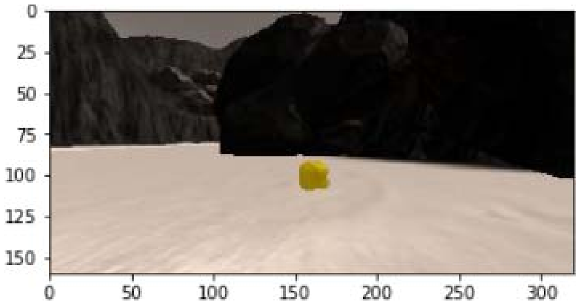
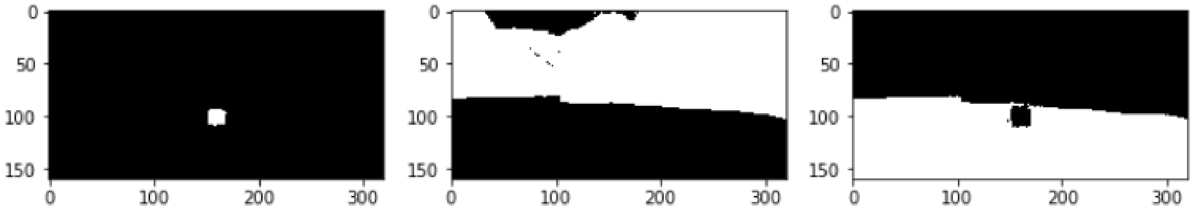
1. Notebook Test

In this task, the main problem is to select color. I have written functions to get different masks. For a RGB image, three channels needs to be filtered. By starting from range [0,255] for each channel, in the order of R,G,B channel, lower bound and higher bound can be adjusted. Using the following picture as test, the range for each channel can be determined.





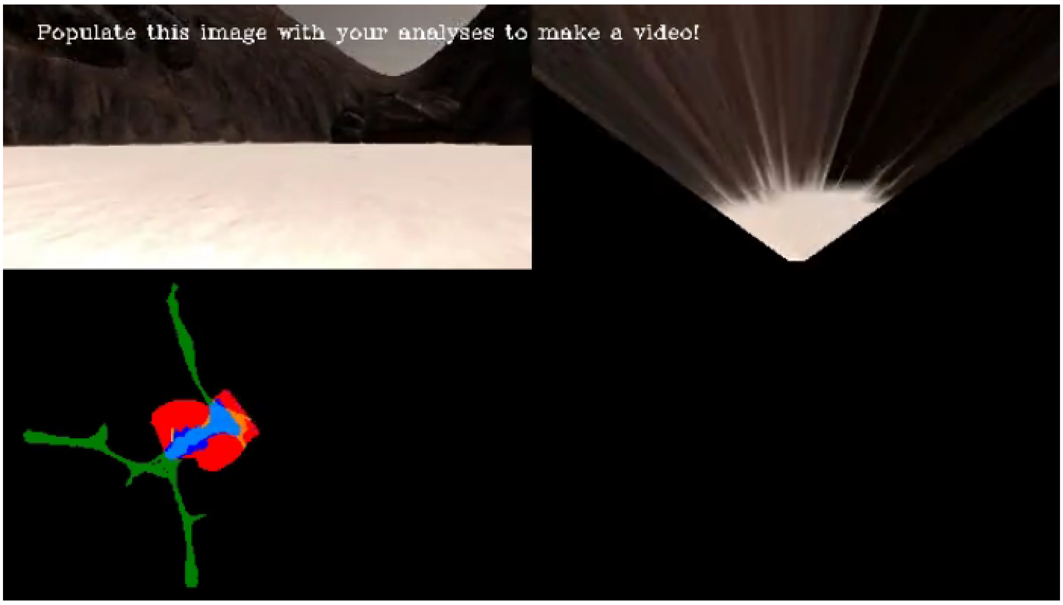
Modification in **process_image()** function

After perspective transform, there are more error for distant area. So, the top 1/3 of the perspective transformed mask is set to zero in order to have better result. (mask_r[:mask_r.shape[0]//3,:]=0)

In addition, identified terrain area will not be changed in the following image processing. The final result is like the following.

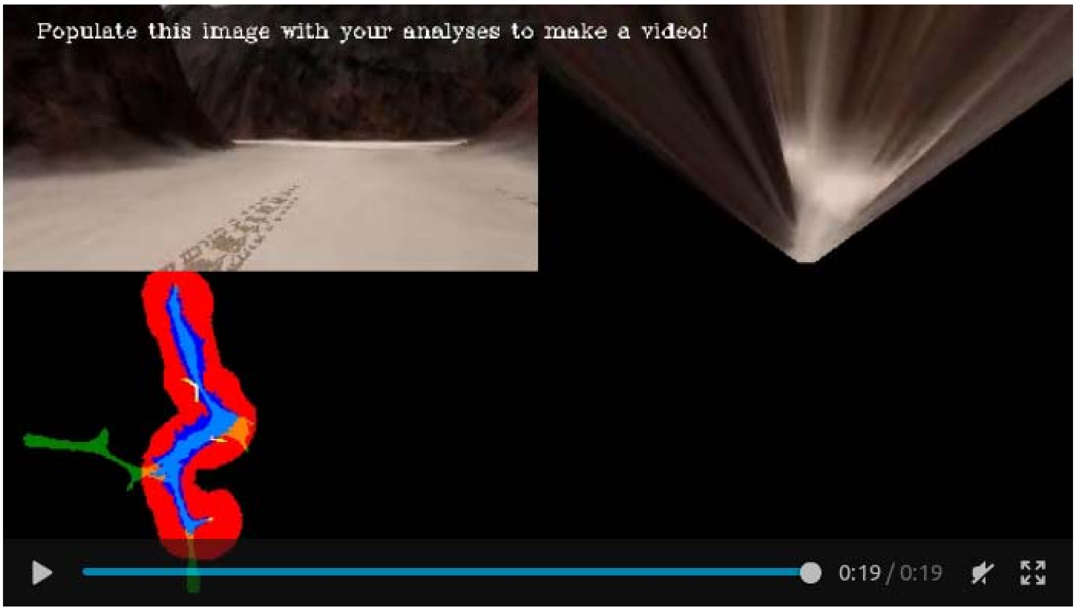
Other parts are normal as they are.

Out[12]:



2. Test on my own data

Out[14]:



Populate this image with your analyses to make a video!

As it can be seen, blue area still extends out. This shows when roll and pitch angles are big. This is solved in autonomous driving.

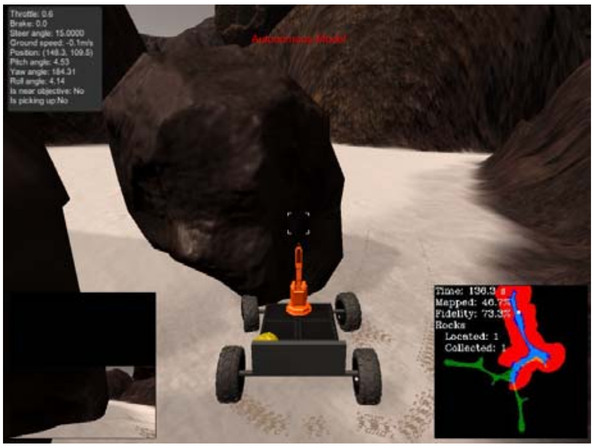
All these two videos are in '/UDRover/output' directory.

3. Autonomous driving

This is the most interesting part, I have finally managed to pick up rocks while mapping most part of the area with fidelity above 60%.

I will illustrate my modification with respect to different problems that I have come across.

1) Fidelity Improvement: In perception.py, only when pitch and roll angles are both smaller than 3 degree that worldmap can be updated.
2) Enlarge Mapped Area: By making rover stick to left part of the road, all the area can actually be traversed. The problem is how to achieve this. This is a problem of how to navigate. I have two modifications. First is to navigate by only consider area that are close (less than 120 distance away), which prevents rover from influence of distant objects. Second, navigate by only consider left 70/128 area, this helps the rover to stick to the left of the road.
3) Shorten the time: the max speed is increased a little.
4) Prevent getting stucked: some times, the rover may go into rocks of obstacles shown in the following figure. The rover keeps going forward without moving one inch in reality.

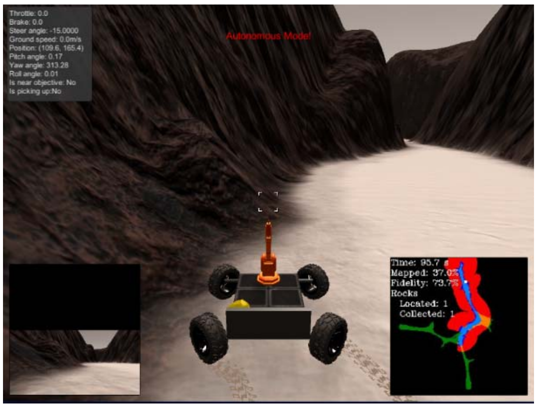


```
Throttle: 0.6
Brake: 0.0
Steer angle: 15.0000
Ground speed: -0.1m/s
Position: (148.3, 109.5)
Pitch angle: 4.53
Yaw angle: 184.31
Roll angle: 4.14
Is near objective: No
Is picking up:No
```

```
Time: 136.3 s
Mapped: 46.7%
Fidelity: 73.3%
Rocks
  Located: 1
  Collected: 1
```

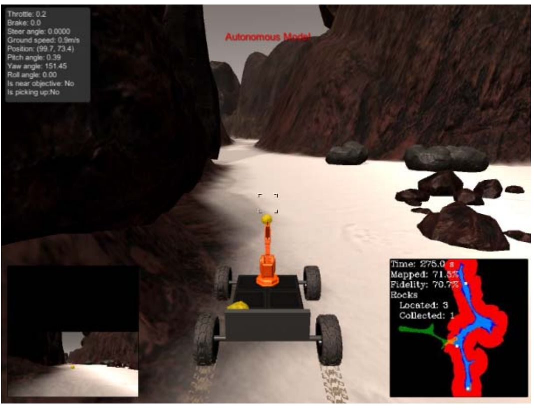
So I add one mode called 'steer', when the rover not moving is detected, the rover will enter this mode to stop moving forward and turn to another direction. Then, the rover can successfully get out of the trouble.

5) Get the Rock!!! : My goal is to pick up the rocks!!! When rock is identified, the rover will enter 'wait' mode (rock! Wait for me!), the rover will run to the closest rock point slowly. And when rock is detected that can be picked up, the rover stops and picks them up. Normally, the rover can pick up all the rocks. In the following pictures, I will show that 5 out of 6 rocks are picked up.



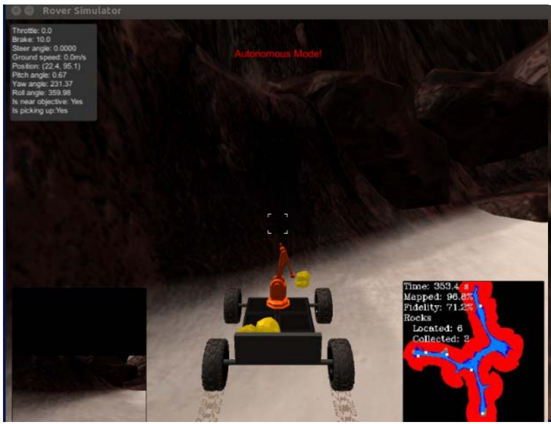
```
Throttle: 0.0
Brake: 0.0
Steer angle: -15.0000
Ground speed: 0.0m/s
Position: (109.6, 165.4)
Pitch angle: 0.17
Yaw angle: 313.28
Roll angle: 0.01
Is near objective: No
Is picking up:No
```

```
Time: 95.7 s
Mapped: 37.0%
Fidelity: 73.7%
Rocks
  Located: 1
  Collected: 1
```



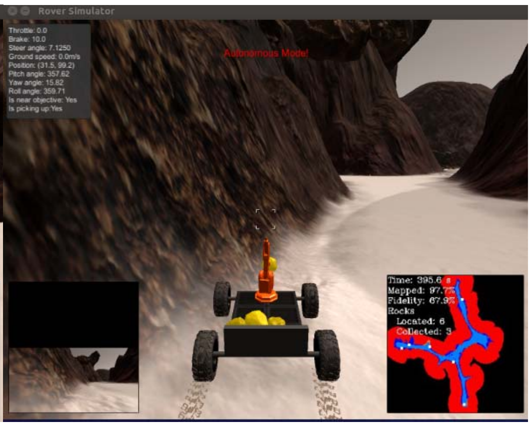
```
Throttle: 0.2
Brake: 0.0
Steer angle: 0.0000
Ground speed: 0.9m/s
Position: (99.7, 73.4)
Pitch angle: 0.39
Yaw angle: 151.45
Roll angle: 0.00
Is near objective: No
Is picking up:No
```

```
Time: 275.0 s
Mapped: 71.5%
Fidelity: 70.7%
Rocks
  Located: 3
  Collected: 1
```



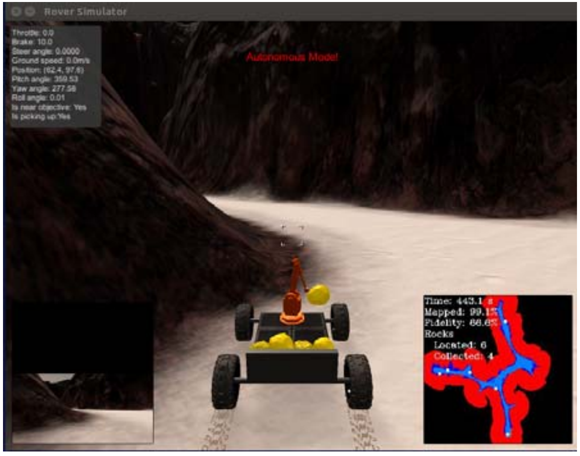
```
Throttle: 0.0
Brake: 10.0
Steer angle: 0.0000
Ground speed: 0.0m/s
Position: (22.4, 95.1)
Pitch angle: 0.67
Yaw angle: 231.37
Roll angle: 359.98
Is near objective: Yes
Is picking up:Yes
```

```
Time: 353.4 s
Mapped: 96.8%
Fidelity: 71.2%
Rocks
  Located: 6
  Collected: 2
```



```
Throttle: 0.0
Brake: 10.0
Steer angle: 7.1250
Ground speed: 0.0m/s
Position: (31.5, 99.2)
Pitch angle: 357.62
Yaw angle: 15.82
Roll angle: 359.71
Is near objective: Yes
Is picking up:Yes
```

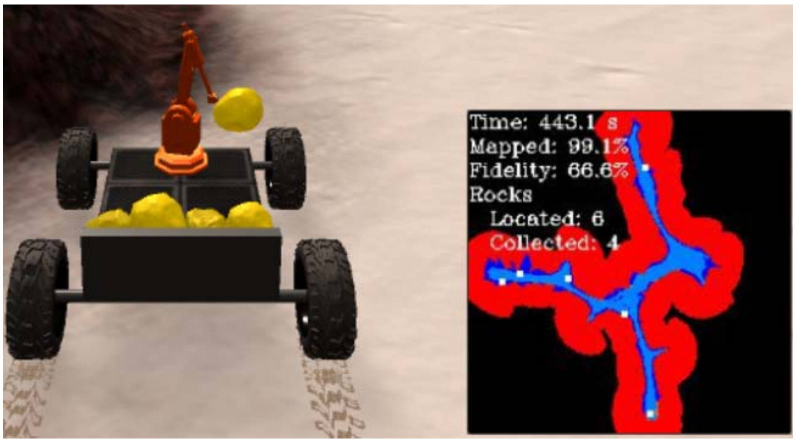
```
Time: 395.6 s
Mapped: 97.7%
Fidelity: 67.9%
Rocks
  Located: 6
  Collected: 3
```



```
Throttle: 0.0
Brake: 10.0
Steer angle: 0.0000
Ground speed: 0.0m/s
Position: (62.4, 97.6)
Pitch angle: 359.53
Yaw angle: 277.58
Roll angle: 0.01
Is near objective: Yes
Is picking up:Yes
```

```
Time: 443.1 s
Mapped: 99.1%
Fidelity: 68.6%
Rocks
  Located: 6
  Collected: 4
```

One failure case is when the rock located not to either side of the road, but in the middle of the wide road. This can be fixed easily. Finally, the next picture shows the overall results. The collected rocks are 5 as the current one is still being transferred.



```
Time: 443.1 s
Mapped: 99.1%
Fidelity: 66.6%
Rocks
  Located: 6
  Collected: 4
```

Discussion about further improvement:

1) Route planning can be added to move rover more efficiently.
2) Rover should be able to run back when hit into an object.
3) Rover can turn more smartly.