CS 7638: Artificial Intelligence for Robotics

Mars Glider (Particle Filter) Project

Fall 2021 - Deadline: Monday October 18th, Midnight AOE

Project Description

The goal of this project is to give you practice implementing a particle filter used to localize a robotic glider that does not have access to terrestrial based GPS satellites. The glider is released from a spacecraft over the surface of mars, and receives a distance to ground measurement from a downward facing radar, as well as an altitude estimate from a barometric pressure sensor.

Your glider has an on-board map of the area it is being dropped into. The map covers an area 10 km on a side (100 sq km), and the robot is supposed to be dropped somewhere near (0,0). The map was generated by radar from the mars surveyor satellite mission, and has a 1x1 meter resolution. Dimensions in the map range from -5,000m to 5,000m.

Your glider will exit the reentry craft somewhere within the mapped area hopefully near (0,0), but possibly as far off as +/- 250m in both X and Y. It will eject out of the reentry craft approximately 5,000 meters (+/- 50m) above "sea level".

The orbit of the re-entry craft is designed so that it will enter the Martian atmosphere with a heading of zero radians (due east) with respect to your map, but due to atmospheric turbulence, the actual heading of your glider upon release may deviate from this planned heading based upon a Gaussian distribution with mu=0 and sigma= pi/4.

As mars has a thin atmosphere, your glide ratio is 5:1, which means that the glider moves forward 5 meters for every meter it falls. It moves 5m/sec, and falls 1m/s. This means that you have at least 950 seconds to localize the glider before it potentially goes "off-map" and is lost.

You also have at least 4,500 seconds of "glide time" before the glider risks hitting the surface, but would need to steer the glider to keep it within the boundaries of your known map.

Note that your software solution is limited to 10 seconds of "real" CPU time, which is different from the simulated "glider time". Unless your localization and control algorithm is VERY efficient, you will probably not go "off-map" or hit the ground before you run into the CPU timeout. If it takes your localization system more than 100-200 glider timesteps to determine the glider location, you may need to improve your localization algorithm.

Note that the radar sensor [sense function] gives you a (noisy) distance to "ground", and not "sea level" (on mars, "sea level" is defined as the mean ground height). The barometric sensor [get_height function] gives you the gliders distance above "sea level", +/- some Gaussian noise.

The glider.py file (which you should not modify, but may examine or import) implements the simulated glider. The opensimplex.py file (which you can safely treat as a black box and should not modify) is used when generating the map function.

The marsglider.py file contains two functions that you must implement, and is the only file you should submit to Canvas->GradeScope.

Part A

The first function is called estimate_next_pos, and must determine the next location of the glider given its atmospheric height and the radar distance to the ground. If your estimate is less than 5 meters from the target glider's actual (x,y) position, you will succeed and the test case will end.

Note that each time your function is called, you will receive one additional data point, and it is likely you will need to integrate the information from multiple calls to the function before you will be able to correctly estimate your glider's position. The "OTHER" variable is passed into your function and can be used to store data which you would like to have returned back to your function the next time it is called (at the gliders next timestep). Note that in part A you are not able to modify the gliders path, so it will be gliding in a (relatively) straight line.

Part B

The second function is called next_angle. The goal of this function is to set the turn angle of the glider (via the rudder) so that the glider returns to the center of its map (0,0) as it glides down to the ground. The test will end once you have navigated the glider to within 10m of the (0,0) target.

Your two functions will have the same input (barometric altitude and RADAR distance to ground), but the next_angle function will return a turning angle in radians (zero for no turn) instead of a predicted location. [Note that the glider can ony turn a set amount per timestep, see the glider.py file for the angle limit.]

The goal in part B is to return your glider as close to (0,0) as possible in X and Y. Note that you only need to return the glider to (0,0) once as the z (height) decreases to be successful, and the actual z value when this occurs does not matter as long as you have not hit the ground yet, so you may take multiple passes to return the glider to (0,0).

The Map Function

In both parts, your function is provided with a function (called the mapFunc) as an input. You may call this function with a specific (X,Y) location and it will return the elevation of the ground above "sea level" at that location on the map of the Martian surface. (We are using functional programming and the

OpenSimplex noise model so that we do not need to maintain and pass around a large data structure that contains all of the map data. You can safely ignore how the map works, and just make use of it.)

Submitting your Assignment

Your submission will consist of the marsglider.py file (only) which will be uploaded to Canvas->GradeScope. Do not archive (zip,tar,etc) it. Your code must be valid python version 3 code, and you may use external modules such as numpy, scipy, etc. [As long as it works with the GradeScope autograder you should be good to go, but if you are looking for specific version numbers try to ensure that your code is compatible with numpy version '1.19.1' and scipy version '1.5.2']

We encourage you to keep any testing code in a separate file that you do not submit. Your code should also NOT display a GUI or Visualization when we import or call your function under test.

Calculating your score

The test cases are randomly generated, and your particle filter is likely to also perform differently on different runs of the system due to the use of random numbers. Our goal is that you are able to generate a particle filter system that is generally able to solve the test cases, not one that is perfect in every situation.

You will receive seven points for each successful test case, even though there are 20 test cases in total (10 in part A, 10 in part B). This means that you only need to successfully complete 15 of the 20 test cases to receive a full score on this assignment. Your maximum score will be capped at 101, although if you are able to solve more than 15 test cases you can brag about it.

Testing Your Code

NOTE: The test cases in this project are subject to change.

We have provided you a sample of 10 test cases where the first five test cases are EASIER than the actual test cases you will be graded with. Each of these first five test cases are designed to allow you to test one aspect of the simulation. Test cases 6-10 are more representative of the test cases that will be used to grade your project.

We may grade your code with 10 different "secret" test cases that are similar, but not an exact match to any of the publicly provided test cases. These "secret" test cases are generated using the generate_params_marsglider.py file that we have provided to you. You are encouraged to make use of this file to generate additional test cases to test your code.

We have provided a testing suite similar to the one we'll be using for grading the project, which you can use to ensure your code is working correctly. These testing suites are NOT complete as given to you, and you will need to develop

other test cases to fully validate your code. We encourage you to share your test cases (only) with other students on Piazza.

By default, the test suite uses multi-processing to enforce timeouts. Some development tools may not work as expected with multi-processing enabled. In that case, you may disable multi-processing by setting the flag `DEBUGGING_SINGLE_PROCESS` to `True`. Note that this will also disable timeouts, so you may need to stop a test case manually if your filter is not converging.

You should ensure that your code consistently succeeds on each of the given test cases as well as on a wide range of other test cases of your own design, as we will only run your code once per graded test case. For each test case, your code must complete execution within the proscribed time limit (10 seconds) or it will receive no credit. Note that the grading machine is relatively low powered, so you may want to set your local time limit to 3 seconds to ensure that you don't go past the CPU limit on the grading machine.

We are using the Canvas->GradeScope autograder system which allows you to upload and grade your assignment with a remote / online autograder. You must submit your `marsglider.py` file to Gradescope to receive credit.

We **are likely, but not required, to use the last grade you receive, (or your selected grade) via the Canvas->GradeScope autograder as your final grade** at our discretion. (See the "Online Grading" section of the Syllabus.)

Academic Integrity

You must write the code for this project alone. While you may make limited usage of outside resources, keep in mind that you must cite any such resources you use in your work (for example, you should use comments to denote a snippet of code obtained from StackOverflow, lecture videos, etc).

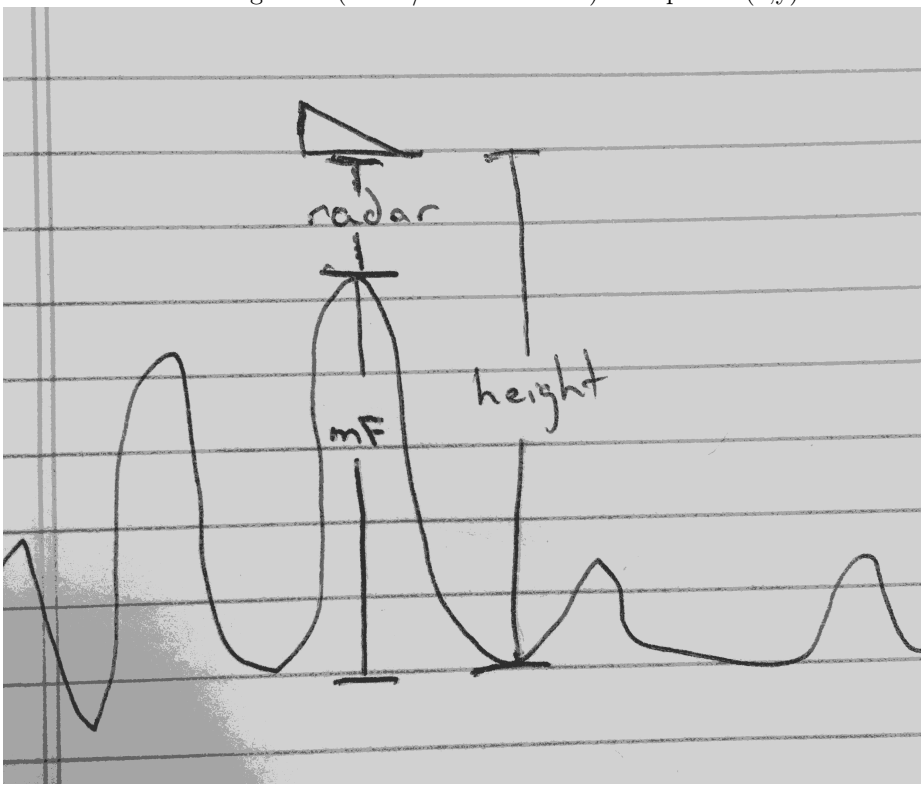
You must not use anybody else's code for this project in your work. We will use code-similarity detection software to identify suspicious code, and we will refer any potential incidents to the Office of Student Integrity for investigation. Moreover, you must not post your work on a publicly accessible repository; this could also result in an Honor Code violation [if another student turns in your code]. (Consider using the GT provided Github repository or a repo such as Bitbucket that doesn't default to public sharing.)

Frequently Asked Questions (F.A.Q.)

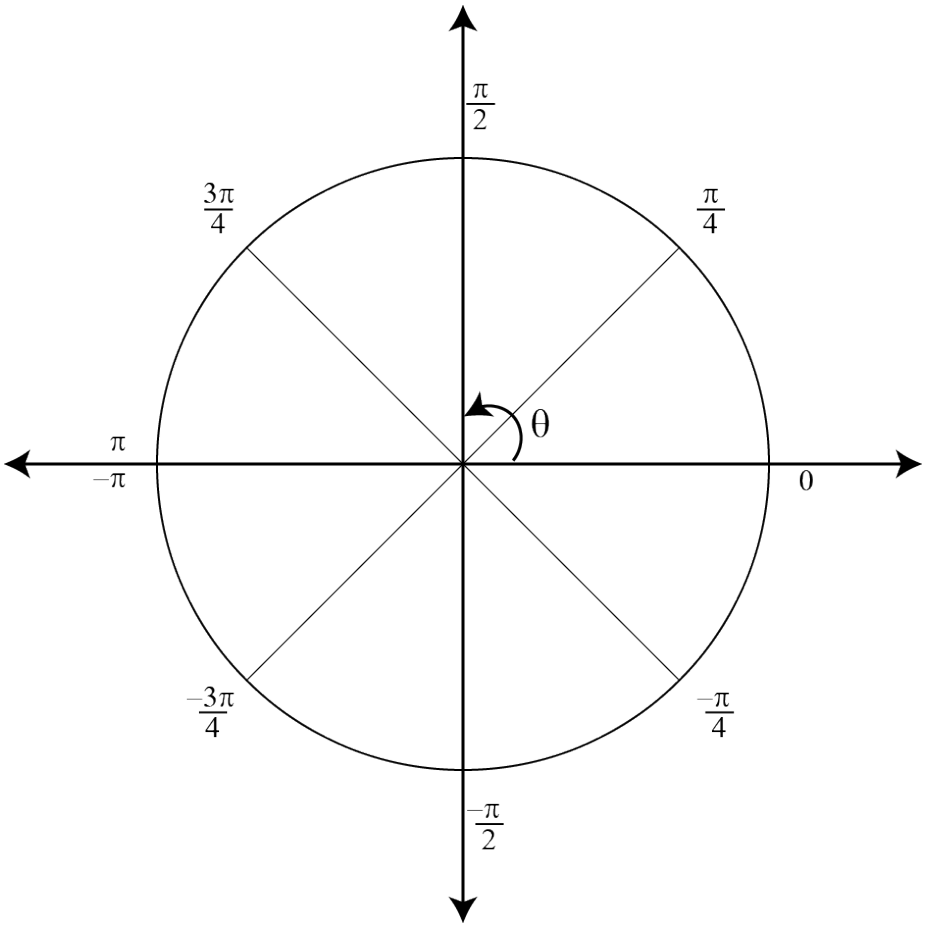
Q How can I simplify this problem to make thinking about it easier?
A Try solving it in only 2 dimensions, and take a look at the video that inspired the problem: Particle Filter explained without equations - https://www.youtube.com/watch?v=aUkBa1zMKv4

Q Are you SURE this can be solved using a particle filter? *A* Yes. See https://www.youtube.com/watch?v=97Gf392GBNg

Q How exactly are my sources of data related? *A* Radar gives the glider's height over ground (+/- measurement error), the barometric measurement height gives the gliders height above sea level (+/- measurement error), and the mapFunction returns the elevation of the ground (above/below sea level) at a specific (x,y) location.



Q Radians? How does that work? *A* The heading of the glider is represented in radians with a range from -pi to pi , with 0 being to the right/east, and -pi being to the left/west (positive pi is ALSO to the left/west).



Q How can I turn on the visualization, or change the TIMEOUT limit? *A* There are some ALL CAPS variables near the top of the testing_suite_full.py file. They are by default set to the same values used by the grader, but you can toggle the True/False values to enable/disable verbose logging and the visualization, and increase the TIMEOUT value (logging & visualization slow things down). When the PLOT_PARTICLES is set to True, you will be presented with a visualization that has a purple dot at your estimated (x,y) for the glider, black triangles representing the particles, and a red triangle showing the target glider. You can also enable a terrain map by setting PLOT_MAP to True, although plotting the map may be slow.

Q What height is the glider at initially? *A* The launch vehicle tries to release the glider at 5,000 m, but has a margin of error of +/- 50 meters. Note that your altimeter will give you a better estimate of your height (subject to measurement noise.)