Writeup Template

You can use this file as a template for your writeup if you want to submit it as a markdown file, but feel free to use some other method and submit a pdf if you prefer.

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.

Rubric Points

Here I will consider the rubric points individually and describe how I addressed each point in my implementation.

Writeup / README

1. Provide a Writeup / README that includes all the rubric points and how you addressed each one. You can submit your writeup as markdown or pdf. Here is a template writeup for this project you can use as a guide and a starting point.

You're reading it!

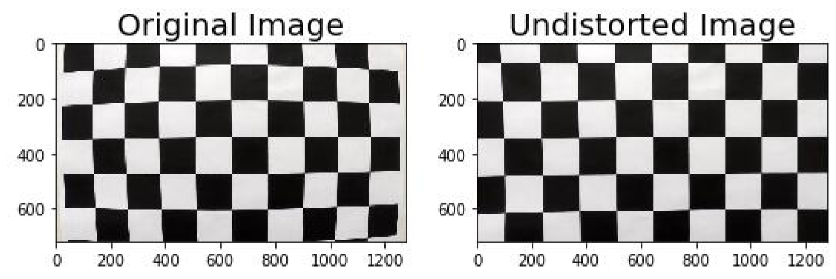
Camera Calibration

1. Briefly state how you computed the camera matrix and distortion coefficients. Provide an example of a distortion corrected calibration image.

The code for this step is contained in the 2nd code cell of the IPython notebook located in "advanced_laner.ipynb"

I start by preparing "object points", which will be the (x, y, z) coordinates of the chessboard corners in the world. Here I am assuming the chessboard is fixed on the (x, y) plane at z=0, such that the object points are the same for each calibration image. Thus, `objp` is just a replicated array of coordinates, and `objpoints` will be appended with a copy of it every time I successfully detect all chessboard corners in a test image. `imgpoints` will be appended with the (x, y) pixel position of each of the corners in the image plane with each successful chessboard detection.

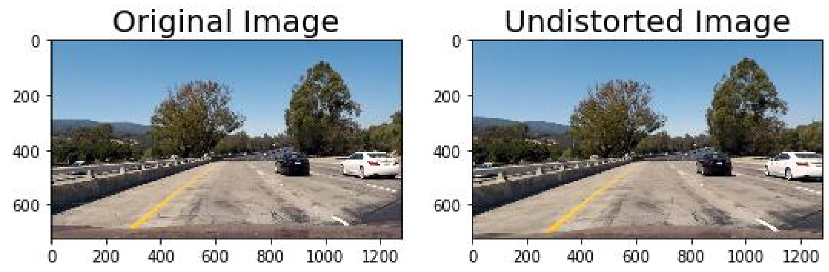
I then used the output `objpoints` and `imgpoints` to compute the camera calibration and distortion coefficients using the `cv2.calibrateCamera()` function. I applied this distortion correction to the test image using the `cv2.undistort()` function and obtained this result:

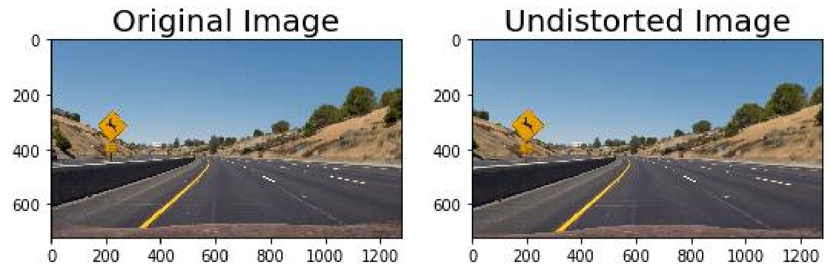


Pipeline (single images)

1. Provide an example of a distortion-corrected image.

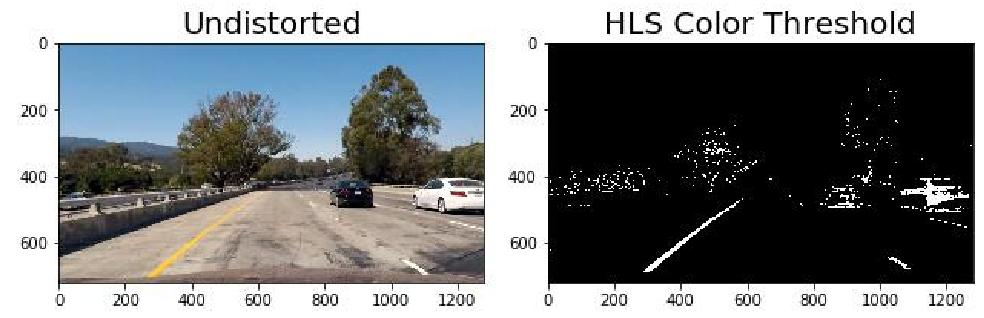
I apply the distortion correction method provided in advanced_laner.ipynb (cell 3) to get the result like this one:

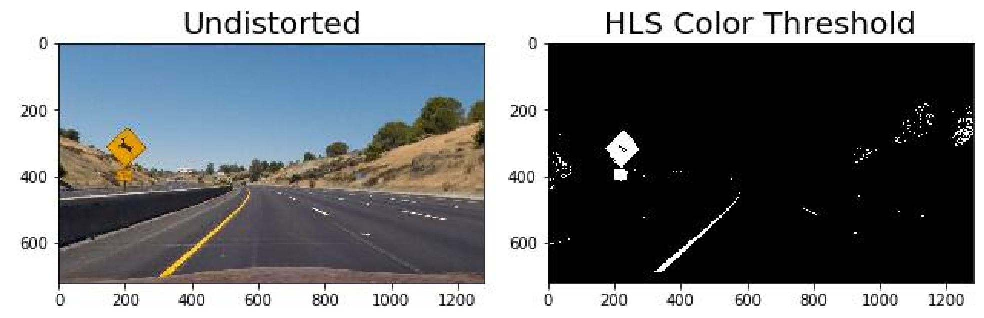


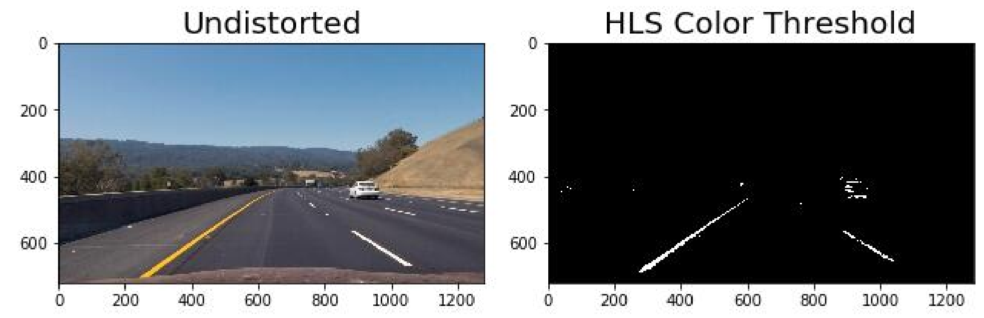


2. Describe how (and identify where in your code) you used color transforms, gradients or other methods to create a thresholded binary image. Provide an example of a binary image result.

I used a S channel of HLS color space to generate a binary image (thresholding steps at cell 5&6 in `advanced_laner.ipynb`). Here are some examples of my output for this step.





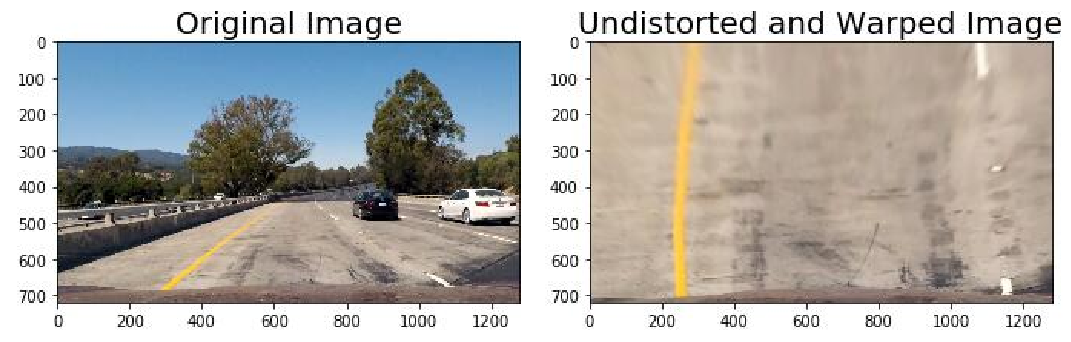


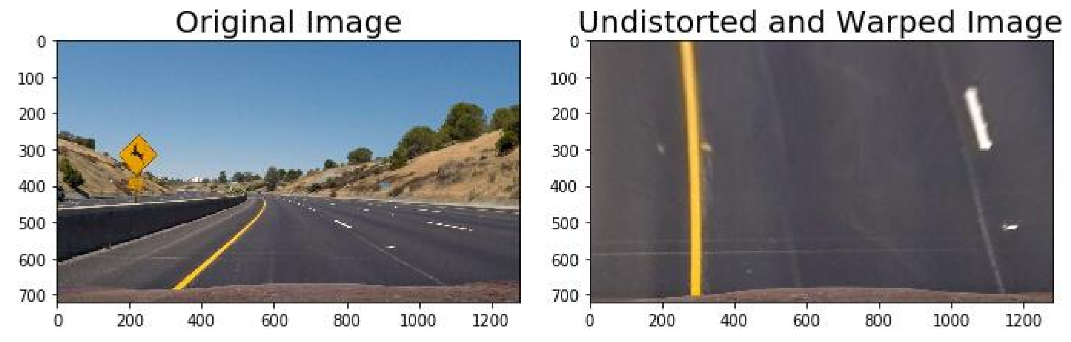
3. Describe how (and identify where in your code) you performed a perspective transform and provide an example of a transformed image.

The code for my perspective transform includes a function called `warper()`, which appears in lines 1 through 8 in the file `example.py` (output_images/examples/example.py) (or, for example, in the 3rd code cell of the IPython notebook). The `warper()` function takes as inputs an image (`img`), as well as source (`src`) and destination (`dst`) points. I chose the hardcode the source and destination points in the following manner, then I got the following source and destination points:

```
| Source        | Destination   |
|:-------------:|:-------------:|
|  585, 482     |    0, 0       |
|  810, 482     | 1280, 720     |
| 1250, 720     | 1250, 720     |
|   40, 720     |   40, 720     |
```

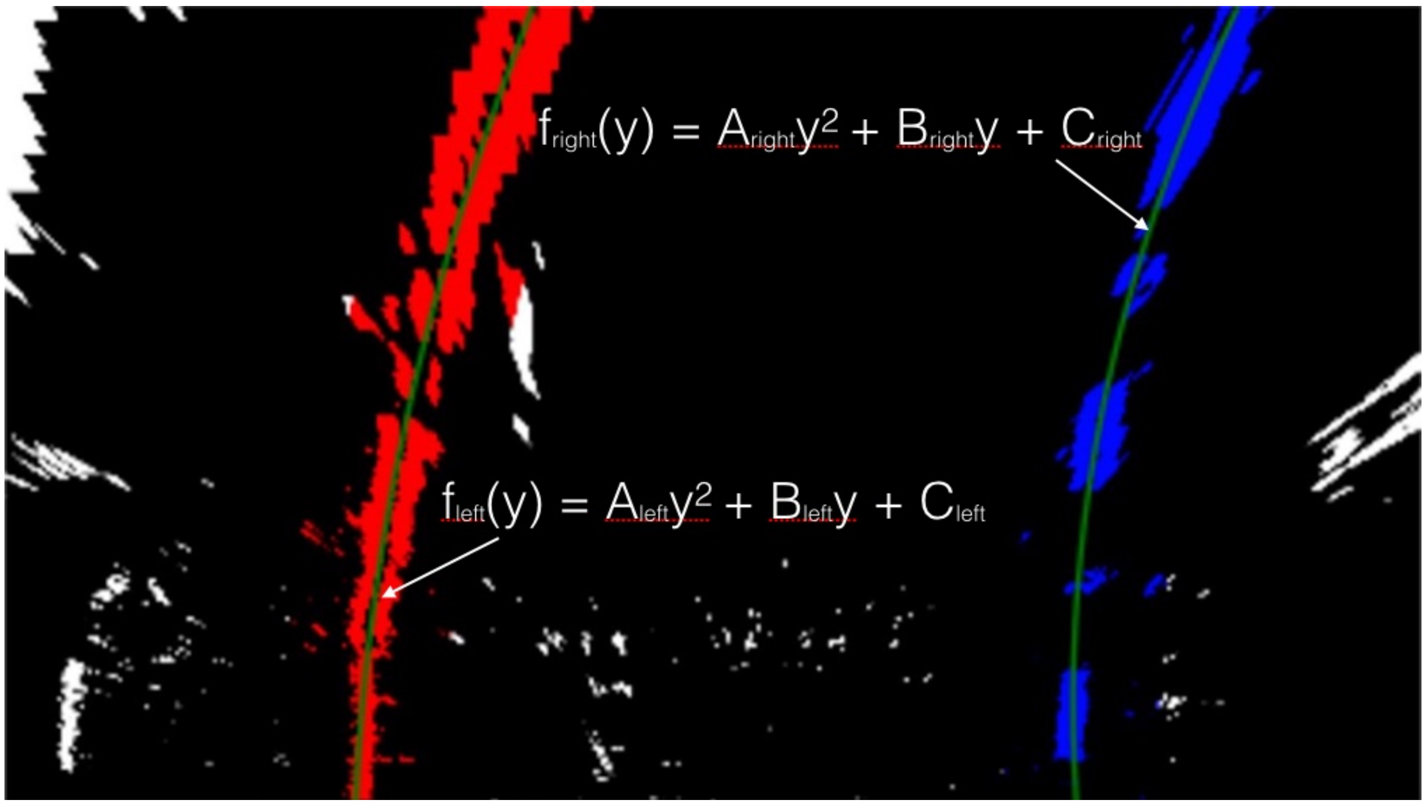
I verified that my perspective transform was working as expected by drawing the `src` and `dst` points onto a test image and its warped counterpart to verify that the lines appear parallel in the warped image.



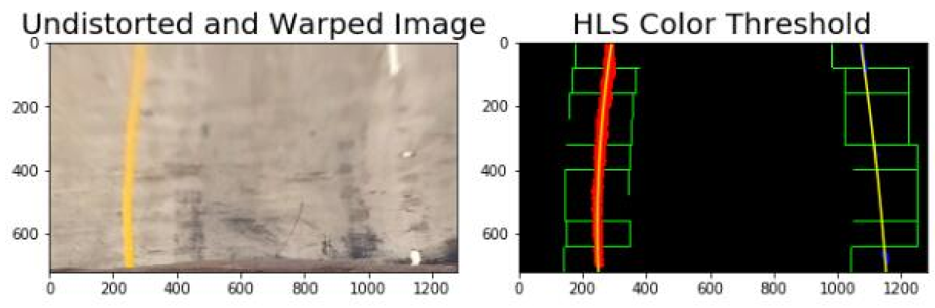


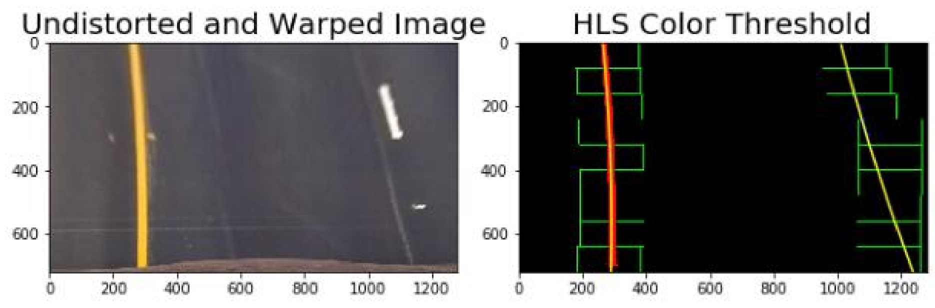
4. Describe how (and identify where in your code) you identified lane-line pixels and fit their positions with a polynomial?

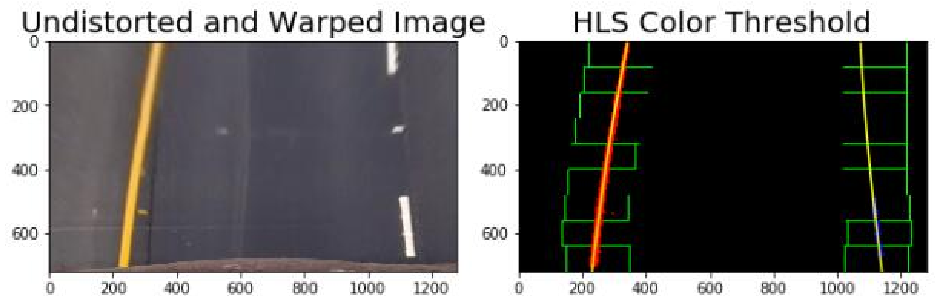
Then I did some other stuff and fit my lane lines with a 2nd order polynomial kinda like this:


$f_{right}(y) = A_{right}y^2 + B_{right}y + C_{right}$
$f_{left}(y) = A_{left}y^2 + B_{left}y + C_{left}$

Moreover, the following are some examples:







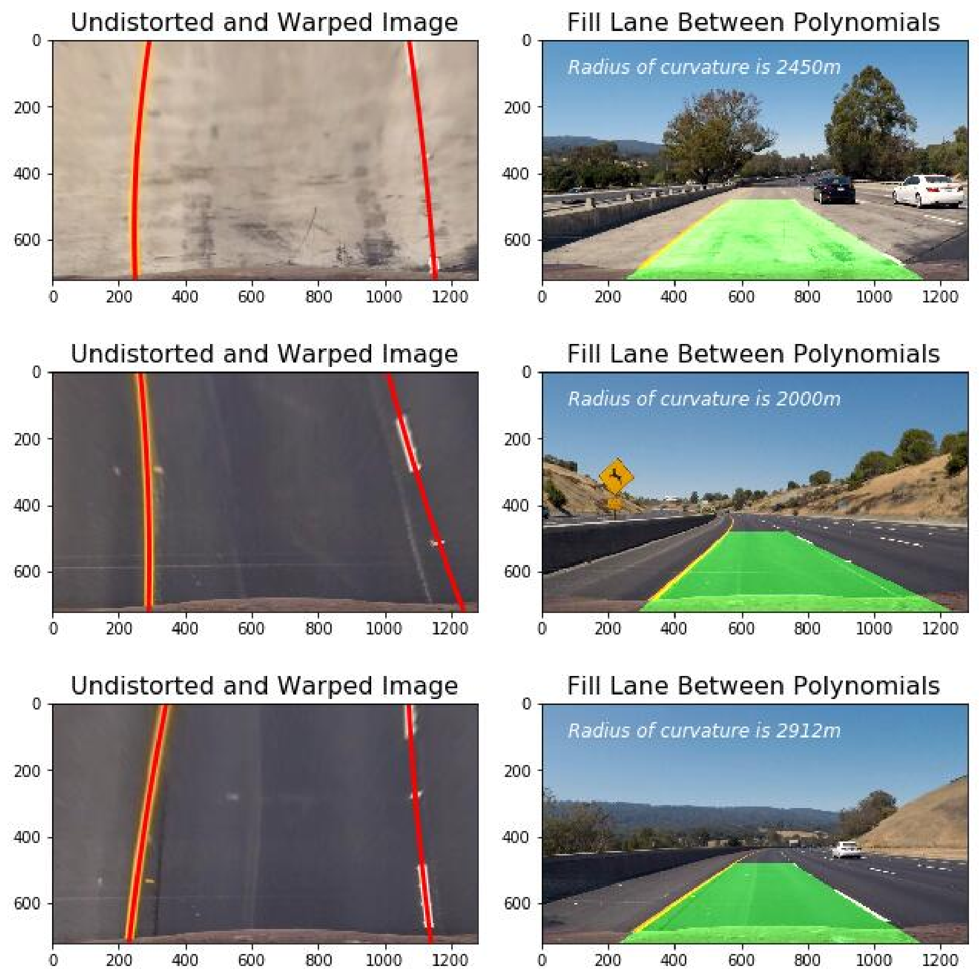
5. Describe how (and identify where in your code) you calculated the radius of curvature of the lane and the position of the vehicle with respect to center.

I did this in the cell #12, and I had a shortcut here(you can check this part in file `advanced_laner.ipynb`):

```
# Fit new polynomials to x,y in world space
left_fit_cr = np.polyfit(ploty*ym_per_pix, leftx*xm_per_pix, 2)
right_fit_cr = np.polyfit(ploty*ym_per_pix, rightx*xm_per_pix, 2)
# Calculate the new radii of curvature
left_curverad = ((1 + (2*left_fit_cr[0]*y_eval*ym_per_pix + left_fit_cr[1]
right_curverad = ((1 + (2*right_fit_cr[0]*y_eval*ym_per_pix + right_fit_cr
# Now our radius of curvature is in meters
```

6. Provide an example image of your result plotted back down onto the road such that the lane area is identified clearly.

I implemented this step in cell #14. Here are some examples of my result on test images:


Undistorted and Warped Image
Fill Lane Between Polynomials
Radius of curvature is 2450m
Undistorted and Warped Image
Fill Lane Between Polynomials
Radius of curvature is 2000m
Undistorted and Warped Image
Fill Lane Between Polynomials
Radius of curvature is 2912m

Pipeline (video)

1. Provide a link to your final video output. Your pipeline should perform reasonably well on the entire project video (wobbly lines are ok but no catastrophic failures that would cause the car to drive off the road!).

The name is result.mp4

Discussion

1. Briefly discuss any problems / issues you faced in your implementation of this project. Where will your pipeline likely fail? What could you do to make it more robust?

There is a big issue when I tried to process the video. It's not smooth. It jumped around from frame to frame a bit! For short, I fixed this problem by taking the same fitting model of the last frame of the video/image.