polynomial line as seen in figure 8. I used the 2nd order polynomial. Additionally, we can use the previous fit to estimate the new fit to save computation time.

Figure 8: Using sliding window to locate lanes



Here is an example of an image that goes through above transformations and identifications, and with the lane region highlighted.

Figure 9: Lane region plotted



```
Radius of curvature: 792.28 m
distance off from center: 0.07 m
mean diff: 795.99
use sliding window; left_fitx is not none; mean_diff_prev=
```

Using in the video.

I used the above techniques to process the video.

Discussion about problems faced and improvements that can be done

One area where I spent a lot of time (besides the final debugging stage) was in the color and gradient transformation stage. There are so many choices on various types of transformations and different parameters that can be used. A suggestion that was made on my previous review was to try other color spaces such as HSV, YUV or LAB. Due to time constraint, I decided not to pursue these at the moment. I am sure there are many improvements that can be made on my method of transformations to improve the result and to optimize time and memory.

Another problem that I faced was that there were several bugs in my codes and that I could only devote at most two hours a day on this project due to my other commitments. I do wish I had a longer block of time but I could not control that. However, I wish I had used supports available much earlier instead of killing myself and trying to get the perfect project before submitting.