Udacity RoboND
Search & Sample Return

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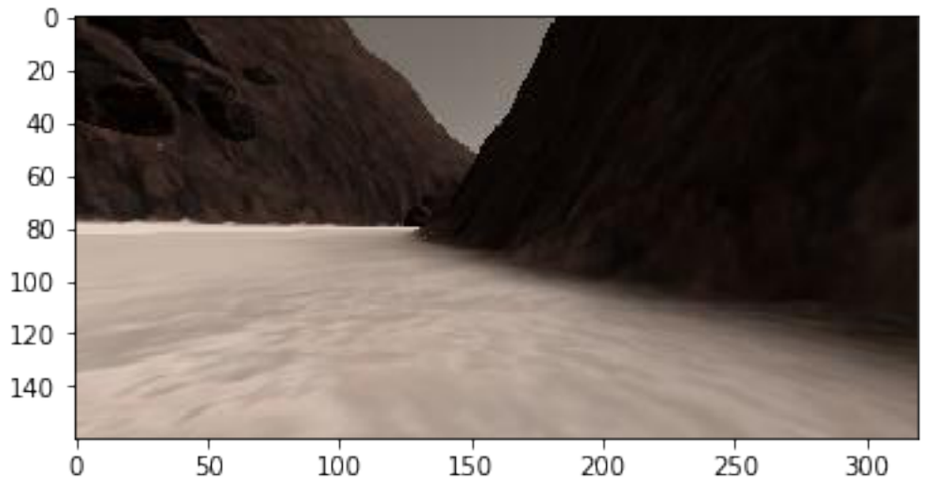
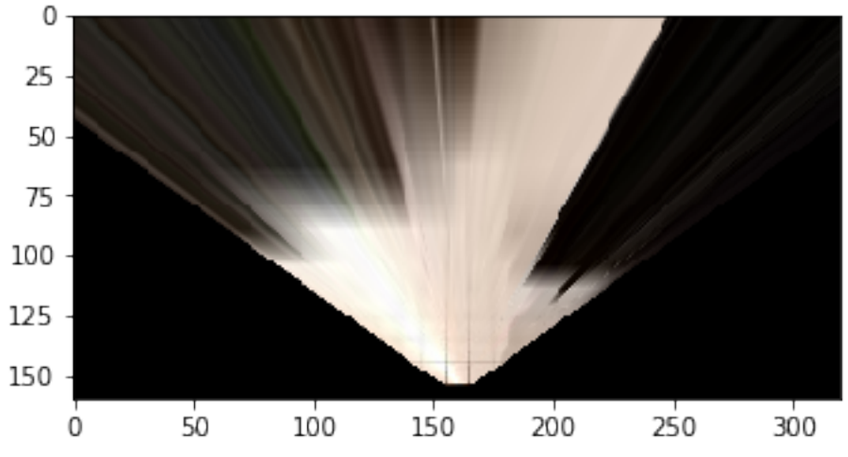
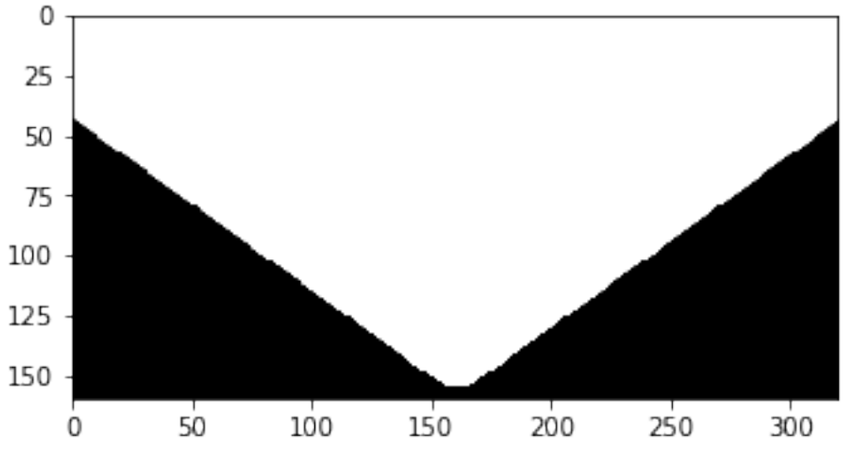
Notebook Analysis

- Code changes in Rover_Project_Test_Notebook.ipynb
- Was not able to record video in the simulator, so only used the provided test data.
- Some image captures from the notebook are shown in next couple of slides.

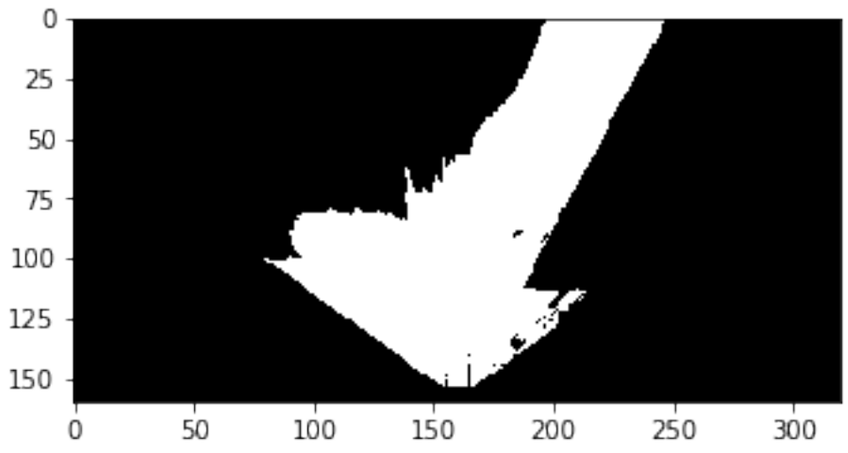
Sample Data and Perspective Transform

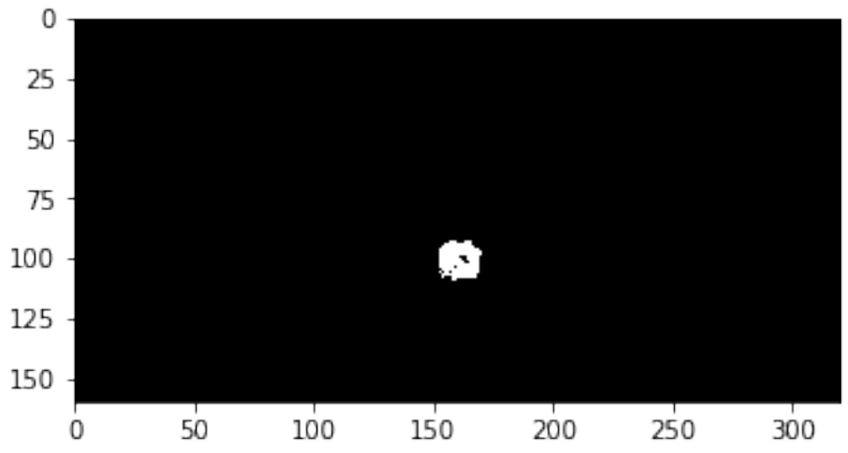




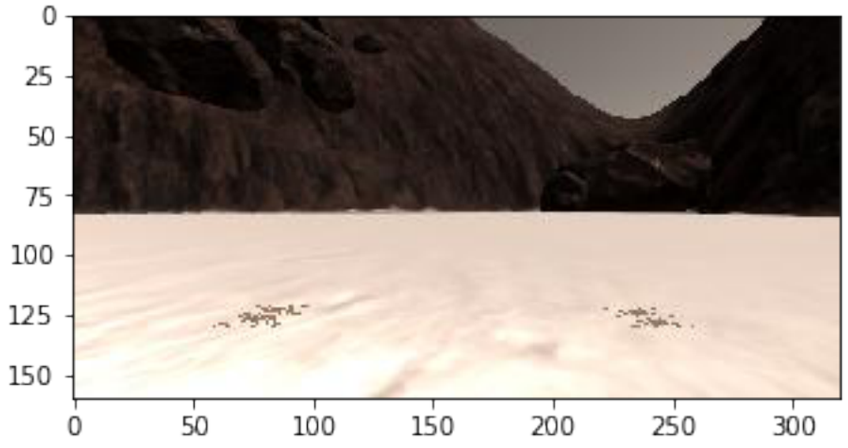


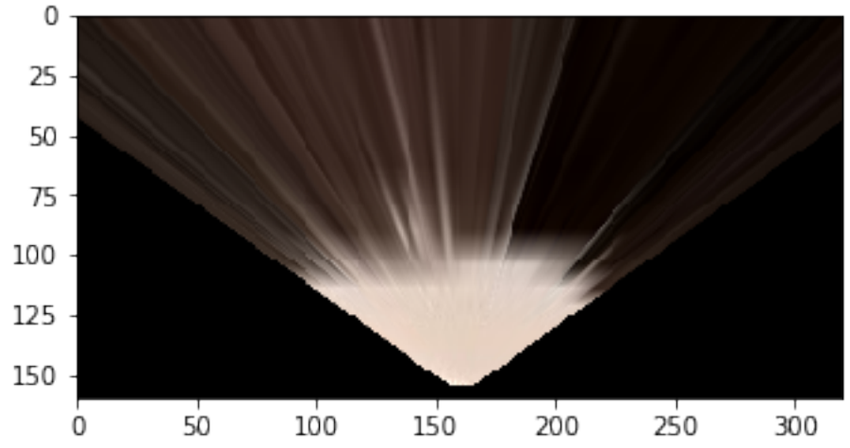
Color Thresholding

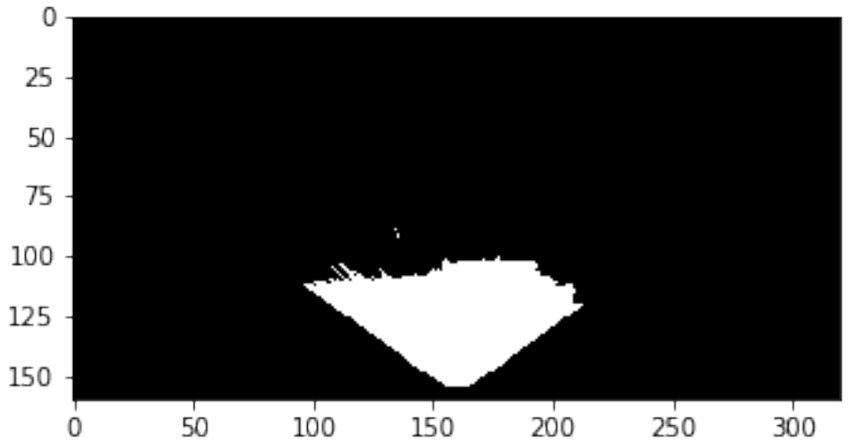


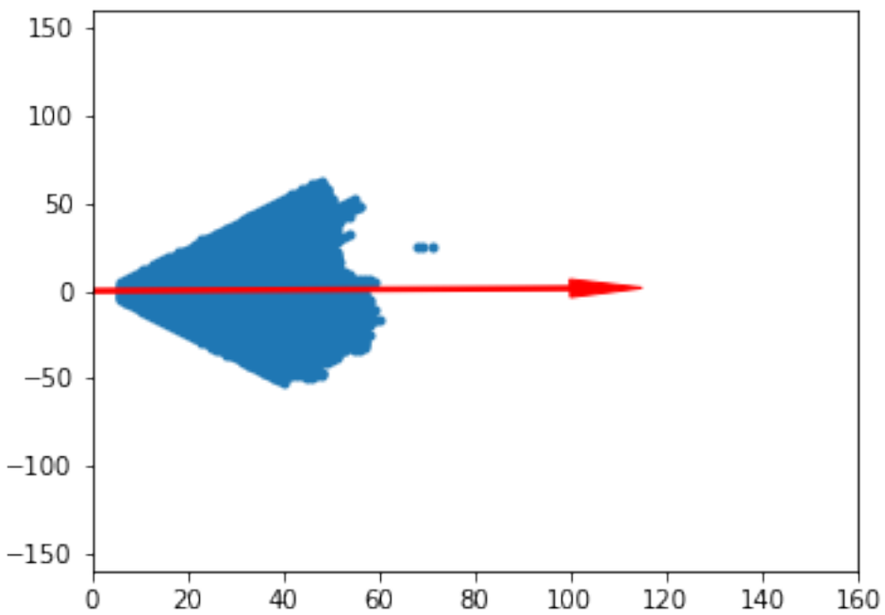


Coordinate Transformation

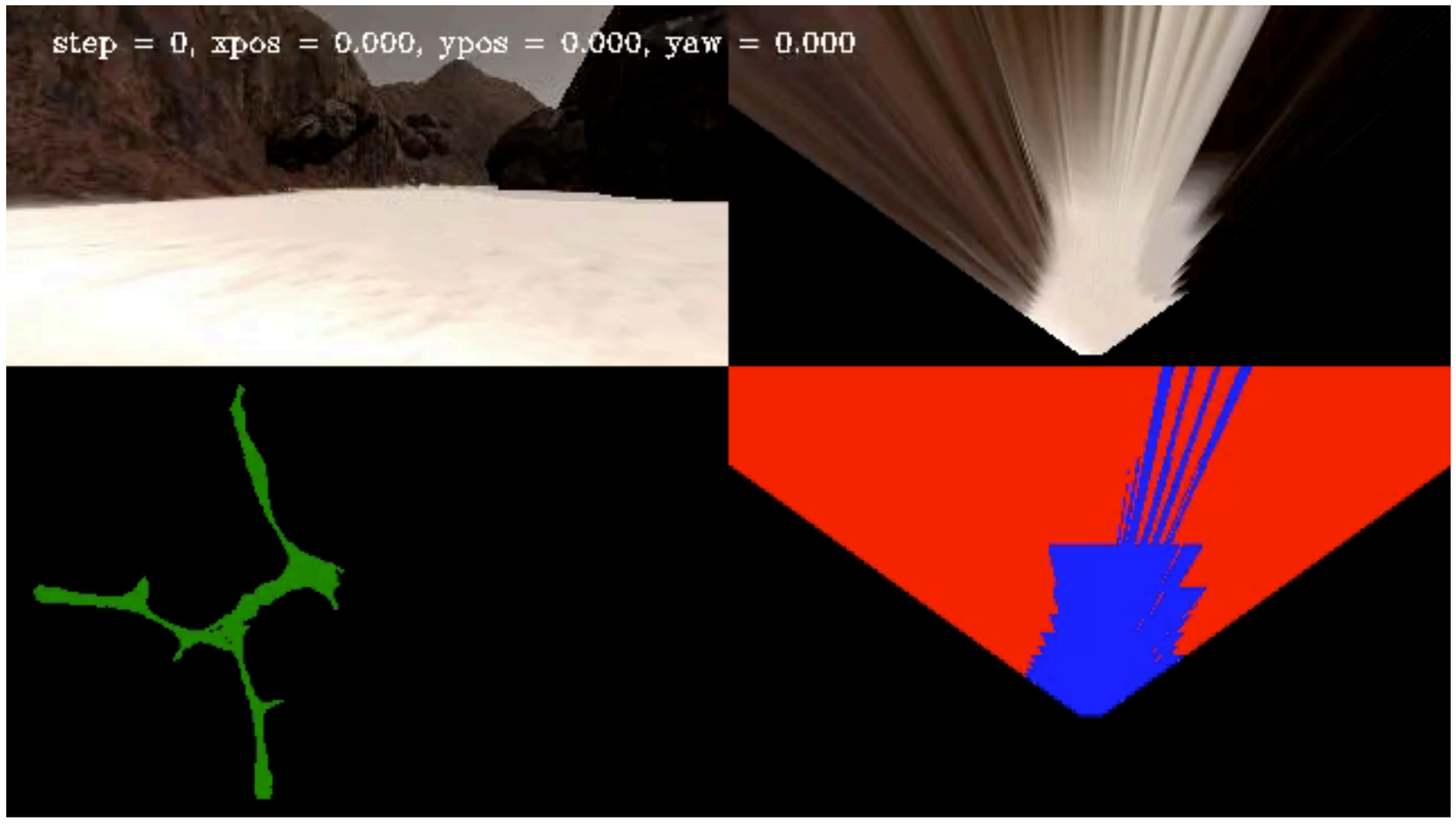








Video of Processed Data



Autonomous Navigation & Mapping

- Code changes: perception.py, decision.py, drive_rover.py, supporting_functions.py

- Simulator settings: 800x600 resolution, Fastest Quality, average FPS = 13

Taking up the Challenge

- Left wall walking
- Not getting stuck in a perpetual circle
- U-turn at a dead-end
- Obstacle avoidance
- Getting unstuck from quick sand
- Collecting gold rocks
- Stopping once a set point is revised, to exit simulation
- Increasing fidelity

Left Wall Walking

- Walk along the left wall to make sure rover can visit everything inside a closed area and safely decide when to stop.

- For this to work, many other tasks have to be restricted in certain ways to make sure the rover will not accidentally end up in the opposite direction, without having explored the road ahead first.

- Solution:

    - For this to work, in ‘forward’ mode the rover looks at adjacent navigable terrain, with a distance of less than 50 meters. This will exclude far away patches of sand around a corner/edge that can be misleading the rover in a wrong direction.

    - The rover deviates from the mean of the above adjacent_angles towards its left, by a multiple (0.5) of their standard deviation.

Not Getting stuck In A Perpetual Circle

- Since the rover is trying to stick to the left, in a wide open area it can easily get into a vicious circle, where it is always pointing to the left with a steering angle of 15! This can happen in one of the open areas in simulation, with a bunch of smaller rocks in the middle.

- Any solution to get of of this circle needs to make sure it does not break the goal of moving along the left wall, and in combination with other scenarios.

- Solution:

    - Regardless of the rover's mode, check to see if the rover's steer has been constantly pointing to the left (between 9 to 15 degrees) for a while (15 seconds), with a rather constant velocity (less than 0.3 change) around 0.4, and while the robot has been in 'forward' mode.

    - If the above pattern is noticed, then for 3 seconds keep changing the planned steer by 10 degrees to right, to get out of the circular pattern.

U-Turn at Dead-Ends

- At the end of a dead-end, where there are not many pixels in front of the rover, the original code would make the rover stop. At this point, the rover should make a U-turn.

- Solution:
  - In ‘forward’ mode, look at the navigable pixels that are 3 degrees around the selected steering angle (which is based on adjacent_angles). If there are not many of them (< 50), or their average distance is too small (< 20), then deviate to right (by 5 degrees). This can repeat until there is enough pixels in front of the rover and it can proceed.

  - Note also that ‘stop’ mode itself uses a steer of -15 if there is not enough navigable pixels in front of the rover.

Obstacle Avoidance

- Hitting objects and getting stuck with them (e.g, under them) is not pleasant, and further more, it can cause the rover end up on the opposite side of the road trying to unstuck itself.

- Solution:
  - In ‘forward’ mode, look at the navigable pixels that are 10 degrees around the selected steering angle (which is based on adjacent_angles while possibly engaged in a U-Turn) and that are farther away from the rover (> 10 meters. These can correspond to the surface of an object right in front of the rover at some height, instead of on the ground). If there are not many such pixels (< 50) then go to ‘stop’ mode. Note that coming out of the ‘stop’ mode is always done by turning -15. If there is another obstacle on the right side of the rover, then the rover can get stuck there, until it finally manages to get out!

  - Use this strategy only if a gold rock is not visible. Otherwise, steer towards the rock instead!

Getting Unstuck From Quick Sand

- There are parts of the terrain that are covered in quick sand, and the rover can get stuck in them.
- Solution:
    - Identify the stuck situation in ‘forward’ mode, by checking to see if progress has not been made in the past number (10) cycles. If so, go to ‘unstuck’ mode with a deviation too right (-5), and there repeat trying to get out by using a steer = -15.

Collecting Gold Rocks

- When trying to collect gold rocks, one must make sure that we won't lose tracking on the left wall, or otherwise we may end up on the opposite direction!

- To do this right, I use two separate strategies for picking up rocks; one for rocks that are near the left wall (on the left of the Rover), and one for rocks that are on the right side of the Rover (with respect to its chosen direction). Some book keeping was needed to remember where a rock was first seen, as turning towards it can incorrectly switch the strategy.

- The two strategies approach the rock the same way:

    - In 'forward' mode, if the rock is less than 20 meters away, then simply turn Rover's steer towards it and move along.

    - But if the rock is closer (< 6.0), then hit the brake and go to 'found' mode.

    - In 'found' mode, keep braking, and then throttling in low speed for up to 31 seconds, until you are close enough to grab the rock. And then try to collect the rock. If this is not achieved in that many cycles, or for some reason (e.g., hitting the brake removed the rock from the view), then go back to 'forward' mode, and try again.

    - Note that after hitting the brake, sequence of events may lead the rover to dismissing the rock and moving on. Hopefully on the way back (if the rock is in a corridor), it has another chance to pick up the rock.

Collecting Rocks on Left

- Once a left rock is collected on the left/near side, the rover can typically just continue moving along the left wall, and if it needs to avoid the wall, the wall avoidance will correctly turn it to the correct direction (right).

- Solution:

    - Whether or not the pick up has been successful in ‘found’ mode, the Rover will move back to ‘forward’ mode with a steer = 0.

Collecting Rocks on Right

- Once a right rock is collected on the right/far side of a corridor, if the rover is too close to the wall, then a right U-turn will happen if it tries to go forward, which will put it on the wrong side of the road. To avoid this, we need to back up a little, and then move forward, so that the natural left wall walking scheme can pull the Rover to the left side of the corridor again.
- Solution:
    - If the Rover successfully picks up a rock on the right, then it goes to ‘retract’ mode, where for 3 seconds it will move backwards with a steer of -1 to correct its yaw, and then it goes to ‘forward’ mode with a steer of 15.
    - If the Rover fails to pick up a rock on right (e.g., because it was going too fast and quickly passed up the rock), then it will simply go back to ‘forward’ mode with a steer of 0.

Stopping The Simulation

- I have not implemented the strategy to return to home yet, as I know it can be another very complex goal.

- Instead, I try to end the simulation at a safe point. I choose the safe point to be the point where the first successfully picked up rock was picked up. Here I utilize the fact that rocks are always placed near a wall. In contrast, the starting point can be anywhere in the arena. Picking a point near a wall helps identifying when we have come full circle.

- Solution:

    - Mark the coordinate and the yaw angle of the Rover when in first picks up a Rock on a left wall.

    - When the rover reaching the vicinity of that point again (< 2.0 meters) after many seconds (77 seconds), with an aligning yaw angle (< 60 degrees difference), then go to ‘Done’ mode. Stay in ‘Done’ mode for 100 cycles, and then terminate the simulation.

Increasing Fidelity

- I simply use the suggested solution of checking the pitch and roll angle of the Rover, to exclude images that are too distorted from negatively impacting the worldmap.

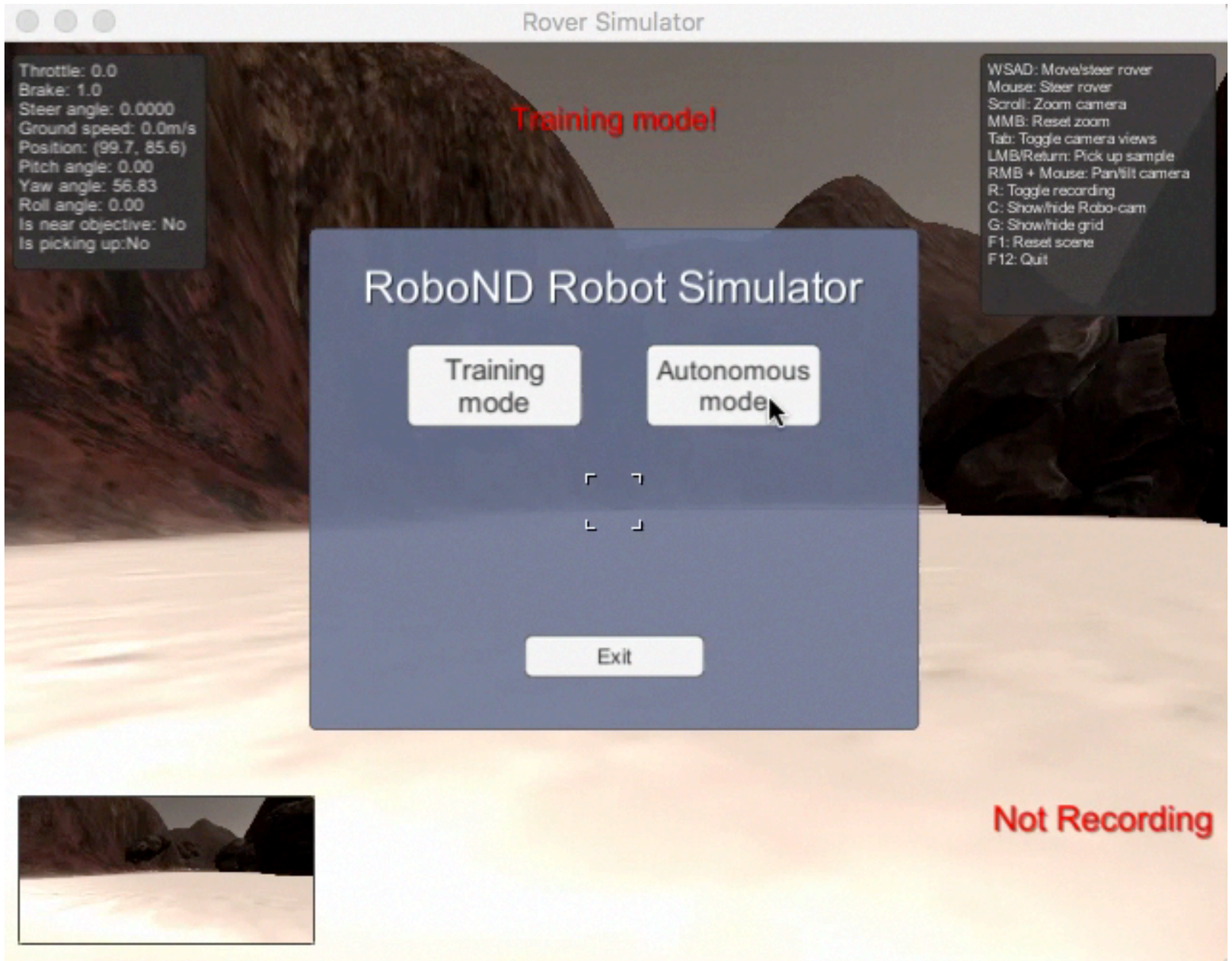
- I also filter the images first, before doing perspective transform.

Results

- Simulator settings: 800x600 resolution, Fastest Quality, average FPS = 13.
- Fidelity: typically >= 75%
- Covered map: typically >= 98%
- Rocks: typically located = 6, collected >= 4
- Time: varies: I kept the main speed parameters unchanged:
    - max_vel=2, throttle_set=0.2, brake_set=10
    - stop_forward=100, go_forward = 300
- Stopping: happens correctly most of the time, unless the picked up rock that was marked as the stopping point of the simulation was placed on a tricky spot from which the Rover had incorrectly made a U-Turn!
- I had initially used the number of steps (instead of time passed) for some of the strategies. Once I started recording the movie (in QuickTime) and the FPS dropped (from about 13 FPS on an older iMac to about 6 FPS), the algorithm broke. Luckily fixing this issue was not too hard.

Sample Autonomous Drive

https://youtu.be/kHe3-4EzxVA



Remaining Challenges

- Going back to Home
- Filling up the holes in the worldmap and increasing fidelity
- Getting unstuck when going over a small rock
- Getting stuck in sand on the way coming out of a narrow corridor
- Getting stuck in a corner where there are obstacles both in the front and on the right