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.

[//]: # (Image References)

[image1]: ./examples/undistort_output.png "Undistorted"

[image2]: ./test_images/test1.jpg "Road Transformed"

[image3]: ./examples/binary_combo_example.jpg "Binary Example"

[image4]: ./examples/warped_straight_lines.jpg "Warp Example"

[image5]: ./examples/color_fit_lines.jpg "Fit Visual"

[image6]: ./examples/example_output.jpg "Output"

[video1]: ./project_video.mp4 "Video"

[Rubric](https://review.udacity.com/#!/rubrics/571/view) 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](https://github.com/udacity/CarND-Advanced-Lane-Lines/blob/master/writeup_template.md) is a template writeup for this project you can use as a guide and a starting point.

You're reading it!

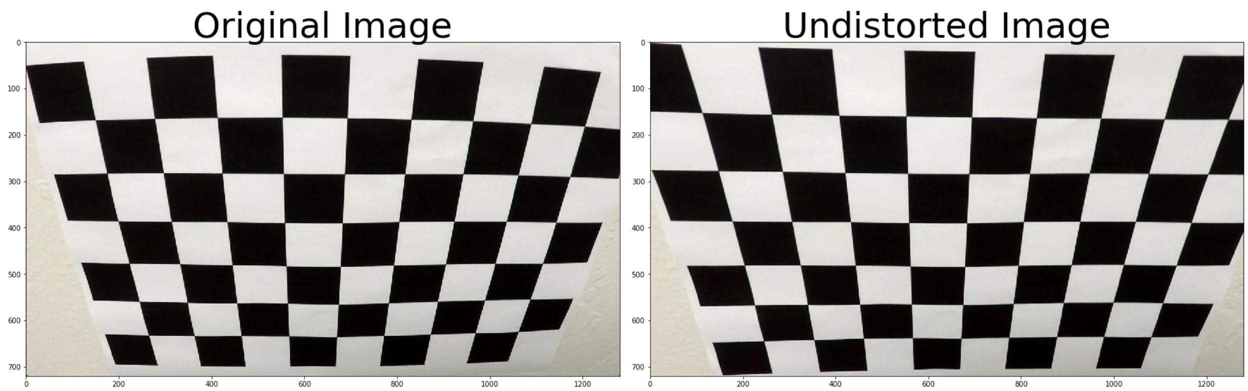
Camera Calibration

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 first code cell of the IPython notebook located in "./CarND-Advanced-Lane-Lines/P2.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.

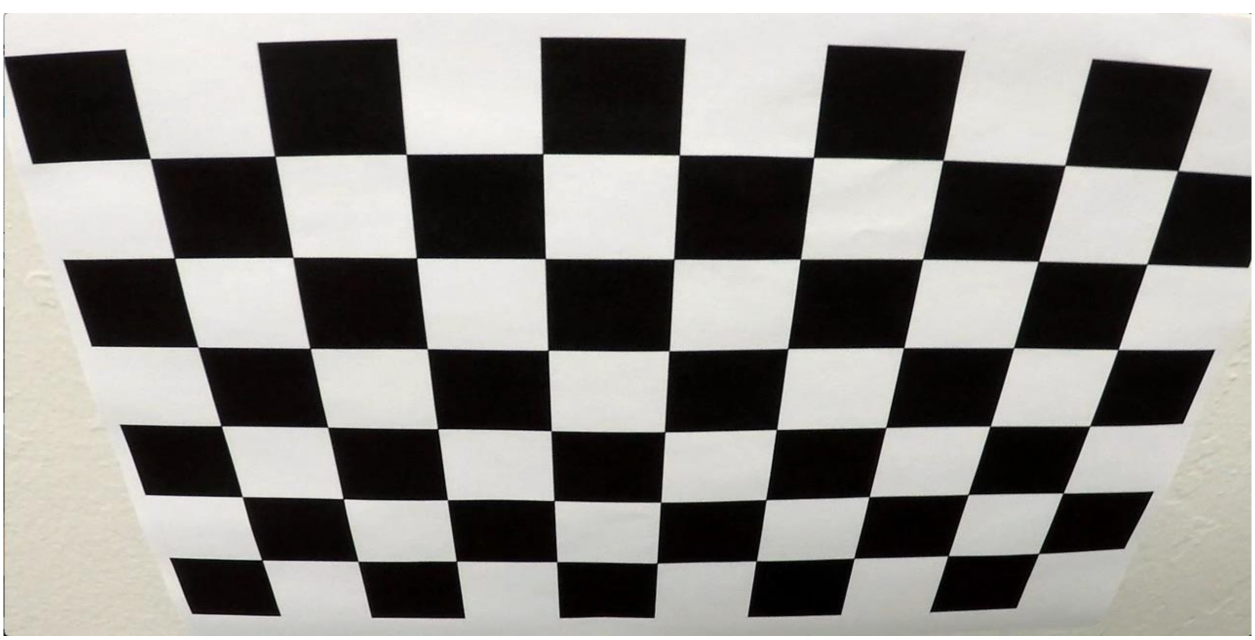
I then used the output `objpoints` and `imgpoints` to compute the camera calibration and distortion coefficients using the `cv2.calibrateCamera()` function. I applied this distortion correction to the test image using the `cv2.undistort()` function and obtained this result:



Pipeline (single images)

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

To demonstrate this step, I will describe how I apply the distortion correction to one of the test images 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 combination of color and gradient thresholds to generate a binary image (thresholding steps at cell 6 in P2.ipynb). Here's an example of my output for this step. (note: this is not actually from one of the test images)

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

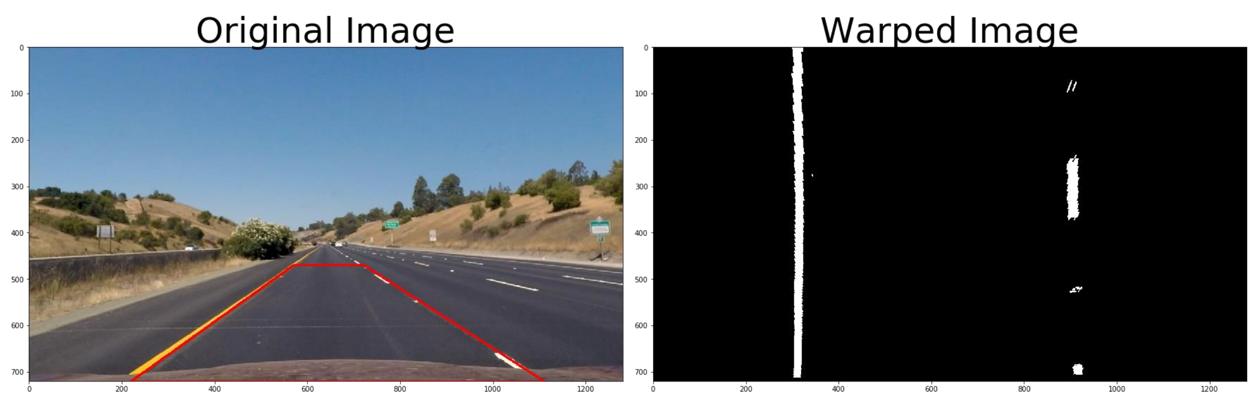
The code for my perspective transform is present in cell 7 in P2.ipynb. The `warper()` function takes as inputs an image (`img`), as well as source (`src`) and destination (`dst`) points. I chose the hardcode the source and destination points in the following manner:

```python
src = np.float32(
    [[(img_size[0] / 2) - 55, img_size[1] / 2 + 100],
    [((img_size[0] / 6) - 10), img_size[1]],
    [(img_size[0] * 5 / 6) + 60, img_size[1]],
    [(img_size[0] / 2 + 55), img_size[1] / 2 + 100]])
dst = np.float32(
    [[(img_size[0] / 4), 0],
    [(img_size[0] / 4), img_size[1]],
    [(img_size[0] * 3 / 4), img_size[1]],
    [(img_size[0] * 3 / 4), 0]])
```

This resulted in the following source and destination points:

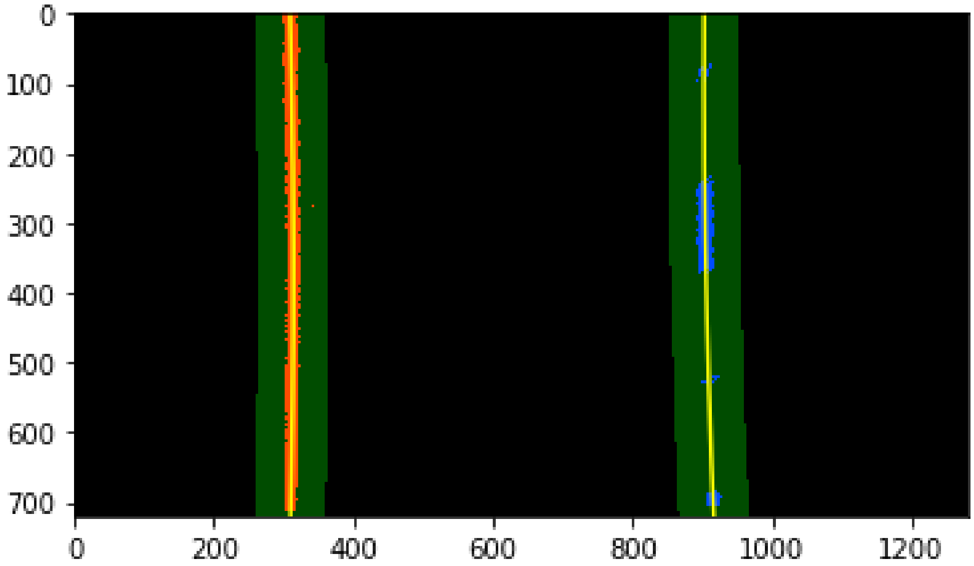
Source	Destination
220, 720	320, 720
1110, 720	920, 720
570, 470	320, 1
722, 470	920, 1

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:

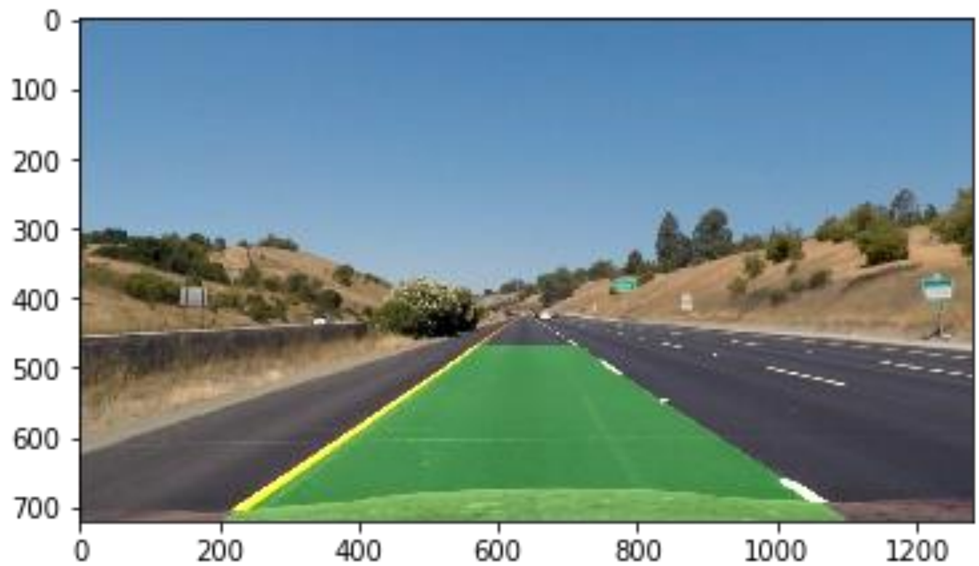


5. Describe how (and identify where in your code) you calculated the radius of curvature of the lane and the position of the vehicle with respect to center.

I did this in cell 11 in my code in `P2.ipynb`

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 12 through in my code in `P2.ipynb` Here is an example of my result on a test image:



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!).

Here's a [link to my video result](./project_video.mp4)

https://view5639f7e7.udacity-student-workspaces.com/view/CarND-Advanced-Lane-Lines/project_video_output.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?

I faced issues in implementing in finding the threshold values for obtaining the thresholded image and using perspective transform to obtain warped image. The pipeline could possibly fail under extreme weather conditions or conditions that are generally not ideal in nature and where visibility can be a problem. It can be made more robust by using test images that are not ideal for processing and testing our code.

Here I'll talk about the approach I took, what techniques I used, what worked and why, where the pipeline might fail and how I might improve it if I were going to pursue this project further.

Firstly, I used camera calibration on chessboard images and undistorted the images. Next, I used Sobel operators and applied various methods like using absolute gradient, gradient magnitude and color threshold and finally combining these results to obtain a gray threshold image. Next, I used perspective transform to obtain warped image and fit a polynomial to the lane lines and finally use sliding window to detect these lines. Lastly find radius of curvature of lane and unwarp the image back to highlight the detected region.

As mentioned earlier, the pipeline may fail in non-ideal situations and we need to use other alternatives for processing test images which are not ideal.